ISSN 0369-5034

NOVA ACTA LEOPOLDINA
Abhandlungen der Deutschen Akademie der Naturforscher Leopoldina
Im Auftrage des Präsidiums herausgegeben von
Harald zur Hausen, Vizepräsident der Akademie
Neue Folge, Nummer 341, Band 92

Science and Music – The Impact of Music

Leopoldina Symposium

Halle/Saale
May 13 to 15, 2004

Organizing Committee:

Wolfgang AUHAGEN (Halle/Saale)
Wolfgang RUF (Halle/Saale)
Uzy SMILANSKY (Rehovot, Israel)
Member of the Academy
Hans WEIDENMÜLLER (Heidelberg)
Member of the Academy

Deutsche Akademie der Naturforscher Leopoldina, Halle (Saale) 2005
In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Science and Music – The Impact of Music

The organizers thank the Albert Einstein Center for Theoretical Physics at the Weizmann Institute, Rehovot, Israel for their generous support of this symposium.

NOVA ACTA LEOPOLDINA

Abhandlungen der Deutschen Akademie der Naturforscher Leopoldina

Im Auftrage des Präsidiums herausgegeben von

Harald zur Hausen

Vizepräsident der Akademie

NEUE FOLGE NUMMER 341 BAND 92

Science and Music – The Impact of Music

Leopoldina Symposium
Halle/Saale
May 13 to 15, 2004

Organization:

Wolfgang Auhagen (Halle/Saale)

Wolfgang Ruf (Halle/Saale)

Uzy Smilansky (Rehovot, Israel)
Member of the Academy

Hans Weidenmüller (Heidelberg)
Member of the Academy

With 75 Figures and 7 Tables

Deutsche Akademie der Naturforscher Leopoldina, Halle (Saale) 2005
In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Redaktion: Dr. Michael Kaasch und Dr. Joachim Kaasch

Die Schriftenreihe Nova Acta Leopoldina erscheint bei der Wissenschaftlichen Verlagsgesellschaft mbH, Stuttgart, Birkenwaldstraße 44, 70191 Stuttgart, Bundesrepublik Deutschland.
Jedes Heft ist einzeln käuflich!

Die Schriftenreihe wird gefördert durch das Bundesministerium für Bildung und Forschung sowie das Kultusministerium des Landes Sachsen-Anhalt.

Bibliografische Information Der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie;
detaillierte bibliografische Daten sind im Internet über http//dnb.ddb.de abrufbar.

06019 Halle (Saale), Postfach 11 05 43, Tel. + 49 345 4723934
Hausadresse: 06108 Halle (Saale), Emil-Abderhalden-Straße 37
Herausgeber: Prof. Dr. Dr. h. c. mult. Harald zur Hausen, Vizepräsident der Akademie
Printed in Germany 2005
Gesamtherstellung: Druck-Zuck GmbH Halle (Saale)
ISBN 3-8047-2237-7
ISSN 0369-5034
Gedruckt auf chlorfrei gebleichtem Papier.

Contents

Nova Acta Leopoldina NF *92*, Nr. 341, 7–8 (2005)

Begrüßung

Volker TER MEULEN (Halle/Saale – Würzburg)

Präsident der Akademie

Meine sehr verehrten Damen und Herren,

im Namen des Präsidiums der Deutschen Akademie der Naturforscher Leopoldina und der Heidelberger Akademie der Wissenschaften darf ich Sie alle herzlich begrüßen und meine Freude darüber zum Ausdruck bringen, daß Sie so zahlreich unserer Einladung gefolgt sind. Beide Akademien haben großes Interesse an der Thematik »Naturwissenschaft und Musik« und danken den Organisatoren für die Gestaltung dieses Symposiums.

Besonders willkommen heißen möchte ich die eingeladenen Sprecher, Moderatoren und Musiker und mich bedanken, daß sie sich bereit erklärt haben, an diesem Symposium teilzunehmen und die Mühen nicht scheuten, zum Teil eine weite Reise auf sich zu nehmen. In diesen Willkommensgruß schließe ich auch die Oberbürgermeisterin der Stadt Halle ein, die uns heute Abend dankenswerterweise zu einem Umtrunk eingeladen hat.

Meine sehr verehrten Damen und Herren,

die Naturwissenschaften, und insbesondere die Medizin, beschäftigen sich schon lange mit der Ontogenese des Ohres und des Gehirnes im Zusammenhang mit Musikentstehung, Musikaufnahme und Musikempfindung. Der Gehörsinn, durch den Schallwellen in Luft oder Wasser aufgenommen werden und der bei Tieren Gefahr oder Beute vermittelt, findet sich nur bei Insekten und Wirbeltieren und ist mindestens 400 Millionen Jahre alt. Jedoch die Möglichkeit, Musik wahrzunehmen, existiert erst seit einem Bruchteil dieser Zeit. Es stellen sich deshalb viele Fragen, z. B., um nur einige zu nennen:

– Welche Strukturen haben sich im Laufe der Zeit in unserem Kopf ausgebildet und wie interagieren sie, damit wir Musik nicht nur hören und differenzieren, sondern auch empfinden können?
– Warum ergreift uns Musik?
– Warum wühlt sie uns auf und spricht uns manchmal auf eine Weise an, wie es die Sprache nicht vermag?
– Warum berührt uns der traurige Ton einer Oboe?
– Warum empfinden manche Menschen bestimmte Tonfolgen als „fröhlich“, andere als „traurig“ und dritte als „gequält“?
– Warum beurteilen manche Menschen eine Musik als „schön“, die anderen überhaupt nicht gefällt?
– Warum geraten einige Menschen bei einem bestimmten Musikstück in emotionale Verzückung, während dieselbe Musik andere unberührt läßt?

Diese Liste könnte beliebig fortgesetzt werden. Natürlich sind solche Fragen nicht neu und wurden zum Teil schon in der Antike gestellt, allerdings mehr aus philosophischer Sicht. Mit dem Fortschritt in den Naturwissenschaften und der Medizin war es erst möglich, sich dem Phänomen „Musik“ wissenschaftlich anzunehmen. Zuerst über die Akustik, die sich mit der Entstehung und Wahrnehmung von Schall und Tönen beschäftigt. Aus ihr heraus entstand eine eigene Forschungsrichtung, die musikalische Psycho-Akustik, die jeden Aspekt der Musik untersucht – von der Wahrnehmung bis zur Empfindung.

Daneben entwickelten sich in jüngster Zeit die Neurowissenschaften, die auf verschiedenen Wegen und mit den unterschiedlichsten *In-vitro-* und *In-vivo-*Methoden versuchen, Einblicke in die Funktionen des Zentralnervensystems zu gewinnen.

Mit modernen nicht-invasiven Untersuchungsmethoden ist es möglich, Zellareale im Zentralnervensystem zu lokalisieren und zu identifizieren, die über das Sinnesorgan „Ohr“ aktiviert werden. Hierdurch haben wir ein Grundwissen darüber erhalten, wie unser Gehirn die musikalischen Strukturen hierarchisch gliedert und zusammenstellt und was passiert, wenn wir Musik spielen und hören.

Faszinierende Einblicke sind gelungen, die während der nächsten Tage diskutiert werden sollen.

Auf unserem Symposium treffen sich Physiker, Physiologen, Psychologen, Musikwissenschaftler, Komponisten und Musiker, die die Anwendung wissenschaftlicher Verfahren diskutieren und Beiträge zur Hervorbringung, Übertragung und Wahrnehmung von Musik vorstellen.

Die Initiative für unser Leopoldina-Symposium ging von Herrn Professor Weidenmüller aus Heidelberg und Herrn Professor Smilansky aus Rehovot, Israel, aus, und ich möchte mich bei diesen beiden Kollegen sehr herzlich für diese Initiative und für ihr Engagement und ihre Organisation bedanken. In diesen Dank schließe ich die beiden Musikwissenschaftsprofessoren Auhagen und Ruf hier aus Halle mit ein, die das Programm inhaltlich mit gestaltet haben.

Ich wünsche uns allen eine interessante Veranstaltung mit neuen Einblicken, wie Musik im Gehirn entsteht und wirkt.

Prof. Dr. Volker ter Meulen
Deutsche Akademie der Naturforscher
Leopoldina
Postfach 110543
06019 Halle (Saale)
Bundesrepublik Deutschland
Tel.: +43 345 4723910
Fax: +43 345 4723919
E-Mail: president@leopoldina-halle.de

Nova Acta Leopoldina NF *92*, Nr. 341, 9–15 (2005)

Music and Mathematics

Manfred R. Schroeder (Göttingen)

With 5 Figures

Abstract

In September 1962, in the presence of Jacqueline Kennedy and Maestro Bernstein, Philharmonic Hall at the new Lincoln Center for the Performing Arts in New York was ceremoniously inaugurated. But its much touted acoustics soon revealed severe limitations. There were disturbing echoes, the celli could not be heard during tutti passages and, most seriously, the listeners felt “detached” from the music emanating from the stage; there was no sensation of being “enveloped” by the music.

The author, then at nearby Bell Laboratories, was one of a committee of four acoustical experts charged by Lincoln Center with the analysis of these problems. Extensive testing revealed that the lack of low-frequencies (the “celli problem”) could be attributed to an insufficient reflection of low-frequency energy by the overhead acoustic panels. The echoes were easily localized and removed by acoustic absorbers. But the main problem, the “lack of envelopment”, had to wait several years before its find clarification. In 1969, after having assumed the directorship of the *Dritte Physikalische Institut* of the University of Göttingen, the author petitioned the German Science Foundation (DFG) to support a large-scale investigation of concert hall acoustics, involving 22 halls in Europe and America. The main conclusion from this study was that good acoustics for music requires energetic sound waves striking a listener’s head from the sides – something that most modern halls with low ceilings and wide seating areas could not provide. To remedy this defect, the author suggested the use of sound diffusing surfaces on the ceiling and side walls of concert halls based on number-theoretic principles, such as quadratic-residues. Quadratic-residues diffusers are now used world-wide, not only in concert halls, but also in recording studios, radio stations and even private homes.

Another field were mathematics has had a considerable impact, going in fact back to the Pythagoreans, are musical scales. New scales have been constructed based on the frequency interval 3:1 replacing the familiar octave interval 2:1. Number theory guarantees excellent harmonic properties if the 3:1 interval is subdivided into 13 equal steps.

Number theory has also yielded interesting recursive algorithms for the generation of simple melodies reminiscent of baroque music.

Zusammenfassung

Im September 1962 wurde die *Philharmonic Hall* des neuen *Lincoln Center for the Performing Arts* in New York im Beisein von Jacqueline Kennedy und Maestro Bernstein feierlich eröffnet. Aber die im Voraus viel gepriesene Akustik zeigte bald ernstliche Mängel. Es gab störende Echos. Die Celli waren während tutti-Passagen unhörbar, und, besonders gravierend, die Hörer hatten das Gefühl von der Musik auf dem Podium „abgekoppelt“ zu sein; es fehlte das Gefühl von der Musik „umgeben“ zu sein.

Der Autor, der damals bei den nahegelegenen *Bell Laboratories* arbeitete, wurde Mitglied eines Komitees von vier akustischen Experten, die vom *Lincoln Center* gebeten wurden, die Probleme der *Philharmonic Hall* zu analysieren. Ausgiebige Messungen zeigten, daß der Mangel an tiefen Frequenzen (das „Celli-Problem“) auf die ungenügende Reflektion von niedrig frequenter Energie durch die akustischen Panele an der Decke zurückgeführt werden konnte. Die Echos waren leicht zu lokalisieren; sie wurden durch akustische Absorber entfernt. Aber das Hauptproblem, der „Mangel an Eingehülltsein“ mußte mehrere Jahre auf seine Lösung warten. Im Jahre 1969, nachdem der Autor die Leitung des Dritten Physikalischen Instituts der Universität Göttingen übernommen hatte, bat er die Deutsche Forschungsgemeinschaft (DFG), eine groß angelegte Studie der Konzertsaal-Akustik von 22 Sälen in Europa und Amerika zu unterstützen. Das Hauptergebnis dieser Studie war, daß eine gute Akustik für Musik energiereiche seitlich einfallende Schallwellen am Kopf des Zuhörers erfordert – eine Bedingung, die in den meisten modernen Sälen mit niedriger Decke und großer Breite nicht erfüllt ist. Um diesem Manko zu begegnen, empfahl

der Autor die Benutzung von schallsteuernden Oberflächen an der Decke und den Seitenwänden von Konzertsälen, die auf zahlentheoretischen Prinzipien, wie quadratischen Resten, basieren. Quadratische-Reste-Diffusoren werden heute weltweit angewendet, nicht nur in Konzertsälen, sondern auch in Aufnahme-Sudios, Rundfunksendern und selbst privat zuhause.

Ein anderes Gebiet, in dem die Mathematik erfolgreich angewendet wurde, ist die schon auf die Pythagoreaner zurückzuführende Konstruktion von Tonleitern, zum Beispiel solche, in denen das bekannte Frequenzverhältnis 2:1 (Oktave) durch ein Frequenzverhältnis 3:1 ersetzt wurde. Die Zahlentheorie garantiert exzellent harmonische Eigenschaften, wenn man das 3:1 Intervall in 13 gleichgroße Schritte einteilt.

Zahlentheoretische Prinzipien führen auch auf interessante rekursive Algorithmen zur Erzeugung einfacher Melodien, die an Barockmusik erinnern.

This paper considers three of the many interactions between Music and Mathematics:

(*i*) Concert Hall Acoustics,
(*ii*) New Musical Scales,
(*iii*) Algorithms for Generating Melodies.

1. Concert Hall Acoustics

In September 1962, in the presence of Jacqueline Kennedy and Maestro Bernstein, Philharmonic Hall at the new *Lincoln Center for the Performing Arts* in New York was ceremoniously inaugurated.

Figure 1 shows Philharmonic Hall in its original configuration in 1962. Note the overhead hexagonal acoustic reflection panels.

But its much touted acoustics soon revealed severe limitations. There were disturbing echoes, the celli could not be heard during tutti passages and, most seriously, the listeners felt "detached" from the music emanating from the stage; there was no sensation of being "enveloped" by the music.

The author, then at nearby Bell Laboratories, was one of a committee of four acoustical experts charged by Lincoln Center with the analysis of these problems. Extensive testing revealed that the lack of low-frequencies (the "celli problem") could be attributed to an insufficient reflection of low-frequency energy by the overhead acoustic panels.

Figure 2 shows the acoustic energy along the middle aisle on the main floor. Note the dramatic attenuation of the low frequencies around 125 Hz compared to 750 Hz.

Before beginning the acoustic measurements, the author asked the ushers, students of the Juillard School of Music, whether there wasn't a good location. Their answer was: yes, Seat A-15, which was therefore included in the measurements. And, indeed, instead of a 30-decibel (dB) attenuation, there was only a 3-dB drop between 750 Hz and 125 Hz.

The echoes were easily localized and removed by acoustic absorbers. But the main problem, the "lack of envelopment", had to wait several years before its find clarification.

In 1969, after having assumed the directorship of the *Dritte Physikalische Institut* of the University of Göttingen, the author petitioned the German Science Foundation (DFG) to support a large-scale investigation of concert hall acoustics, involving 22 halls in Europe and America. The main conclusion from this study was that good acoustics for music requires energetic sound waves striking a listener's head from the sides – something that most modern halls with low ceilings and wide seating areas could not provide.

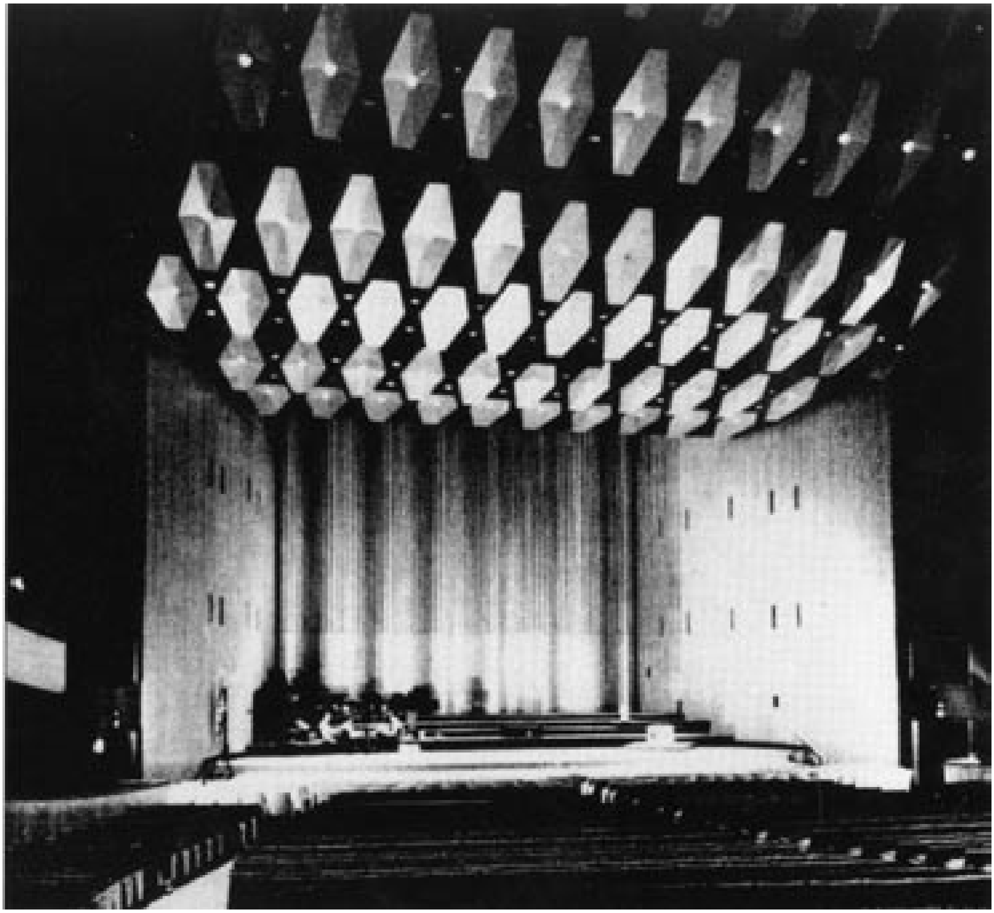

Fig. 1 Philharmonic Hall, New York, in its original state in 1962. Note the overhead acoustic reflection panels.

To remedy this defect, the author suggested the use of sound diffusing surfaces on the ceiling and side walls of concert halls based on number-theoretic principles, such as quadratic-residues.

Figure 3 shows a quadratic residue diffuser in cross-section based on the prime number $p = 17$. For $p = 17$, the quadratic residues are $a_n = 0, 1, 4, 9, 16, 8, 2, 15, 13, 13, 15, ...$ (Note that $5^2 = 25$ which is congruent 8 modulo 17 and $6^2 = 36$ which is congruent 2 modulo 17 etc.). The depth of the channels are proportional to these residues a_n creating local reflection coefficients $r_n = \exp(2\pi\, i\, a_n/17)$. It can be shown that the Fourier Transform of the (periodic, with period 17) r_n has constant magnitude resulting in a uniform diffusing pattern at 16 different frequencies, see Figure 4.

Quadratic-residue diffusers are now used world-wide, not only in concert halls, but also in recording studies, radio stations and even private homes.

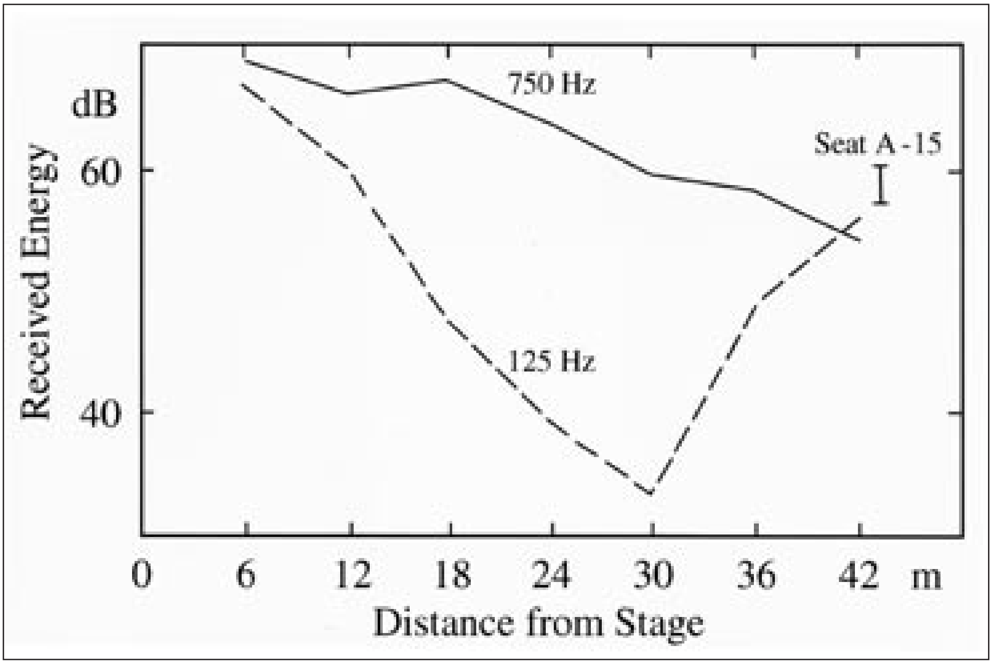

Fig. 2 Philharmonic Hall, New York: The received acoustic energy from the stage along the center of the main floor. Note the steep drop for the low notes (125 Hz).

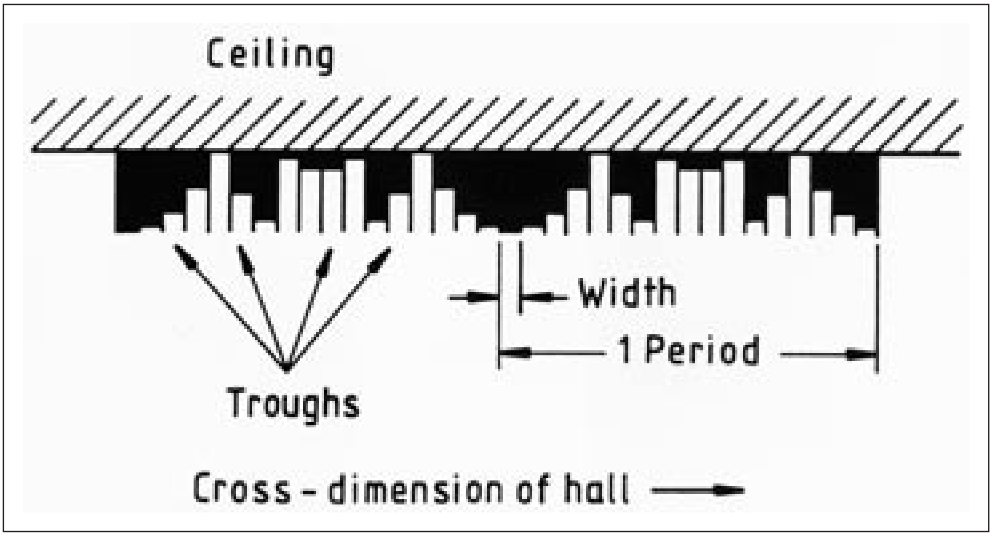

Fig. 3 Quadratic-residue diffuser based on the prime number 17.

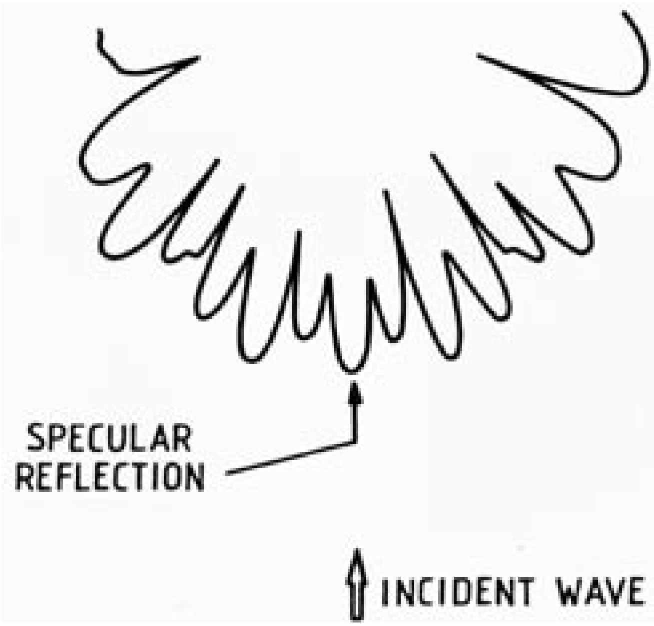

Fig. 4 Back scatter from quadratic-residue diffuser: The diffuse reflection from the diffuser shown in Fig. 3. Note the preponderance of desirable lateral reflections.

2. New Musical Scales

Many musical scales are based on the octave, i.e. a frequency ratio 2 : 1. By subdividing the octave into 12 equal ratios or "semitones", $2^{1/12}$, the most important intervals, can be well approximated. For example, the perfect fifth, having a frequency ratio of 3 : 2 = 1.5 is well represented by seven semitones: $2^{7/12} = 1.498$ instead of 1.5, where the difference is called "Pythagorean comma". The scales based on $2^{1/12}$ are called "well-tempered" scales.

In the 1970s Heinz Bohlen and John R. Pierce introduced musical scales based on the frequency interval 3 : 1. They found that by subdividing the "tritave", as he called it into 13 equal ratios, they could approximate several ratios of small integers very well. Thus, for example, the ratio 5 : 3 = 1.666... is well represented by 6 "tritave semitones":

$$3^{6/13} = 1.660 \text{ which is very close to } \frac{5}{3} \qquad [1]$$

and, amazingly,

$$3^{4/13} = 1.402 \text{ close to } \frac{7}{5}, \qquad [2]$$

with an error of less than 2 parts in a thousand. Bohlen and Pierce proceeded to construct both mayor and minor musical scales based on the frequency ratio 3 : 1 in close analogy to the scales based on the octave (2 : 1).

What is the mathematical reason behind these uncanny coincidences? The answer comes from number theory, namely *continued fractions*, as Kees van Prooijen, a Dutch music theorist, first discovered. For example, if we desire to approximate the integer 5 by a power of 3, we have to consider the ratio

$$r = \frac{\log 3}{\log 5} = \cfrac{1}{1 + \cfrac{1}{2 + \cfrac{1}{6}}} \cdots \qquad [3]$$

and approximate it by a rationed number:

$$\frac{13}{19}. \qquad [4]$$

Thus, 5 equals about $3^{19/13}$ and similarly 7 is close to $3^{23/13}$. As a consequence well-tempered tritave scales can be based on the "semitone" $3^{1/13}$, which equals about 1.463 customary semitones. Music composed using the tritave scales needs time to be appreciated.

3. Algorithms for Generating Melodies

Consider the integers 0, 1, 2, 3, 4, ... written in binary notation 0, 1, 10, 11, 100, ... and count the number of 1s: 0, 1, 1, 2, 1, 2, 2, 3, 1, 2, 2, 3, 2 ...

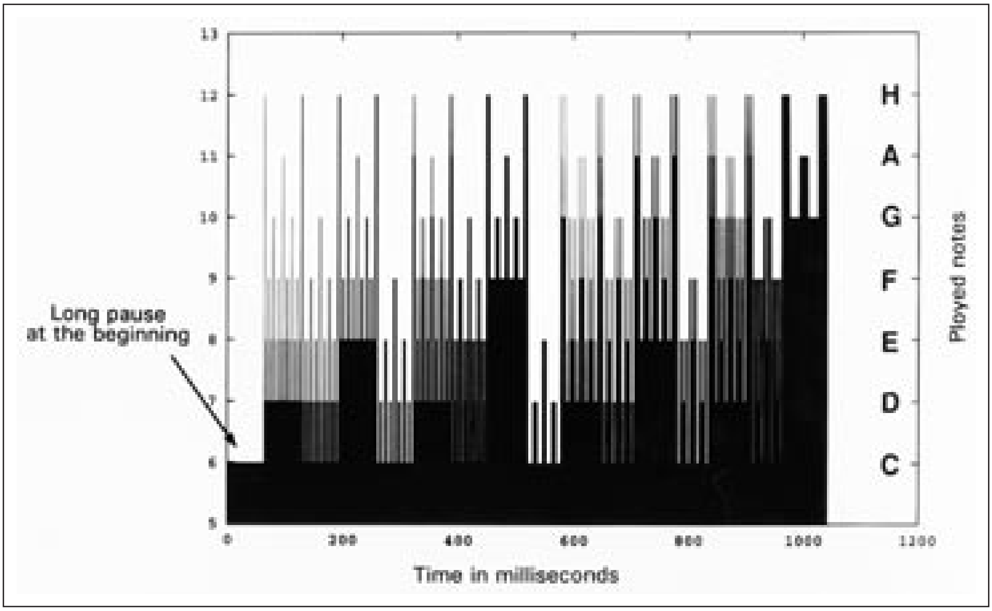

Fig. 5 Every 63rd term of the number-theoretic sequence 01121223122322334 derived from the binary representation of the integers. Note the "fractal" nature of the notes.

The result is a self-similar sequence because taking every second term reproduces the (infinite) sequence: 0, 1, 1, 2, 1, ... Converting these numbers to a musical scale, say C major, with C = 6, D = 7, etc. results in an attractive self-similar melody. However, taking every 3rd or 7th or, say, every 63rd term, see Figure 5, results in a distinctly "baroque" sounding tune. Many musical pieces have been composed involving this and similar algorithms, see (and listen to !) www.reglos.de/musinum.

Further Reading

Bohlen, H.: 13 Tonstufen in der Duodezime. Acustica Vol. 39, pp. 76–86. Stuttgart: S. Hirzel (1978)
Pierce, J. R.: The Science of Musical Sound. New York: Scientific American Library, W. H. Freeman 1983
Schroeder, M.: Fractals, Chaos, Power, Laws: Minutes from an Infinite Paradise. New York: W. H. Freeman 1991
Schroeder, M. R.: Number Theory in Science and Communication. Berlin: Springer 1999 (Third Edition)

Prof. Dr. Manfred R. Schroeder
Rieswartenweg 8
37077 Goettingen
Germany
Phone: +49 551 21232

Festliche Übergabe des Präsidentenamtes von Benno Parthier an Volker ter Meulen

am 13. Februar 2003 im Freylinghausen-Saal der Franckeschen Stiftungen zu Halle (Saale)

Nova Acta Leopoldina N. F., Bd. *89*, Nr. 335
Herausgegeben vom Präsidium der Akademie
(2003, 54 Seiten, 17 Abbildungen, 22,80 Euro, ISBN 3-8047-2039-0)

Die Übergabe des Präsidentenamtes in der Deutschen Akademie der Naturforscher Leopoldina lieferte die Gelegenheit für eine erneute Standortbestimmung der Akademie, nachdem die Leopoldina erst 2002 ihr 350. Gründungsjubiläum begangen hatte. Nach der Begrüßung durch Leopoldina-Vizepräsident Ernst-Ludwig Winnacker (Bonn/München) beschäftigte sich der scheidende Präsident Benno Parthier (Halle/Saale) mit den erforderlichen Weichenstellungen und Entwicklungen der Wirkungsfelder der Akademie in den zurückliegenden Jahren seiner Präsidentschaft. In seiner Antrittsrede umriß der neue Präsident Volker ter Meulen (Würzburg) die weiteren Aufgaben der Leopoldina und ging dabei auch auf die heißdiskutierte Frage einer nationalen Akademie für Deutschland ein. In seinem Festvortrag sprach Wolfgang Frühwald (München) zum Thema „Eine liebenswerte Wissenschaft und ein glücklicher Sisyphos. Zum Leben und zur Arbeit einer nationalen Akademie“.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Nova Acta Leopoldina NF *92*, Nr. 341, 17–31 (2005)

The Domain of Tonal Melodies: Physiological Limits and Some New Possibilities

Ralph van Dinther and Roy D. Patterson (Cambridge)

With 10 Figures

Abstract

There is size information in musical sounds: There is the pitch of the note, which is correlated with instrument size, and there is the size of the resonators in the instrument, or the scale of the impulse response, which is also correlated with instrument size. If a violin and cello play the same note, it is still possible to tell which is the larger instrument. With regard to pitch, auditory neuroscientists have recently used brain imaging to show that the there are overlapping but distinguishable regions in the human brain for the processing of octaves and the cycle of notes within the octave. With regard to resonator size, they are using operator theory from quantum mechanics to understand the scaling of the impulse response, and to develop an auditory version of the Mellin Transform to explain how humans perceive size information in speech and music.

In this paper we argue that it is the auditory system that restricts the domain of notes that can be used to make melodies. We show that, within the domain, it is possible to change the size of an instrument and to change the octave of a note without going through the cycle of notes within the octave.

The results have interesting implications for musicians; namely, that the notes currently used to make melodies with traditional instruments are just a small portion of the notes available to composers.

Zusammenfassung

Musik enthält Information über Größe: Sowohl die Tonhöhe einer Note als auch die Resonanzen oder die Impulsantworten des Instruments sind mit seiner Größe korreliert. Anhand des Klanges kann man sagen, daß ein Cello größer ist als eine Geige, selbst wenn auf beiden dieselbe Note gespielt wird. Mit Hilfe von bildgebenden Verfahren konnte gezeigt werden, daß das menschliche Gehirn die Tonhöhe von Oktaven und die Tonhöhe von Noten im Oktavenzirkel in unterschiedlichen, wenn auch überlappenden Regionen verarbeitet. Die Skalierung der Impulsantwort im Hinblick auf die Größe der Resonatoren kann mit Hilfe einer der Quantenmechanik entliehenen Operatortheorie beschrieben werden. Die menschliche Fähigkeit zur Wahrnehmung der Größe in Sprache und Musik kann durch ein Modell einer auditorischen Version der Mellin-Transformation verstanden werden, das daraus entstanden ist.

Wir schlagen hier vor, daß der ganze Bereich von Noten, mit denen Musik gemacht werden kann, durch das auditorische System beschrieben werden kann.

Wir zeigen, daß es innerhalb dieses Bereiches möglich ist, durch Änderung der Größe des Instrumentes die Oktave einer Note zu ändern, ohne um den Oktavenzirkel zu gehen. Dies könnte für Musiker interessant sein, denn es bedeutet, daß die Noten, die Komponisten herkömmlich verwenden, nur einen kleinen Ausschnitt dessen darstellen, was möglich ist.

1. Introduction

Through the centuries, composers of orchestral music have been inspired to write melodies by musical instruments including the voice. At the same time, they have been restricted to the range of sounds these instruments can produce. Auditory perception research has broadened the understanding of how people perceive sounds, and it has provided new insights and ideas for extending the range of musical sounds. In general these new sounds cannot be produced by acoustical instruments. However, the development of electronic instruments and computers means that it is now possible to apply our knowledge of auditory perception to sound manipulation. Moreover, computers enable us to produce new classes of notes in a controlled manner with respect to auditory theory. This paper will focus on two methods of extending the domain of musical notes in ways that might be musically productive: One focuses on the special rules that make it possible to blend instruments from the same family when they are playing notes whose pitches bear a simple integer ratio. This is the basis of the well known "Shepard" tone, and we will show that it is just a special case of a more general "helix circle" sound which would appear to have considerable potential in composition. The second extension involves numerical methods for manipulating size information in musical sounds. It appears that we can provide the composer with synthetic, but highly realistic, instrument sounds where the composer has direct control over the size of the instrument just as they do over the pitch it produces. This means that the traditional pitch helix is more than just a wire. It is a complete surface and composers can write compositions where the melodies can change simultaneously in pitch and instrument size, to execute ordered trajectories from circles to paisleys on the surface of the pitch helix.

Pitch is essential for tonal melodies since it is pitch that defines musical intervals. The first section of this paper describes constrains on notes that can be used to make tonal melodies and presents the domain of melodic pitch, including some recent experiments performed to determine the lower limit of pitch (Krumbholz et al. 2000) and the domain of melodic pitch (Pressnitzer et al. 2001) for multi-harmonic sounds.

The second section describes ways of extending the domain of musical sounds and presents some applications.

2. The Domain of Melodic Pitch

In orchestral music the range of notes available within the families of instruments all fall within the range of notes of the piano keyboard. The range is considerably less than the range of hearing and this raises the question why the range of notes of musical instruments are restricted to the keyboard range, and what the limits are on notes that can be used to convey melody. In this section we describe the domain of melodic pitch and how it is determined.

The ANSI definition of pitch says that pitch is that auditory attribute of sound according to which sounds can be ordered on a scale from low to high. For musicians, this definition is of little use; it is incomplete and vague. A number of scientists (e.g. Stevens et al. 1937 and Stevens and Volkman 1940) have tried to tie pitch to the physical scale of acoustic frequency, but it only works for isolated sine tones (e.g. Schouten 1938, Schouten et al. 1962 and Terhardt 1974). The pitches of complex sounds, such as the vowels of speech and the notes of music, are more closely related to the repetition rate of the waveform, or the fundamental of the harmonics of the sound. This residue pitch has already been studied since the 19^{th} century by Seebeck (1841).

This paper is about complex sounds, so pitch refers to the number of cycles per second (cps) of a waveform; within the period, the waveform can have any shape. The frequency of a sinusoidal tone is acoustic frequency in Hertz and it is this frequency that defines the limits of human hearing (20–20000 Hz). It is range of acoustic energy that humans are sensitive to. The range of human hearing is much larger than the range of pitch of most of the musical instruments, which does not extend below 27.5 cps or above 5000 cps. Auditory research has shown that above about 2 kHz, a sequence of tones does not convey melody reliably. Above this acoustic frequency the nerve impulses in the cochlea become progressively less well phase-locked to the stimulus. KRUMBHOLZ et al. (2000) investigated the lower limit of pitch for filtered, periodic click trains by measuring rate discrimination threshold (RDT). KRUMBHOLZ et al. (2000) found that the RDT of a periodic click train is about 30 cps when the harmonics are in cosine phase.

Figure 1 shows a Stabilized Auditory Image (SAI) (PATTERSON et al. 1995, IRINO and PATTERSON 2002) of a periodic, band-pass-filtered click train with a click every 8 ms (125 cps). The top panel shows the filtered click train in the time domain. The SAI is a simulation of the first internal representation of sound of which we are consciously aware. The ordinate is the tonotopic dimension produced by the basilar membrane in the cochlea, it is similar to a log-frequency axis. The abscissa is the time interval between neural impulses in the auditory nerve. The bottom panel shows the point-wise summation of the SAI across channels for each time interval; the right-hand panel shows the point-wise summation over time interval for each frequency channel.

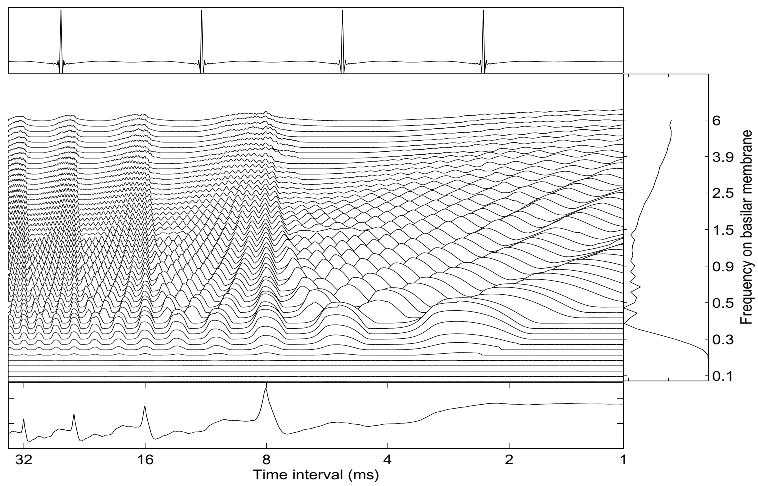

Fig. 1 Stabilized Auditory Image of an 8 ms click train (central panel). The top panel shows the click train in the time domain. The bottom and right-hand panels show point-wise summations over channels and time interval, respectively.

The SAI was computed with the auditory image model (AIM) (PATTERSON 1994) and an implementation referred to as aim-mat (BLEECK et al. 2004). It is constructed in three stages. First, a spectral analysis is performed by a bank of gammatone filters (IRINO and PATTERSON 1997) which models the basilar membrane motion in the cochlea. The second stage simulates the neural transduction process performed by the inner hair cells; the result is a simulation of the neural activity pattern at the level of the cochlear nucleus. Periodic sounds with repetition rates above 32 cps are perceived as static or stationary, which indicates that the auditory system applies some kind of temporal integration to the neural activity patterns before we perceive them. Auditory research also indicates that the phase-locked fine structure observed in the neural activity patterns plays a role in the quality or timbre of a complex sound (Krumbholz et al. 2003). This is achieved in the third stage of AIM using 'strobed' temporal integration (Patterson et al. 1992, Irino and Patterson 1997). This process maps the repeating patterns produced by periodic sounds in the neural activity pattern onto one stabilized version of the pattern. The result is the SAI. In Figure 1 the vertical ridge at 8 ms shows that there is a concentration of time-intervals at 8 ms in many channels. This is the representation of pitch in AIM. The secondary vertical ridges arise because there are also concentrations of time intervals at multiples of 8 ms in the neural pattern. The bottom panel presents the summary SAI in which the period of the sound appears as an isolated maximum relative to the background level.

A click train with a click rate below 10 Hz does not produce a pitch; each click is heard as a separate event. For rates between 10 and 30 Hz, the dominant perception is one of flutter, and there are no ridges in the SAI or the summary SAI. It is only when the click rate rises above 30 Hz that the vertical ridge associated with pitch builds up in the SAI.

The click train in Figure 1 was band-pass filtered between 300 and 6,000 Hz, and so there is no energy at the fundamental or the second harmonic. This does not change the pitch chroma although it does change the timbre slightly. If the high-pass cutoff is progressively increased, the strength, or salience, of pitch becomes weaker as the harmonics are removed, but the chroma remains the same. Ultimately, the pitch deteriorates what (Plomp 1976) refers to as rattle pitch, and in this case, the ridges in the SAI become broad and the peaks in the summary SAI fade into the background.

The domain of melodic pitch is closely related to rate discrimination threshold (RDT). Krumbholz et al. (2000) measured RDT for periodic click trains that were filtered into bands with high-pass cutoffs ranging in frequency from 0.2 to 6.4 kHz. The results for a RDT of 3 % are presented in Figure 2, where it can be seen that RDT increases rapidly as the cutoffs increases above 1 kHz. Pressnitzer et al. (2001) investigated the lower limit of melodic pitch for band-pass filtered click trains. Threshold was defined as the lowest rate that would support detection of a semitone change in a short melody. They found that the lower limit was effectively the same as the 3 % RDT observed by Krumbholz et al. (2000).

The region in the right-hand lower corner of the figure is shaded to indicate that notes cannot be produced in this region; the fundamental cannot be lower than the lowest harmonic. The region between RDT of 3 % and the shaded region is the domain of melodic pitch. Notes in this region can be used to make melodies where listeners would recognize if a note changed by a semitone. By and large, the notes of music and the vowels of speech all fall within this region.

There is more information in a complex tone than just its pitch. There is also information about octave height and the size of the instrument. These are the topics of the next two sections.

3. Octave Height

For musicians, pitch has two dimensions in the sense that a note has an octave (e.g. C_1, C_2, C_3, ...) and a position on the cycle of notes within the octave (*C*, *C#*, D, *D#*, *E*, *F*, *F#*, *G*, *G#*, *A*,

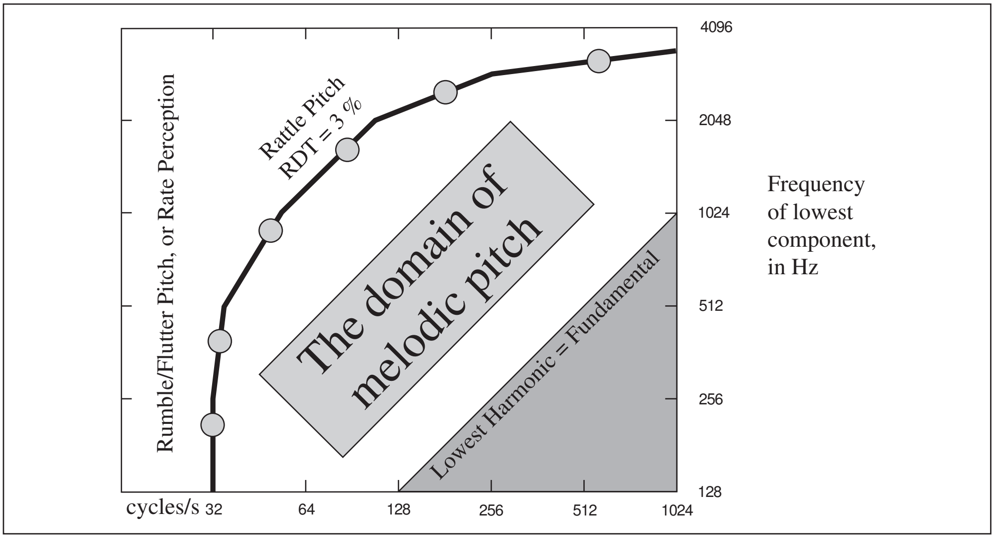

Fig. 2 The domain of melodic pitch

A#, *B*, *C*). In auditory perception, these dimensions are referred to as octave height and pitch chroma, and Warren et al. (2003) have shown that there are overlapping but distinct regions of activation in the brain for the processing of pitch chroma and octave height. The musical scale of the keyboard can be represented as a helical curve with one complete octave of notes per winding Figure 3. In this representation, octave equivalence can be accommodated by allowing notes on the surface of the cylinder that encompasses the helix. On the cylinder, octave height is just the vertical dimension of the helix; the circular dimension is pitch chroma.

The structure of the helix prompted Shepard (1964) to create his "eternally ascending tone", in which the height of the note is gradually lowered an octave while it steps sequentially up through the 12 values of chroma in the octave. The sequence goes on forever without ever rising into the next octave. Shepard's "tone" was composed of harmonics spaced an octave apart, and it was filtered by Gaussian spectral filter (on a logarithmic frequency scale). As the top component is progressively attenuated and passes out of the top of the filter, another component comes in at a very low level at the bottom of the filter and, with care, the sound can be made to cycle over 12 notes. Schroeder (1986) connected these *self-similar* waveforms with fractal objects.

Patterson (1990) suggested a method for varying octave height in multi-harmonic sounds that covers a much broader range of sounds than the Shepard tone, and which includes the sounds of many musical instruments. The procedure involves attenuating the odd harmonics of the sound as illustrated in Figure 4. As the odd harmonics are attenuated the octave height increases and when they are completely attenuated the note is an octave higher. Most orchestral instruments have a broad range of harmonics, and the odd harmonics can be attenuated to raise the octave height. One interesting exception is the clarinet; in the lower register the second harmonic is almost complete absent, which give the clarinet its characteristic hollow tone. The attenuation procedure can be made more general to handle incomplete harmonic sequences as follows: Define an *N*-dimensional frequency space *F* where *N* is the frequency

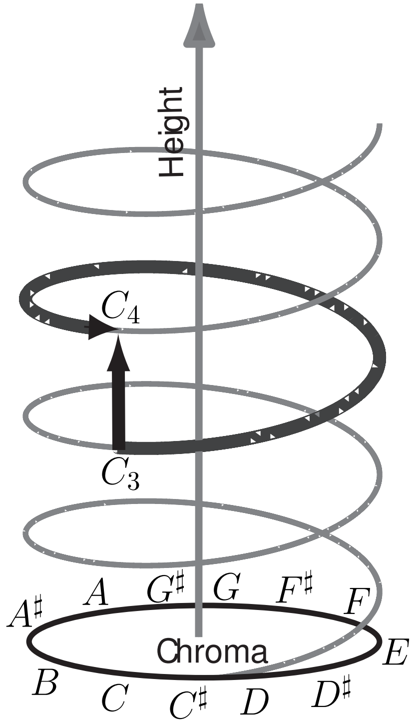

Fig. 3 The pitch helix. At the base of the helix the chroma steps are indicated by 12 semitones. After one complete cycle on the helical line, the pitch is exactly one octave higher. The vertical arrow shows a shortcut in which the octave height changes without going through the cycle of notes.

range. Each dimension represents the amplitude of one component on the frequency-axis for the frequencies $\{1, ..., N\}$. The amplitude spectra of the signal and its octave are represented by two vectors, say $\mathbf{v} := (v_1, v_2, ..., v_N)$ and $\mathbf{w} := (w_1, w_2, ..., w_N)$, respectively, in this frequency space F. The octave height can then be varied by simply following the linear path between the two vectors in the frequency space F; $(1-\lambda)\mathbf{v} + \lambda\mathbf{w}$ for $\lambda \in [0,1]$. In the right panel in Figure 4 stages are shown for changing the octave height in the case where some harmonics are absent.

The procedure amounts to defining the note for the two octave boundaries and then mixing the two octaves in varying proportions to produce intervening notes with the same chroma and very similar timbre. The possibility of changing octave height without changing the chroma provides the composer with a set of notes that fills in the space between the notes provided on traditional instruments. In the next section, we review the size information in musical instruments and show how it is possible to provide the composer with control of the perception of instrument size.

4. Size Information in Musical Sounds

The size information in a musical note is related to the pitch of the notes and the scale of the impulse response of the instrument. Music theory tends to emphasize the pitch component of size information and overlook the scale of the impulse response. The impulse response of an

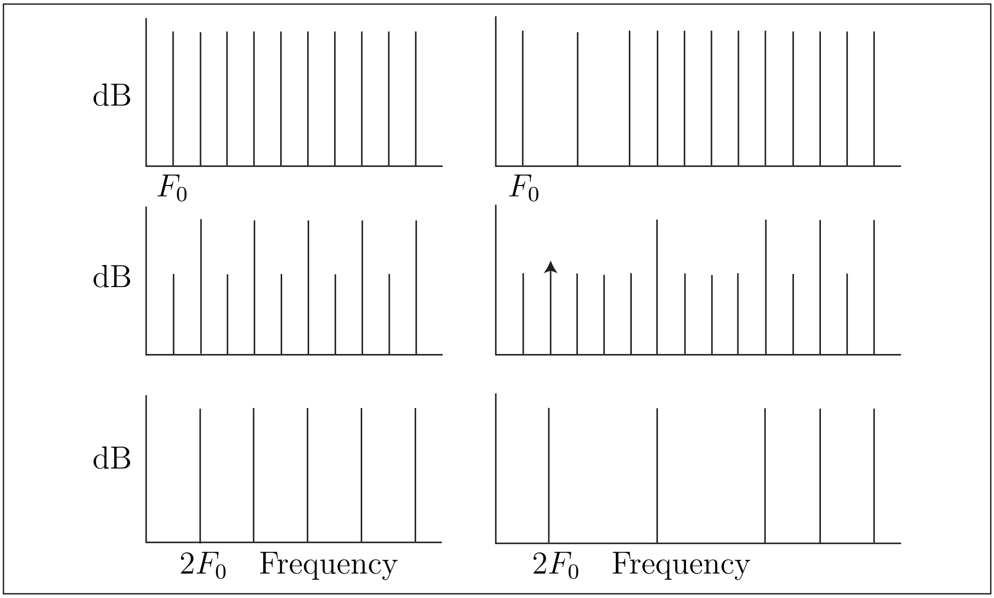

Fig. 4 Methods for increasing the octave height. In the left panel the odd harmonics are attenuated which transforms a complex sound with fundamental frequency F_0 into a sound with fundamental frequency $2F_0$. The right panel illustrates the general method for increasing octave height, for the case where two harmonics are absent.

instrument reveals the natural, resonant frequencies of vibration which decrease as the size of the instrument increases. A musical instrument vibrates readily at its resonant frequencies, and resists vibration at other frequencies. Similarly, a vibrating object will pick out its resonant frequencies from a complex excitation and resonate at those frequencies "filtering out" other frequencies in the excitation wave. Most vibrating objects have multiple resonant frequencies, for example, the primary resonances of string instruments are the main wood and air resonance (Benade 1976). These resonances are important indicators of the quality of the instrument. For a 1713 Stradivarius the air resonance and main wood resonance lie near the frequency of the *D* string and a little bit below the frequency of the *A* string, respectively (Hutchins 1962).

As the size of the body of a musical instrument increases, the frequencies of the resonances decrease in inverse proportion as illustrated in Figure 5. The top and bottom panels show the power spectra of notes produced by bowing a viola and a cello, respectively. The instruments are playing the same note (pitch). The hypothetical solid lines plotted above the harmonics in the panels represent resonance curves for the two instruments. The air resonance (A), main wood resonance (W), and bridge resonance (B) are indicated in the figure. For the viola the air, main wood and bridge resonances are about 230 Hz, 350 Hz and 2,000 Hz, whereas the resonances of the cello are about 125 Hz, 175 Hz and 1,500 Hz.

Since the two instruments play the same note, the figure helps us understand how we perceive the body size information in string sounds; we perceive the shift of the center of gravity of the spectrum as instrument size. Most musical instruments generate sounds with distinctive spectral envelopes, and so in most cases, the location of the resonances can be used to judge

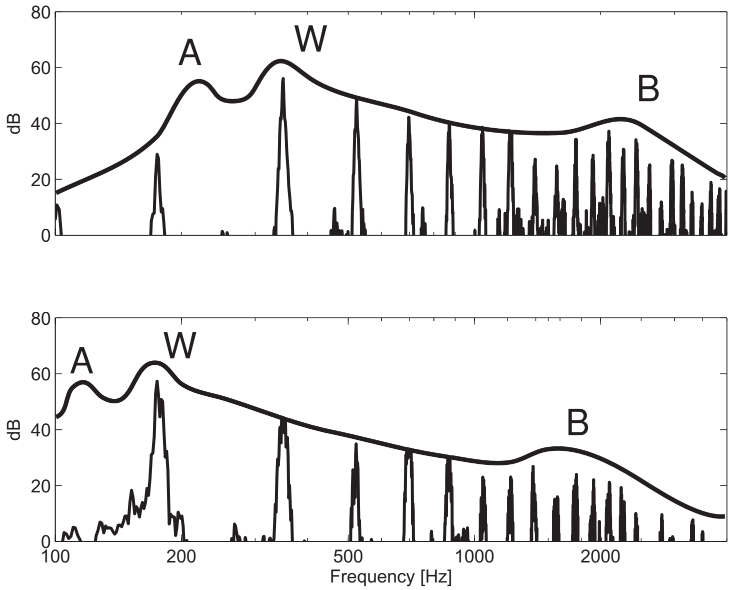

Fig. 5 The power spectra of sounds produced by bowing the viola (*top panel*) and cello (*bottom panel*). The frequency axis is logarithmic. The solid lines are hypothetical spectral envelopes showing the air resonance (A), the main wood resonance (W) and the bridge resonance (B).

instrument size. For woodwinds, important parameters which have an effect on the shape of the spectral envelope are the shape and size of the mouthpiece, and the tone-hole cutoff frequency. For brass instruments, it is mainly the mouthpiece and the bell that determine the characteristic sound of brass (Benade 1976).

We have to be careful about the definition of the size of an instrument because some instruments change in size during playing, for example brass instruments. Both the pitch and the scale of the impulse response change during playing, which suggests, that it would be difficult to judge the size of these instruments. However, a change in size within an instrument does not always result in a shift of the spectral envelope. In the case of the trombone changes in body length contribute to the pitch of the note, and the spectral envelope is mainly determined by the mouthpiece and bell. Figure 6 shows a stylized picture of a trombone.

The total length L that the air passes through is the sum of the length of the mouthpiece, the tubes and the bell: $L := L_0 + 2L_1 + 2L_2 + L_3 + L_4 + L_5$. The length of $L_2 := \lambda L_1$ for $\lambda \in [0,1]$ is variable due to the slider, and the total length of the tube can be extended to a maximum of $2L_1$. The cylindrical part of the trombone is a closed air column and produces resonant standing waves at the fundamental frequency and its odd harmonics. The length of the tube determines the spacing between the resonant frequencies. A longer tube length will lower the resonant frequencies and will decrease the spacing between them in the spectrum.

The effect of the bell raises the lower resonances from those of a closed tube toward a harmonic sequence. This effect is related to the location of the barrier at the bell from where the sound waves are reflected. For low-frequency sounds the barrier is near the end of the bell

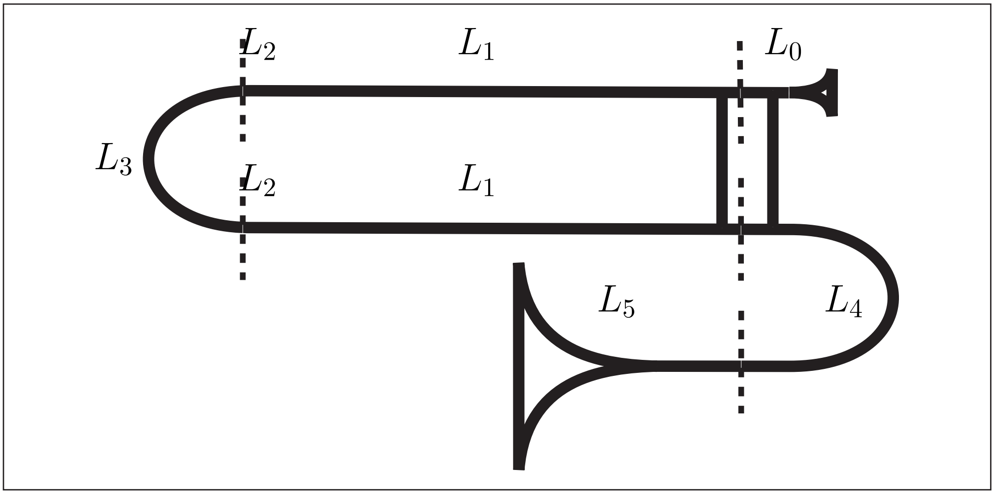

Fig. 6 Schematic of a trombone showing the tube lengths, L_0 to L_5, from mouthpiece to bell.

where it meets the cylindrical tube; for higher frequencies the barrier is shifted towards the mouth of the bell. Above a certain frequency, depending on the flaring of the bell, the sounds penetrate the barrier and are not reflected, and thus the resonances at those frequencies are absent.

The mouthpiece tends to force the high resonances into a harmonic sequence with respect to the resonances of a closed tube. The mouthpiece acts like a Helmholtz resonator, its natural resonant frequency depends on the volume of the cup and the constriction diameter. The mouthpiece is an important parameter for the shape of the resonance curve. The resonances of the tube that lie near the natural resonance of the mouthpiece are emphasized and can increase the impedance in that neighborhood by about five times. The larger the cup volume and the diameter of the mouthpiece, the lower is its natural resonant frequency. As a consequence, the spectral shape is shifted in the frequency domain, and the sound produced by the instrument is perceived to be larger.

Methods for measuring the resonances of brass instruments were reported by Benade (1976) and Backus (1977). Backus measured the resonance data for the mouthpiece by exciting the air column by a loudspeaker through a capillary tube near the mouthpiece end and measuring the pressure in response to the excitation by a response microphone which was attached at the mouthpiece. Figure 7 shows the resonances of a brass instrument. In the top panel the resonances are shown for the tube alone. The bottom panel shows the resonances of a complete brass instrument. The dashed vertical lines represent the resonances of the tube (top panel) and the complete instrument (bottom panel). The dotted vertical lines show the resonances when the tube length is extended. The solid vertical lines in the bottom panel show overlapping resonances of the two different tube lengths. The arrows in the figure show the spacing between the resonances.

We observe from the top panel of Figure 7 that an extension of the tube length results in a shorter spacing between the resonances. In the bottom panel we observe that an extension of

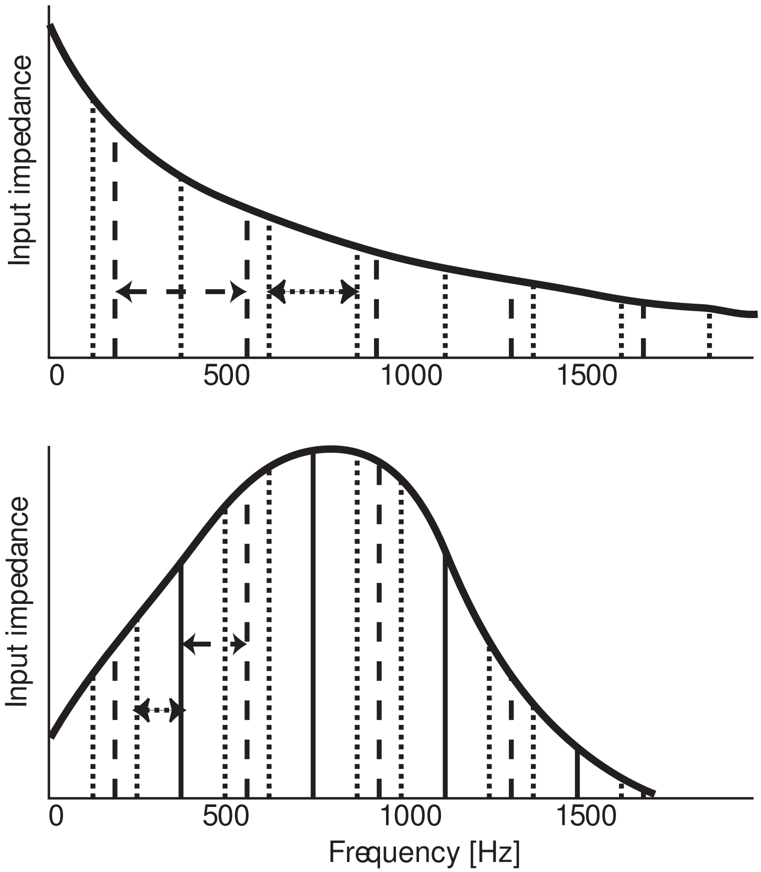

Fig. 7 Resonance curves for a piece of cylindrical tubing (*top panel*) and a complete brass instrument (*bottom panel*). The dashed and dotted lines show the resonances for two different tube lengths. The solid lines in the bottom panel show overlapping resonances for the two tube lengths. The arrows show the spacing between the resonances.

the tube length affects the spacing between the resonances, but does not shift the resonance curve.

In summary, the shape and size of the mouthpiece and the bell are important factors in determining the shape of the spectral envelope and its location on the frequency axis, whereas the length of the tube contributes mainly to the pitch of the note (the repetition rate of the wave). Playing different notes on a brass instrument will not cause a shift of the spectral envelope of the sound, and thus listeners can use this cue to judge its size. Similar arguments apply for woodwind instruments, such as the saxophone and clarinet.

In the next section, we describe (*i*) experiments on the perception of size information in vowel sounds scaled by the vocoder, and (*ii*) a new high-fidelity vocoder and how it can be adapted for use as a mucoder (music coder).

Size Perception and the Mucoder STRAIGHT

Smith and Patterson (2004) have shown that listeners are able to discriminate between vowels sounds produced with the same pitch but different vocal tract lengths. Moreover, they have shown that listeners are even able to do this task for vocal tract lengths well beyond normal experience. They argue that the auditory system performs some kind of active normalization to all input sounds (Irino and Patterson 2002), and that it is not necessary to learn statistical relations between pitch and resonant frequency in natural sounds as suggested by Assmann (Assmann et al. 2002).

The stimuli for these experiments were produced by a vocoder referred to as STRAIGHT which is actually a sophisticated speech processing package that dissects and analyzes an utterance at the level of individual glottal cycles (Kawahara et al. 1999). It segregates the pitch and vocal tract length information and stores them separately, so that the utterance can be resynthesized later with arbitrary shifts in pitch and vocal tract length. Utterances recorded from a man can be transformed to sound like women and children. The advantage of STRAIGHT is that the spectral envelope of the speech that carries the vocal tract information is transformed, as it is extracted, to remove the harmonic structure associated with the original glottal pulse rate (pitch), and the harmonic structure associated with the frame rate of the analysis window. As a result, the resynthesized utterances are of extremely high quality even when the speech is resynthesized with pitches and vocal tract lengths well beyond the normal range of human speech. The vocoder STRAIGHT also proves to be a fairly good mucoder; that is, a device for encoding, manipulating and resynthesising music.

Informal experiments indicate that manipulating musical notes with STRAIGHT to vary the pitch and instrument size works quite well for some instruments (e.g., brass) but not so well for others (clarinet). The success or failure seems to depend largely on the degree to which the wave used to re-excite the spectral envelope matches that which normally excites the instrument. STRAIGHT simulates the stream of glottal pulses in a vowel by summing a series of harmonics of the voice pitch. Initially, the harmonics are in cosine phase and the wave is like a band-pass filtered click train. Then, to make the speech sound more natural, a sophisticated form of jitter is applied to the phase of the high-frequency harmonics. The excitation of brass instruments is pulsive with much less phase jitter than in speech, and so STRAIGHT can be modified to mucode brass notes with considerable success, by simply turning off the phase jitter module. To adapt STRAIGHT for other instruments is somewhat more complicated, but the principal is the same and for some instruments, at least, the technique appears straightforward. For example, the excitation of the clarinet is like the sum of a series of odd harmonics of the pitch, since the clarinet is a classical tube closed at one end.

With STRAIGHT we are able to change the pitch, the body size, and the octave height of musical instrument sounds almost independently. In the next section we will present some musical applications of these concepts.

5. Some Applications Using Body Size and Octave Height for Creating New Notes

In this section we demonstrate how to change the octave height and body size of instrument sounds. For convenience, we describe the manipulations applied to a recorded instrument in terms of the resulting change in body size; namely *grow – stay – shrink*. The first manipulation "grow" refers to an increase in body size; the second, "stay", refers to no change in body size; the third, "shrink" refers to an decrease in body size. Figure 8 shows a spectrogram of a cello where the "grow-stay-shrink" transform has been applied. The *x*-axis is time, the *y*-axis is frequency, and the gray level shows the energy. The darker bands show the resonances.

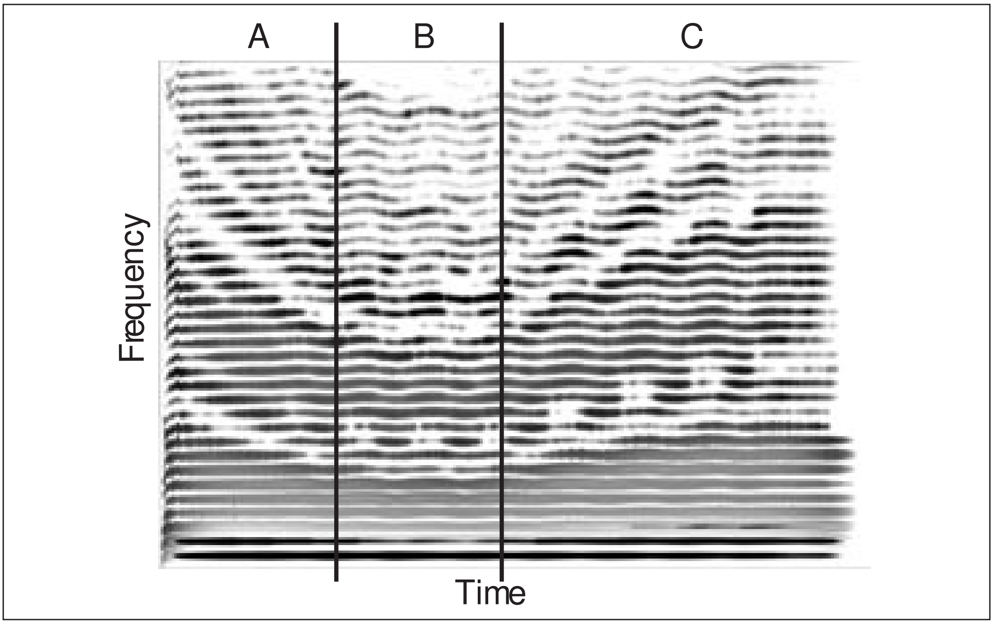

Fig. 8 Spectral view of a sustained sound produced by bowing a cello. The manipulations "grow-stay-shrink" causes the resonance to shift downward in frequency at first (*A*) and then back upward (*C*).

During the first manipulation (*A*), the resonances of the cello are shifted down in time and we perceive the instrument growing. In the last part (*C*), the resonances return upwards over time and the instrument is perceived to shrink.

The shrink manipulation can be combined with the octave height manipulation to produce a sound in which a tenor is gradually 'morphed' into a boy. The octave height is increased an octave over the course of the sound. Figure 9 shows a spectral view of this example in which the odd harmonics can be observed to decrease in magnitude of time.

Attenuation of 24 dB on the odd harmonics is sufficient to give the perception of the higher octave. At the same time, the formants are shifting upwards which imparts the perception of a person shrinking.

The final example is an "auditory zoom" *zoom in – zoom out* of the sort that would be appropriate to accompany an object appearing in a scene as a spec, then zooming in to its appropriate size and finally zooming out to a spec again. The spectrum of the instrument is compressed to a single frequency at the start. The frequency dimension is expanded as the note proceeds to its full size. Then at the end, it is progressively compressed again and the sound disappears back into a spectral point. In Figure 10, the manipulations "zoom in" and "zoom out" are applied to the singing voice.

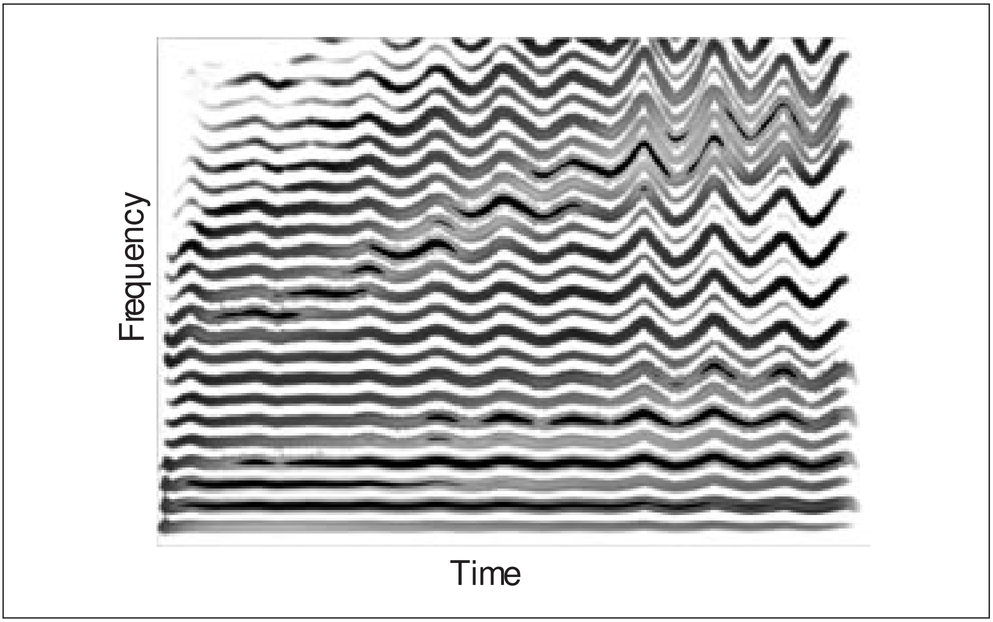

Fig. 9 Spectral view of a sustained sound produced by a tenor. In time the formants or shifted upwards, causing the perception of a person shrinking. At the same time, the odd harmonics are attenuated which causes an increase in octave height.

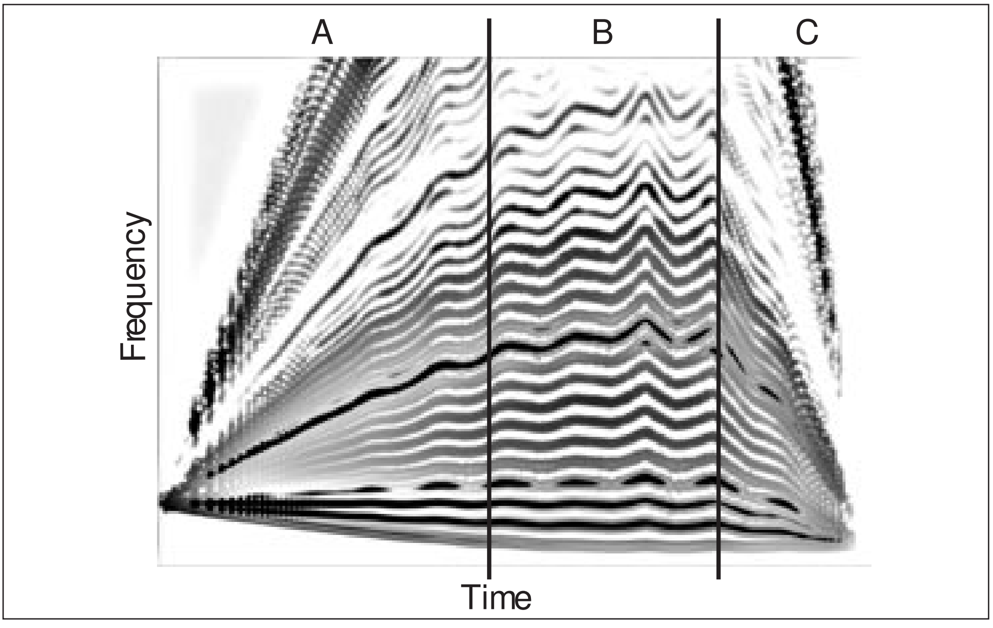

Fig. 10 Spectral view of a sustained sound produced by a tenor. In (*A*) the harmonics emerge from one spectral point frequency and in (*C*) they disappear into a second spectral point.

The Figure 10 shows (*A*) how the harmonics appear from one frequency and gradually are transformed to form a full spectrum of harmonics in part (*B*), at which point the voice sounds natural. In part (*C*) the harmonics are reduced again to a single frequency. One could, of course, have the instruments of an orchestral family zoom in from spectral points appropriate to the centroid of their average spectrum. The options would appear to endless, constrained only by the creativity of the scientist and the composer.

References

Assmann, P., Nearey, T., and Scott, J.: Modeling the perception of frequency-shifted vowels. In: Proc. ICSLP, 425–428 (2002)

Backus, J.: The Acoustical Foundations of Music. New York: W. W. Norton 1977

Benade, A.: Fundamentals of Musical Acoustics. Oxford: Oxford University Press 1976

Bleeck, S., Ives, T., and Patterson, R.: Aim-mat: the auditory image model in MATLAB. Acta Acustica *90*, 781–788 (2004)

Hutchins, C.: The physics of violins. Scientific American *207*, 78–93 (1962)

Irino, T., and Patterson, R.: A time-domain level-dependent auditory filter: the gammachirp. J. Acoust. Soc. Amer. *101*, 412–419 (1997)

Irino, T., and Patterson, R.: Segregating information about the size and shape of the vocal tract using a time-domain auditory model: The stabilised wavelet mellin transform. Speech Comm. *36*, 181–203 (2002)

Kawahara, H., Masuda-Kasuse, I., and Cheveigne, A. de: Restructuring speech representations using pitch-adaptive time-frequency smoothing and instantaneous-frequency-based f0 extraction: Possible role of repetitive structure in sounds. Speech Comm. *27*, 187–204 (1999)

Krumbholz, K., Patterson, R., Nobbe, A., and Fastl, H.: Microsecond temporal resolution in monaural hearing without spectral cues? J. Acoust. Soc. Amer. *113*, 2790–2800 (2003)

Krumbholz, K., Patterson, R., and Pressnitzer, D.: The lower limit of pitch as determined by rate discrimination. J. Acoust. Soc. Amer. *108*, 1170–1180 (2000)

Patterson, R.: The tone height of multi-harmonic sounds. Music Perception *8*, 203–214 (1990)

Patterson, R.: The sound of a sinusoid: Time-interval models. J. Acoust. Soc. Amer. *96*, 1419–1428 (1994)

Patterson, R., Allerhand, M., and Giguère, C.: Time-domain modelling of peripheral auditory processing: A modular architecture and a software platform. J. Acoust. Soc. Amer. *98*, 1890–1894 (1995)

Patterson, R., Robinson, K., Holdsworth, J., McKeown, D., Zhang, C., and Allerhand, M.: Complex sounds and auditory images; pp. 67–83. In: Cazals, Y., Demany, L., and Horner, K. (Eds.): Auditory Physiology and Perception. Oxford: Pergamon 1992

Plomp, R.: Aspects of Tone Sensation. London: Academic Press 1976

Pressnitzer, D., Patterson, R., and Krumbholz, K.: The lower limit of melodic pitch. J. Acoust. Soc. Amer. *109*, 2074–2084 (2001)

Schouten, J.: The perception of subjective tones. Proc. K. Ned. Akad. Wet. *41*, 1086–1093 (1938)

Schouten, J., Ritsma, R., and Cardozo, B.: Pitch of the residue. J. Acoust. Soc. Amer. *34*, 1418–1424 (1962)

Schroeder, M.: Auditory paradox based on fractal waveform. J. Acoust. Soc. Amer. *79*, 186–189 (1986)

Seebeck, A.: Beobachtungen über einige Bedingungen der Entstehung von Tönen. Ann. Phys. Chem. *53*, 417–436 (1841)

Shepard, R.: Circularity in judgements of relative pitch. J. Acoust. Soc. Amer. *36*, 2346–2353 (1964)

Smith, D., and Patterson, R.: The existence region for scaled vowels in pitch-vtl space. Proc. ICA *1*, 453–456 (2004)

Stevens, S., and Volkman, J.: The relation of pitch to frequency; a revised scale. Amer. J. Psychol. *53*, 329–353 (1940)

Stevens, S., Volkman, J., and Newman, E.: A scale for the measurement of the psychological magnetude of pitch. J. Acoust. Soc. Amer. *8*, 185–190 (1937)

TERHARDT, E.: Pitch, consonance, and harmony. J. Acoust. Soc. Amer. *55*, 1061–1069 (1974)
WARREN, J., UPPENKAMP, S., PATTERSON, R., and GRIFFITHS, T.: Separating pitch chroma and pitch height in the human brain. Proc. Nat. Acad. Sci. USA *100*, 10038–10042 (2003)

Dr. Ralph VAN DINTHER
Prof. Dr. Roy D. PATTERSON
Centre of the Neural Basis of Hearing
Department of Physiology
University of Cambridge
Downing Street
Cambridge CB2 3EG
Great Britain
Phone: +44 1223 333859
Fax: +44 1223 333840
E-Mail: roy.patterson@mrc-cbu.cam.ac.uk

350 Jahre Leopoldina – Anspruch und Wirklichkeit

Festschrift der Deutschen Akademie der Naturforscher Leopoldina 1652–2002

Herausgegeben von
Benno Parthier (Halle/Saale) und Dietrich von Engelhardt (Lübeck)
(2002, 816 Seiten, 130 Abbildungen, 8 Tabellen, 54,90 Euro, ISBN 3-928466-45-3)

Die älteste deutschsprachige Akademie prüft „Anspruch und Wirklichkeit" ihrer Vergangenheit und läßt 350 Jahre wechselvoller Geschichte in ihren naturwissenschaftlichen und medizinischen Rahmenbedingungen Revue passieren. Die Festschrift wendet sich an eine interessierte Öffentlichkeit, die allmählich diese besondere Akademie in der deutschen und internationalen Akademienlandschaft mit ihrer spezifischen wissenschaftlich-kulturellen Bedeutung wahrnimmt, nachdem die Wirkungen von 40 Jahren defizitärer Existenz „hinter dem eisernen Vorhang" überwunden werden konnten. (Klappentext)

Inhalt:

Mit Beiträgen von:
Gunnar Berg (Halle/Saale), Johanna Bohley (Halle/Saale), Dietrich von Engelhardt (Lübeck), Menso Folkerts (München), Bernhard Fritscher (München), Sybille Gerstengarbe (Halle/Saale), Fritz Hartmann (Hannover), Lothar Jaenicke (Köln), Ilse Jahn (Berlin), Joachim Kaasch (Halle/Saale), Michael Kaasch (Halle/Saale), Kai Torsten Kanz (Lübeck), Andreas Kleinert (Halle/Saale), Eberhard Knobloch (Berlin), Dorothea Kuhn (Marbach), Irmgard Müller (Bochum), Uwe Müller (Schweinfurt), Gisela Nickel (Ober-Olm), Thomas Nickol (Halle/Saale), Benno Parthier (Halle/Saale), Horst Remane (Halle/Saale), Hermann-J. Rupieper (Halle/Saale), Klaus Sander (Freiburg i. Br.), Thomas Schnalke (Berlin), Werner Schroth (Halle/Saale), Eugen Seibold (Freiburg i. Br.), Eduard Seidler (Freiburg i. Br.), Richard Toellner (Rottenburg-Bieringen) und Gudrun Wolfschmidt (Hamburg).

Druck-Zuck GmbH, Seebener Straße 4, 06114 Halle/Saale
Buchbestellung on-line: www.druck-zuck.net

Nova Acta Leopoldina NF *92*, Nr. 341, 33 – 47 (2005)

Perception of Musical Patterns: Ambiguity, Emotion, Culture

Richard Parncutt (Graz)

With 1 Figure

Abstract

All music contains pitch-time patterns. Gestalt principles, which are learned from perceptual interaction with the environment, explain how the elements of auditory patterns are perceptually grouped and how *auditory scenes* are analyzed. This enables a perceptually grounded understanding of the rules of harmony and counterpoint. Patterns such as rhythms, chords, melodies, and entire tonal passages tend to be perceived relative to reference points in pitch-time space (downbeat, root, tonic tone or chord) and to have various identities and associations. All these references are, or can be, ambiguous or multiple. Musical emotions are generated either *via* (ambiguous or multiple) associations from outside the music or (ambiguous or multiple) structures and associated expectations within the music. Ambiguity does not itself generate emotion; instead, both ambiguity and emotion result from pattern recognition processes. Thus, the relationship between ambiguity and emotion is not causal. The art of musical composition and performance involves the manipulation of ambiguous expectations and emotions. Learning, context, ambiguity and multiplicity are central concepts in both psychoacoustics and cultural musicology, suggesting a considerable potential for interaction between musical sciences and humanities.

Zusammenfassung

Jede Musik enthält Tonhöhe-Zeit-Muster. Gestaltgrundsätze, die aus den Wahrnehmungsbeziehungen mit der Umgebung erlernt werden, erklären, wie die Elemente der auditiven Muster perzeptorisch gruppiert und wie auditive Szenen analysiert werden. Dies ermöglicht ein wahrnehmungsbasiertes Verständnis der Regeln für Harmonie und Kontrapunkt. Muster wie Rhythmus, Akkorde, Melodien und ganze Tonpassagen werden häufig bezüglich der Referenzpunkte im Tonhöhe-Zeit-Raum (erster Schlag, Grundton, Tonika oder Akkord) wahrgenommen und haben oftmals verschiedene Identitäten und Assoziationen. Alle diese Referenzen sind, oder können sein, vieldeutig bzw. mannigfaltig. Musikalische Emotionen werden entweder durch (vieldeutige bzw. vielfache) Verbindungen außerhalb der Musik oder durch (vieldeutige bzw. vielfache) Strukturen und Erwartungen in der Musik hervorgerufen. Die Mehrdeutigkeit erzeugt selbst keine Emotionen, sondern Mehrdeutigkeit und Emotion resultieren aus Mustererkennungsprozessen. Somit ist die Beziehung zwischen Mehrdeutigkeit und Emotion nicht kausal. Die Kunst musikalischer Komposition und Darstellung schließt die Gestaltung mehrdeutiger Erwartungen und Emotionen mit ein. Lernen, Kontext, Mehrdeutigkeit und Vielfältigkeit sind sowohl in der Psychoakustik als auch der kulturellen Musikwissenschaft zentrale Konzepte, die ein beachtliches Potential für die Interaktion zwischen Musik- und Geisteswissenschaften aufzeigen.

1. Introduction

A *pattern* is a spatial arrangement of elements that belong together, or a display of the essential elements of a more complex scene. In modern auditory psychology, patterns of sound are analyzed within the context of an *auditory scene* (Bregman 1990). Visualized as a graph of frequency against time, the auditory scene is a representation of the contents of short-term (or working) auditory memory, i.e. sounds in memory that are available for simultaneous processing. The research field of *auditory scene analysis* is based on, and extends, the gestalt principles of perceptual psychology.

Most musical patterns are pitch-time patterns, or combinations of rhythm and melody. Essential to the perception of such patterns is the concept of *accent* (Jones 1987) or the *salience* of an event (Parncutt 1989, 1994a, 2003). The elements of a pattern are usually not perceived to be equally important, even if they are physically identical (e. g. in rhythm: Povel and Essens 1985, in melody: Huron and Royal 1996). The more important (or salient) elements become points of reference (or accents), relative to which the rest of the pattern is perceived. The resultant hierarchical structures facilitate cognitive processing (Deutsch 1999, Krumhansl 1990).

An interesting and difficult question that tends to be avoided in music perception research is the relationship between pattern perception and musical emotion. In this paper, I will attempt to address this question by surveying typical patterns in western music and relevant theories of their perception and of musical emotion. I will consider the interdisciplinary nature of the question, the inherent ambiguity and multiplicity of musical patterns, and relevant theories of learning and culture.

2. Interdisciplinarity

The (*natural*) *sciences* shed light on the perception of musical patterns by, for example, considering how human sensory systems evolved to promote survival in typical environments. Such environments include not only a variety of sound sources, such as other humans and animals that may be dangerous as well as all kinds of everyday sounds, but also surfaces that obstruct, reflect or absorb the passage of sound between source and perceiver. In response to these physical constraints, the auditory system has developed the ability to separate partials with different frequencies (Terhardt 1998), while retaining the ability to separate successive sound events and process complex temporal patterns (rhythms), and to store enough information about pitch-time patterns (primarily speech and environmental sounds) to allow them to be recognized. Physiologically, these processes are enabled by the basilar membrane in the cochlea and by the brain's neural networks (Sano and Jenkins 1989).

The *humanities* address the cultural environments that shape sensory systems within the lifespan of each individual. A full understanding of the perception of musical patterns is not possible without reference to the specific patterns available to be perceived in a given historical or ethnological context. To understand the perception of pitch-time patterns in tonal western music, it is necessary to consider how the syntax of tonal western music evolved (Eberlein 1994). For example, a theory that accounts for the finality of the authentic (dominant-tonic) cadence should equally be able to explain the finality of the double-leading-tone cadence of the 14th Century. A theory that purports to explain the avoidance of parallel fifths and octaves should be consistent with the considerable variations in the strictness with which parallel fifths and octaves were avoided in different periods of western music history.

Where the *experience* of music is of primary interest, it is necessary to address philosophical and phenomenological issues such as the reality of experience, the question of mind-body duality, and the separate existence of knowledge, information and culture (Popper and Eccles 1977). For while the physical world and a cultural and historical context are necessary prerequisites for the existence of music, it is only in the world of experience or the "mind" that the "impact of music" – the topic of this volume – is felt. The experience of pattern recognition, like almost every other experience, is linked to emotional responses, whose understanding is essential for an understanding of music's essence.

3. Gestalt Principles

The most important function of the auditory (or visual) system is to identify environmental objects on the basis of the sound (or light) that they emit. To do that, it is necessary to recognize patterns of sound (or light). This involves grouping the parts of a pattern together and ignoring stimuli that do not belong to the pattern. It involves separating the foreground from the background, and understanding the foreground.

The well-known gestalt principles of similarity, proximity, good continuation, closure and so on operate similarly in the visual and auditory domains. According to the principle of *proximity*, the tones of a melodic phrase should be close to each other in pitch and time if the melodic phrase is to be perceived as a unit, and a chord is more likely to fuse (blend) if its tones begin synchronously (Bregman 1990). According to the principle of *closure*, a harmonic complex tone can be perceived as such even if some of the harmonics are inaudible due to masking by other sounds (and even if one of those is the fundamental). According to the principle of *common fate*, the synchronous movement of an object's parts or contours suggests that they belong together; in the auditory case, a complex sound whose partials have coherently varying frequencies or amplitudes is likely to be perceived as a unit, even if the partial frequencies are not harmonic (Marin and McAdams 1991).

The gestalt principles do not necessarily apply as clearly or strongly in hearing as they do in vision. For example, *good continuation* is a stronger cue in vision – it is easy to see two lines crossing as just that, but hard to hear two melodies cross unless other cues such as timbral or loudness differences between the melodies support this interpretation (Deutsch 1999). This difference between vision and hearing may be explained in terms of experience with real physical environments. We often see lines cross that are otherwise identical (consider the letter x, or two similar sticks lying on top of each other the ground). But we seldom hear two harmonic complex tones with about the same timbre, loudness and pitch, such that one is gradually rising in pitch and the other falling; and if we do (for example, when listening to someone talking against a background of other people talking), we are generally only interested in one of the two tones. Thus, part-crossing is avoided in music, but line-crossing is commonplace in the visual arts.

This example suggests that gestalt principles primarily reflect regularities in auditory stimuli produced by objects in typical human environments. The details of gestalt perception are acquired from the outside world, and may be acquired either within the course of a single lifetime (by learning) or over the course of several generations in which organisms that more successfully recognize specific patterns are more likely to survive and pass on their ability the next generation.

According to the gestalt principle of *closure*, a pattern can be perceived even if it is incomplete. This principle is important, and surprisingly analogous, for the perception both of pitch in a single sound and a rhythm's underlying pulse. The pattern in each case is physically equally spaced: the partials of a harmonic complex tone are equally spaced in frequency, and a musical pulse is equally spaced in time. In both cases the equal spacing is not always exact: for example the partials of piano tones are stretched relative to the harmonic series, and rhythmic beats deviate both randomly and systematically (or intentionally) from metronome ticks. Since (exactly or approximately) equally spaced patterns in frequency and time exist in abundance in the physical world, it is not immediately clear whether equally spaced patterns are recognized on the basis of their inherent regularity or their familiarity. While the inherent regularity of these stimuli is obvious, equally strong arguments exist to support the learning assumption: complex tones whose partials are equally spaced but are not clearly harmonics of an audible fundamental (e. g., a spectrum comprising the frequencies 45, 145, 245, 245 Hz) do not fuse well; and regular rhythms are only heard as rhythmic (that is, they are only associated with dance) within the range of human heartbeats and footsteps (i.e. with periods of about a second or less).

4. Ambiguity and Multiplicity

If a given pattern has different interpretations, and an observer is generally only aware of one of these at a time, we may say that the pattern is *ambiguous*. If an observer is simultaneously aware of more than one interpretation, we may speak of *multiplicity* (Parncutt 1989).

Both ambiguity and multiplicity are commonplace in music theory. Any piece of music may be analyzed or interpreted in several equally good ways (Bent and Pople 2001). Even within a given analysis, ambiguity and multiplicity can exist within and between different levels. An example of ambiguity within the level of the basic beat or tactus is *hemiola*: it is intuitively impossible to simultaneously maintain a cognitive representation of both 3/4 and 6/8 meter, but it is not hard for trained listeners to switch quickly from one to the other. When different interpretations exist simultaneously on different hierarchical levels, we may speak of multiplicity; for example, surface harmonies can contradict prolonged structural harmonies (Temperley 2001).

Music theorists are sometimes reluctant to acknowledge ambiguity. Generations of North American music students have been drilled by their Schenkerian instructors that the tonic six-four chord, when it immediately precedes a dominant, is a double suspension, and therefore not a tonic but a dominant (Forte and Gilbert 1982). Another interpretation is that the tonic six-four has both tonic and dominant function simultaneously. This very ambiguity (or multiplicity) is one of the reasons why this chord is perceived as tense and as requiring of resolution in common-practice tonality.

Ambiguity may be divided into conscious and non-conscious ambiguity. Meyer (1956) was concerned with the conscious case: "A sound term can have different meanings at different times, but this does not prove that the term, or the hypothetical meaning which it first has, is ambiguous. [...] If we are certain in our minds as to the meaning of a sound term when it first appears, then it is not ambiguous at that time" (p. 51). This contrasts with Terhardt's (1974) concept of the pitch ambiguity of a complex tone, according to which a listener hears the pitch to be different on different occasions – but on each occasion is aware of nothing other than "the" pitch at that time. Since the borderline between conscious and non-conscious in music perception is operationally so difficult to locate, and one can so easily become the other (depending on listener and context), I will ignore Meyer's point and consider both kinds of ambiguity.

Regarding non-conscious ambiguity, switching mentally between two perceptual interpretations of a musical event or passage can cause the identity of the music to change completely. For example, when Sloboda (1983) asked pianists to sight-read a series of passages, two of which differed only in the placement of the barlines, none of the pianists noticed the relationship between the two almost identical passages. The perceptual difficulty of switching from one pulse or metrical framework to another is reflected by the term rhythmic *hysteresis* (Large 2000, Peper et al. 1995). In other cases of ambiguity, the identity of the music does not change, for example when we hear the same chord relative to a different root, even if the two root candidates are harmonically distant (e.g., tritone substitutions in jazz), or a passage relative to a different tonic. In these cases the distinction between ambiguity and multiplicity becomes unclear. An analytically perceived complex sonority appears to comprise several tones, so the sonority has multiple pitches; the same sonority heard holistically is ambiguous with respect to its pitch. In both cases, we are talking about the same pitches or tone sensations, whose saliences (and hence the degree of multiplicity or ambiguity) may can be predicted either in the time domain (Cariani and Delgutte 1996) or in the frequency domain (Terhardt et al. 1982, Parncutt 1989).

Ambiguity and multiplicity can emerge from competition between gestalt principles (Bregman 1990). Consider the role of the principle of *proximity* in determining the perception of implied polyphony: a single melodic line that implies two or more lines. If temporal proximity more strongly determines grouping than pitch proximity, a single line will be perceived – one tone after the other. If the effect of pitch proximity is stronger than the effect of temporal proximity, the higher tones may separate perceptually from the lower tones, creating two separate lines, each with its own shape and rhythm – implied polyphony.

The principle of *closure* leads to ambiguities when a stimulus can be matched to more than one possible pattern. In the simplest case, an equally-spaced spectrum of frequencies can be matched to equally-spaced pitch templates in different octave registers; similarly, a rhythm that is mainly equally spaced may be matched to a pulse either at the same speed or at half or double the speed (Parncutt 1994b). The psychological reality of both kinds of ambiguities may easily be demonstrated in psychoacoustical experiments in which listeners match a pure tone to a complex tone and regularly commit "octave errors" (Terhardt et al. 1986) or tap out the underlying beat of a rhythm on different metrical levels (Edlund 1995, Parncutt 1994a, Povel and Essens 1985). Another example of ambiguity is the perception of musical phrasing, which is primarily determined by the principles of similarity and proximity (Deliège and Mélen 1997). It is generally possible to segment a piece of music in different ways into phrases, and to join phrases in different ways into different hierarchical levels, because various cues compete to determine phrase endings and beginnings: the time gap between phrases is usually longer than between successive notes within a phrase (a strong cue to segmentation; Lerdahl and Jackendoff 1983), and phrases tend to rise at the start and fall at the end (a weak cue; Huron 1996).

These examples of perceptual ambiguity suggest that musical patterns are *inherently* ambiguous, and raise the question of the extent to which ambiguity is deliberate or preferred. Music tends to be preferred if its *complexity* is moderate (not too simple, not too complex: Berlyne 1974). Ambiguity, seen as an aspect of complexity, may be one of the most interesting aspects, and possibly a definitive characteristic, of literature, poetry and music. Musical ambiguity is like a game that composers and performers play with listeners' expectations. By contrast, the main function of everyday speech is to communicate explicit information, making ambiguity generally undesirable.

In both language and music, context disambiguates. That is, an element that is ambiguous when presented in isolation may lose some or all of that ambiguity when it appears in context. "The fact that as we listen to music we not only interpret present stimuli on the basis of past events but also view past events and expect future ones on the basis of present stimuli means that a process at first felt to be ambiguous may later be seen as less so. Similarly processes at first considered unambiguous may later be seen as involving or leading toward ambiguity. In other words, ambiguity depends upon the structural architectonic viewpoint taken toward the stimulus series in question." (Meyer 1956, p. 52.)

5. Specific Musical Patterns

Musical patterns include rhythms, melodies, chords, chord progressions, and counterpoint (combinations of simultaneous melodies). The reference points relative to which musical patterns are perceived include downbeats, roots and tonics. The recognition of a specific pattern within the auditory scene, such as a known melody, involves not only the segmentation of the musical "surface" into chords, melodies, and so on and the identification of salient elements of the pattern, but also interaction between that surface and memory (e. g. the memory for musical melodies). How is this memory organized?

In the case of melody, Dowling (1978) demonstrated the importance of contour for musical memory. A melody is recognized if its pitches rise and fall in a given sequence, even if the pitch and time intervals between successive tones are changed. But they should not change too much: it helps if the distinction between steps and leaps, and – in the case of rhythm – between relatively long and short tones (Fraisse 1963) is maintained. This suggests that a kind of information reduction (or higher-level categorical perception) is involved in memory for melodies. That would be consistent with the surprisingly large number of melodies that most people can recognize, and the short time interval within which recognition takes place.

Modern musical cultures typically include a very large number of different melodies, each of which has its own identity (title, text, composers, performers, symbolic meanings and so on). These many melodies are constructed from a limited number of possible contours and rhythms. Melodies may be perceived to be similar according to a variety of structural criteria (Deliège 2001) as well as extramusical associations, the context in which the music is heard, and the listener's social identity (Baumann and Halloran 2004, Clarke and Dibben 1997). Since similar melodies can be confused with each other (e. g., Hébert and Peretz 1997), a melody may have an ambiguous or multiple identity. This principle is exploited in everyday composition and improvisation, as an original statement of a melody is varied. A variation that is too distant from the original will, at least at first, sound like a new melody. The ambiguity between "new" and "derived" may be regarded as part of the composition. Music analysis often involves discovering and exploring relationships of this kind.

Empirically, it is easy to test whether someone recognizes a melody – just play it to them and ask them to name it or sing it back. It is not so easy to test the recognition of a chord, since only musicians with the appropriate training can label a chord in terms of its root and quality. Cognitive psychologists addressing questions of musical structure (e.g., Krumhansl 1990) have paid surprisingly little attention to the phenomenon of chord roots, by comparison to the perception of melody and of tonality. This is surprising, given that a chord's quality depends on the intervals between the root and the other tones: to recognize a chord according to its quality (e.g. minor triad, dominant seventh), it is necessary to identify a reference pitch and a pattern of intervals relative to that pitch. Moreover, standard harmonic theory, in both classical traditions and in popular music and jazz, conceives of harmonic progressions in terms of roots.

Generations of music theorists tried but failed to develop a satisfactory general theory of the root of a chord that could account for the root of the minor triad – especially during the latter part of the 19th century. This research program not only failed to discover the specific functional nature of the relationship between the harmonic series and chord roots – it also did not take proper account of the ambiguity of chord roots, and to develop a plausible, general account of that ambiguity. If, as Terhardt (1974) and Parncutt (1988) assumed, the perception of a chord root involves much the same process as the perception of the pitch of a single complex tone, we may expect the root of a chord to be ambiguous. For example, the root of a D-minor chord functioning as a supertonic triad in the key of C major can be regarded either as D (more likely if the chord is in root position) or as F (more likely if the chord is in first inversion). This ambiguity is reflected in RIEMANN's (1893) functional approach, in which the supertonic harmony is called *Subdominantparallel*.

Of course, tonality is ambiguous, too. Music theorists often disagree about the key of a musical passage: Schenkerians hear entire pieces relative to a single tonic, while other analysts speak of sequences of modulations to near and far tonalities in the same pieces. Listeners in psychoacoustical experiments disagree about which tone represents the tonic, or sounds most final, after a given passage, and both theorists and psychological models disagree about the exact point in time at which modulations occur (AUHAGEN 1994, HURON and PARNCUTT 1993, VOS and LEMAN 2001). Since ambiguity is typical of pattern recognition, it is appropriate to regard the perception of tonality, like the perception of chord roots, as a form of pattern recognition. If so, what is the nature of the pattern?

Musical keys are usually instantiated by tonal cadences such as progressions from subdominant to dominant to tonic. In order to explore how cadences determine tonality, KRUMHANSL and KESSLER (1982) asked listeners how well individual tones in the chromatic scale follow such progressions. The resultant tone profiles (Fig. 1) quantified the music-theoretical intuition that the tonic tone is more stable than the dominant, which in turn is more stable than the mediant, which is more stable than the other diatonic tones in a key, which are more stable than the non-diatonic tones.

The question then arises as to the origin of the profiles. Since they evidently existed psychologically in the 17th century, by which most commentators (e.g., DAHLHAUS 1967, EBERLEIN

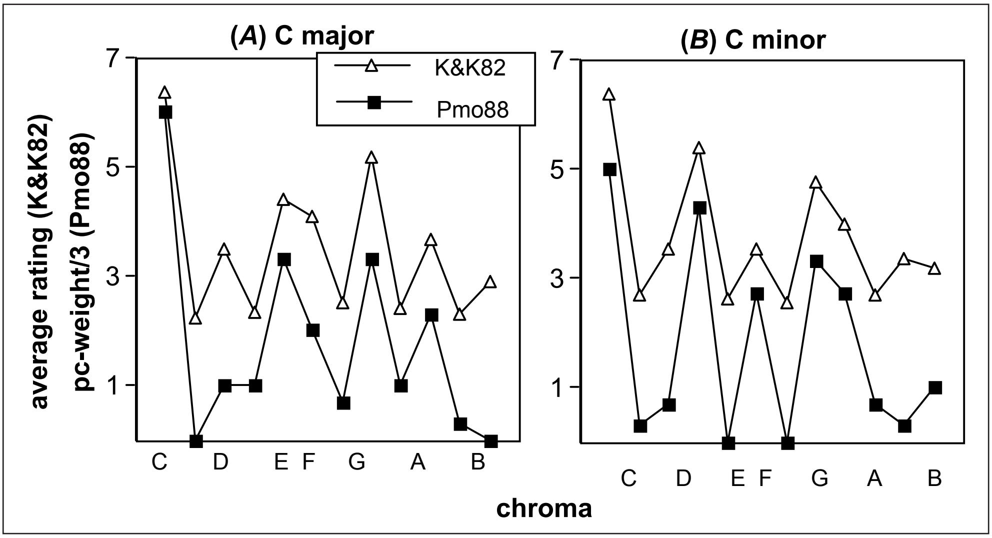

Fig. 1 Comparison of (*A*) the major and (*B*) minor key profiles of KRUMHANSL and KESSLER (1982) with calculated chroma salience within the corresponding tonic triad according to PARNCUTT (1988). Open triangles: key profiles, i.e. experimental goodness-of-fit ratings on a 7-point scale, averaged over three cadential progressions (IV-V-I, II-V-I, VI-V-I) and a single tonic triad (I). Filled squares: pitch-class weight according to PARNCUTT (1988) with root-support weights P1/P8 = 10, P5 = 5, M3 = 3, m7 = 2, M2/M9 = 1, m3 = 0, divided by 3 for ease of comparison.

1994, Randel 1971) agree that major-minor tonality had completely "emerged", a causal explanation must lie in an earlier period of music history; and since they are essentially patterns of pitch, their origin must involve (other) patterns of pitch that were familiar to listeners of the 17th and earlier centuries.

A good candidate for such a pattern is the pattern of pitch evoked or suggested by a major or minor triad. These sonorities gradually became more prevalent in polyphonic music over a period spanning several hundred years, from the 13th to the 16th centuries (Randel 1971). During that time, they also increasingly functioned as reference points (departure and resting points) in the gradually "emerging" major-minor system.

According to Parncutt (1988), the perceptual salience of a particular pitch class within a chord is a measure of the probability that that pitch class will function as chord's root. That probability also depends on the temporal context in which the chord appears. My tone profiles (or pitch-salience profiles) of major and minor triads are compared with Krumhansl's tone profiles of major and minor keys in Figure 1. The correlation is high, as Krumhansl and Kessler (1982) themselves noted when comparing tone profiles following an isolated (tonic) triad with profiles following cadential progressions. Thus, pitch salience within the tonic triad is a good predictor of stability within the corresponding major or minor key. Put another way, Krumhansl's key profiles are none other than pitch-salience profiles of tonic triads, and can be entirely reduced to the chord-root phenomenon.

In summary, neither the root of a chord nor the major-minor tonality of a passage can easily be defined, determined experimentally, or predicted using a model. Recent mainstream research in cognitive psychology (e. g., Vos and Leman 2001) has devoted much more attention to the more difficult problem of tonality. In so doing, it has largely ignored the role of chord roots in determining tonality. The approach just described establishes a connection between the two that is both qualitative and quantitative. That is, it is not only informative about the nature and function of roots and tonics – it also enables quantitative predictions to be made on the basis of relatively few assumptions or adjustable parameters (the principle of parsimony). It also explains why Krumhansl's tone profiles are so informative, although they (intentionally) say nothing about voice-leading aspects of tonality (Butler 1989). The comparison with the pitch-salience profile of the tonic triad makes it clear that (and why) the key profiles encapsulate only the vertical or harmonic aspect of major-minor tonality, and entirely ignore the melodic or voice-leading aspect. In this sense, they may be regarded as cognitive representations of Dahlhaus' (1967) *harmonic tonality*.

These considerations offer a partial answer to the question of what exactly is "recognized" or "identified" when we hear music relative to a given tonality or tonic. In explaining the inherent ambiguity of tonality, they indirectly contribute to an understanding of musical emotion in tonal music.

6. Emotion

In his seminal monograph on musical emotion, Meyer (1956) distinguished between two schools of thought. "Referentialists" claim that musical emotions are generated externally, through *associations* with extra-musical experiences (e. g., vocalizations in infant-adult vocal play, in which melodic contours have specific meanings; Papousek et al. 1991). "Absolutists" claim that musical emotions are generated internally, through the *structure* of the music itself

– or through supposedly "purely musical" processes, such as the fulfillment or denial of expectations within musical pitch-time structures. Clearly, both are right. Musical emotions can both be influenced from outside and be generated within the music. The interesting point for the present purpose is that both aspects of musical emotion involve pattern recognition.

Emotional associations between musical pitch-time patterns and non-musical patterns are commonplace. Consider the experiential (perceptual and emotional) world of an infant. Infants are very good at extracting and storing information from their environment. They are also very interested in the emotional state of the adults that surround them, because their ability to communicate emotionally – to detect and manipulate the emotional state of others – is essential for their survival. When babies are active, they need a *happy* adult to entertain them; when they are sleepy or sleeping, they need a *tender* adult to look after them. Adults who are *sad* or *afraid* are less useful to infants, and those who are *angry* can be downright dangerous. Infants recognize these states by listening to adult speech (Papousek et al. 1991). Happy speech is relatively fast and loud, clearly articulated, and covers a relatively wide pitch range. Tender speech is slower and quieter; the individual tones have softer attacks, and are more legato. Thus, long before infants start to understand the *lexical* meaning of speech (that is, the meaning that is maintained when speech is written down), they are good at deciphering its *gestural* meaning. Beyond these general states or moods, speech can include gestures that communicate specific meanings. For example, a sudden rise in pitch can be used to elicit attention or encourage the taking of a turn. Such gestures also have strong emotional connotations.

Emotional cues in speech (e. g. the loudness, abruptness, accentuation and distortion of angry speech) correspond closely to emotional cues in music, suggesting that the speech cues determine the musical cues. In both speech and music, listeners are quite good at decoding such cues, although the message can sometimes be ambiguous (Juslin and Persson 2002). The existence of complex relationships between emotions and patterns of pitch, loudness and time (rhythm) suggests that an infant's experience of the voice of adults, which presumably begins well before birth, may be an important precursor of music and may even represent music's origin (Parncutt 1993). Since the internal sounds of the mother's body are structurally similar to melody (voice) and rhythm (footsteps, heartbeat), the emotions generated by music may be closely related to maternal love as experienced by the fetus and infant.

The emotionality of musical pitch-time patterns may also be explained by the structure of those patterns. Meyer (1956) assumed that "emotion or affect is aroused when a tendency to respond is arrested or inhibited" (p. 14). At any point in a piece of music, listeners have expectations that the music will continue in a specific fashion; if no such expectations exist, the music is meaningless or incomprehensible. For example, if the music follows a pattern that is typical of the end of a phrase, and the listener is familiar with music with this kind of syntax, that listener will expect the phrase to end soon. According to Meyer, the emotional flavor of a passage is influenced by whether such expectations are realized or not: the realization of implications is associated with feelings of fulfillment, satisfaction or relief, whereas non-realization is associated with surprise, disappointment or frustration. "Ambiguity is important because it gives rise to particularly strong tensions and powerful expectations. For the human mind, ever searching for the certainty and control which comes with the ability to envisage and predict, avoids and abhors such doubtful and confused states and expects subsequent clarification." (Meyer 1956, p. 51.)

This theory sounds fine in principle, but for many it is too abstract to connect with real emotional experiences. The findings of Sloboda (1991) made Meyer's theory more concrete. His experimental participants were keen listeners to "classical" music. They showed him the exact points in musical scores that corresponded to their strongest emotional experiences. Certain kinds of patterns occurred repeatedly in the data: harmonic progressions descending by a cycle of fifths to the tonic, passages containing repeated melodic appoggiaturas, melodic and harmonic sequences, enharmonic changes, harmonic or melodic acceleration to a cadence, the delay of final cadences, new or unprepared harmonies, sudden dynamic or textural changes, repeated syncopations, and prominent events that arrive earlier than expected. These results are consistent with Meyer's theory, because in all of these cases, listeners had strong expectations that were either fulfilled or denied.

How can expectations explain the emotional quality of one of the structures to emerge from Sloboda's study, the harmonic progression descending by fifths to the tonic? In Western music of the 18^{th} and 19^{th} centuries, progressions in which roots fell by a fifth or third (e.g., C major to F major or A minor) were much more common than progressions in which roots rose by a fifth or third (e. g., C major to G major or E minor) (cf. data of Eberlein 1994). Modern listeners who are familiar with this repertoire should, therefore, be entirely unsurprised by such progressions. According to this logic, such progressions should be uninteresting and hence unemotional.

In searching for a resolution to this paradox, we might begin by asking why the asymmetry between rising and falling fifths and thirds between chord roots exists at all. Agmon (1994) proposed that a progression of two chords is preferred or "makes a stronger effect" (p. 245) if the root of the second chord is not included among the tones of the first chord. Agmon's *root newness* principle is reminiscent of Meyer's *implication-realization* idea: a chord progression may "make a stronger effect" if the root of the second chord is implied by the first chord, but not played. The implication arises through familiarity: since progressions through a falling fifth or third are more common than progressions through a rising fifth or third, listeners tend to expect the falling progressions.

Agmon's *root newness* and Meyer's *implication-realization* may be combined into a single concept based on the *perceptual saliences* of the involved pitches and the resultant *pitch commonality* of the progressions (Parncutt 1989). According to Terhardt's theory of pitch perception, each individual chord in a progression implies pitches that are not physically present. Both major and minor triads imply pitches a fourth and a sixth above the root: CEG implies F and A, and CEbG implies F and Ab (see Fig. 1). These implied pitches correspond to missing fundamentals – fundamentals of partials that are physically present in the chord, but belong to different tones. If, for example, the fundamental (1^{st} harmonic) of a harmonic complex tone is an F (in any octave), then the 3^{rd} harmonic is a C and the 5^{th} is a G; therefore, C and G together (and hence CEG or CEbG) can imply F. If the 1^{st} harmonic is an A, then the 3^{rd} harmonic is an E and the 7^{th} is a G; therefore, E and G together (and hence CEG) can imply A. And so on. The reason for the asymmetry in the distribution of chord progressions (falling fifths and thirds between roots being more common than rising) may be that the pitch salience profile of major and minor triads is itself asymmetrical. In the falling-fifth progression from C major to F major, the implied tones in the first chord (F and A) are realized in the second chord; but in the rising-fifth progression from C to G, the implied pitches in the first chord (F and A) are not realized in the second, and the new tones in the second chord (B and D) are more weakly implied in the first (D is implied more weakly than F or A, and B is not implied at all, according to the pitch model). A similar line of argument can explain why falling-third progressions are more prevalent than rising.

In both cases, the second chord in the more common progression may be considered as a realization of an implication created by the first. The perceptibility of this implication can easily be demonstrated: In experiments in which musical chords are followed by probe tones and listeners asked how well the tone goes with the chord, listeners clearly distinguish between tones that go well (such as F or A following C major) and tones that do not go well (such as F# or Ab following C major) (Parncutt 1993). Thus, the emotional effect of harmonic progressions descending by a cycle of fifths to the tonic may be linked to the implication-realization effect just described. The repeated fulfillment of expectations may lead to a strong feeling of relief or even abundance. The expectation is generated not only by the implied and realized pitches but also by the predictability of the pattern.

This kind of academic theorizing sounds impressive and can keep psychologists and philosophers happily occupied for hours, but it is hardly sufficient to explain the *intensity* of musical experiences as repeatedly and systematically observed, for example, by Gabrielsson and Lindström (2003). My theory of the prenatal origins of music (Parncutt 1997) is an attempt to solve this problem. It assumes that the source of musical emotion is mainly external to music. Musical emotions are held to be cultural elaborations of emotions perceived and encoded in non-linguistic memory by the fetus, as it associates maternal emotions with typical patterns created the internal sounds of its mother's body – her voice, breathing, heartbeat, digestion, footsteps and other movements.

Is there a causal connection between ambiguity and emotion? If so, it should be valid outside of music – specifically, in the visual arts. But art theory does not offer a clear answer to this question. Most psychology texts include a discussion of famous ambiguous figures, such as the one that can be seen either as two faces or as a vase, depending on which part of the figure is seen in the foreground (figure-ground perception), or the one that can be seen either as a young or an old woman (Boring 1930). But there is no suggestion that this ambiguity may *itself* have an emotional connotation. The famous ambiguous paintings by Escher (e.g. the continuously rising staircases) are not regarded as particularly emotional–unless a fascination with ambiguity is regarded as emotion.

This suggests that the association of ambiguity and emotion in music observed by Meyer is not a causal relationship. The ambiguity does not cause the emotion; instead, something else must cause both of them. That something is evidently the process of pattern recognition itself. Every pattern that is recognized has associations, which include emotions–otherwise the pattern would be meaningless and there would be no motivation to recognize it. And pattern recognition generally results in ambiguity: if the pattern is regarded as a template that is matched to a stimulus, there are generally different template positions that produce a reasonable match. Seen in this light, the ambiguity-emotion connection is an artifact.

An approach of this kind can explain the emotional quality of the simplest musical passages, such as a single tone or a string of equally space beats. The equally-spaced pattern that is recognized in each case is not emotionally neutral, if the harmonic pitch pattern is linked to the spectrum of a voiced speech sound, and the rhythmic pulse is linked to human heartbeats and footsteps. So even at this simple level, where (as we have seen) pattern recognition already produces ambiguity, we would expect pattern recognition to be associated with emotion.

7. Auditory Learning

The theoretical ideas presented in this paper rely strongly on the assumption that the auditory system can quickly learn a large number of auditory patterns and associate them with specific meanings (Gibson 1953). This is consistent with a range of empirical observations. Bregman's (1990) theory of auditory scene analysis assumes that the auditory system learns complex pitch-time-loudness patterns and uses this acquired knowledge to "parse the auditory scene", that is, to determine which parts of the scene belong together and hence to which environmental sound sources. Dowling's (1978) approach to the question of melody recognition focuses on how melodies are encoded in memory and is consistent with the ability of people to learn a very large number melodies, regardless of their musical training. Palmer and Krumhansl (1987) assumed that musical meters such as 2/4 and 6/8 have characteristic profiles of strong and weak beats on different hierarchical levels, and that these are learned by exposure to music in these meters. Central to Burns' (1999) account of musical intonation is the idea that intonation is preferred if performers and listeners are familiar with it; thus, instrumentalists such as violinists who can easily vary their intonation over a wide range may nevertheless stay close to the familiar tuning of the piano. Eberlein's (1994) analysis of the evolution of western tonal syntax relies heavily on the notion that the people (musicians, listeners) of a given historical period are familiar with the sound of the music of that period including the details of its syntax, and that developments in syntax are always constrained or driven by this familiarity.

Physiologically, all these kinds of auditory learning can easily be explained by the concept of neural networks (Gjerdingen 1990). The same concept can explain the ambiguity of pattern recognition and how it is possible for the response to a given pattern to change when a listener is exposed to new patterns.

The pitch model of Terhardt et al. (1982)[1] is consistent with the assumption of perceptual learning: the pattern of spectral pitches within a single complex tone (i.e. the harmonic series) is assumed to be learned from exposure to harmonic complex tones in early life (although this information could also be genetically transmitted and linked to periodicity). The concept of rhythm that I presented in Parncutt (1994a) relies on a similar idea: the perception of pulse in musical rhythms is assumed to be based on the perception of extra-musical pulses in heartbeats and footsteps.

---

1 This paper relies on a spectral approach to pitch perception. Since periodicity in the time domain corresponds to harmonicity in the frequency domain, and pitch perception primarily involves harmonic complex tones, spectral and temporal approaches to pitch often differ little in their predictions and implications. Periodicity information is present throughout the auditory system, since neural firing in different parts of the auditory pathways is to a large extent phase-locked (cf. van Dinther and Patterson, this volume). However, the brain also includes tonotopic representations of pitch (Pantev et al. 1989; Schreiner and Langner, 1997). The perception of slightly inharmonic sounds such as piano tones can be explained either in the frequency or the time domain – in both cases it involves permissible departures from harmonicity or periodicity, which may be tuned to margins of error present in physical sounds. Terhardt's attempts to algorithmically predict pitch shifts did not produce clear enough evidence to disprove time-domain theories; further experimental work is necessary to clarify this question. An advantage of a time-domain approach is its proximity to the real physical signal, both in the air and in the brain. By contrast, frequency is not a direct property of sound, but a parameter that is derived from frequency analysis (Terhardt 1998); in this sense, a theory of pitch based on frequency is neither direct nor parsimonious. An advantage of the frequency-based approach is that it is relatively easily to implement in a computer algorithm and to apply in music-theoretical contexts. Terhardt's model estimated the saliences of all pitches evoked by a sound, which makes it both easy to test and to criticize. Temporal models have been slow to emulate this feature, which is particularly relevant to the question of music-structural ambiguity.

At this level, the mystery of musical meaning may be considered to be solved. At another level, it remains a mystery. Music psychologists are still a long way away from predicting emotional responses to specific music experienced in specific situations. Neural networks cannot be considered in isolation from the human environment; it is essential to consider the cultural context. But that is constantly changing and, at least for the moment, scientifically intractable. To address a problem of such enormous dimensions, it will be necessary to bring humanities and sciences closer together.

8. Culture

"Culture" is often used as a collective term for the physical and intellectual products of human society. It includes commonly held ideas, their intersubjective generation and development, and their sharing and communication. It also includes all forms of art, including music.

From a cognitive-psychological viewpoint, culture is limited by cognitive constraints such as memory limitations (D'Andrade 2001). The syntax of music, like any other aspect of culture, is subject to cognitive constraints and interactions with other aspects of culture. Perception of music within a given culture is inextricably linked to the historical development of the syntax and semantics of the development of musical language in that culture. For example, the syntax of western music in the middle ages and renaissance depended strongly on the compositional conventions of the time. These depended in part on the social functions of the music in question, and partly on universal perceptual principles (Eberlein 1994, Huron 2001). Compositional conventions influenced the music-stylistic norms of their time, that is, the statistical properties of music (how often specific patterns happened, and how often they were followed by other specific patterns). These in turn influenced how people perceived music (based on information stored in neural networks), such as their pitch-time expectations at a particular point in a piece of music, how people reacted emotionally, and what meaning they ascribed to the sounds that they heard. There may therefore be no *direct* connection between universal principles of perception (such as the gestalt principles, or the perception of harmonic complex tones in speech) and the principles of music perception.

These scientifically oriented ideas are consistent with parallel developments in the humanities, where the meaning of a musical text (or of any other text) is considered to be multiply determined; it is not restricted to its original, intended meaning but develops as the culture within it is embedded develops (Kramer 1993). Scholars in the humanities stress that musical actors (performers, composers, improvisers, listeners, consumers) are constantly learning and developing, and that everything they learn depends on the cultural context of which they themselves are part. At the same time, scientists stress that the auditory system is also constantly "learning" – within the same cultural context. The concepts of learning, context, ambiguity and multiplicity link together the apparently incompatible disciplines of *psychoacoustics* and *cultural studies*. This combination appears to have considerable potential for productive exploitation in future research.

References

Agmon, E.: Principles of chord progression. In: Deliège, E. (Ed.): Proceedings of the Third International Conference on Music Perception and Cognition; pp. 245–246. Liège (B): Centre de Recherches et de Formation Musicales de Wallonie 1994

Auhagen, W.: Experimentelle Untersuchungen zur auditiven Tonalitätsbestimmung in Melodien. Kölner Beiträge zur Musikforschung Bd. *180*. Kassel: Bosse 1994

Baumann, S., and Halloran, J.: An ecological approach to multimodal subjective music similarity perception. In: Parncutt, R., Kessler, A., and Zimmer, F. (Eds.): Conference on Interdisciplinary Musicology: Abstracts; pp. 44–45; and Proceedings (http://gewi.uni-graz.at/~cim04/) 2004

Bent, I. D., and Pople, A.: Analysis. In: Sadie, S. (Ed.): The New Grove Dictionary of Music and Musicians (2nd ed.) *1*, 526–589 (2001)

Berlyne, D. E.: Studies in the New Experimental Aesthetics. Washington: Hemisphere 1974

Boring, E. G.: A new ambiguous figure. Amer. J. Psychology *42*, 444–445 (1930)

Bregman, A. S.: Acoustical Scene Analysis. Cambridge, Massachusetts: MIT Press 1990

Burns, E. M.: Intervals, scales and tuning. In: Deutsch, D. (Ed.): Psychology of Music. 2nd ed., pp. 215–264. San Diego: Academic Press 1999

Butler, D.: Describing the perception of tonality in music: A critique of the tonal hierarchy theory and a proposal for a theory of intervallic rivalry. Music Perception *6*(3), 219–242 (1989)

Cariani, P. A., and Delgutte, B.: Neural correlates of the pitch of complex tones. I. Pitch and pitch salience. J. Neurophysiology *76*, 1698–1716 (1996)

Clarke, E., and Dibben, N.: An ecological approach to similarity and categorisation in music. In: Ramscar, M., et al. (Eds.): Proceedings of the Interdisciplinary Workshop on Similarity and Categorisation. Department of Artificial Intelligence; pp. 37–41. Univ of Edinburgh 1997

Dahlhaus, C.: Untersuchungen über die Entstehung der harmonischen Tonalität. Kassel: Bärenreiter 1967

D'Andrade, R.: A cognitivist's view of the units debate in cultural anthropology. Cross-Cultural Research: The J. Comparative Social Science *35*, 242–257 (2001)

Deliège, I.: Similarity perception ↔ Categorization ↔ Cue abstraction [Special issue]. Music Perception *18*(3) (2001)

Deliège, I., and Mélen, M.: Cue abstraction in the representation of musical form. In: Deliège, I., and Sloboda, J. (Eds.): Perception and Cognition of Music; pp. 387–412. Hove, East Sussex: Psychology Press 1997

Deutsch, D.: Grouping mechanisms in music. In: Deutsch, D. (Ed.): The Psychology of Music. 2nd ed., pp. 299–348. New York: Academic 1999

Dowling, D.: Scale and contour: Two components of a theory of memory for melodies. Psychological Review *85,* 341–354 (1978)

Eberlein, R.: Die Entstehung der tonalen Klangsyntax. Frankfurt/Main: Lang 1994

Edlund, B.: Making meter evident – On the playing of an ambiguous Bach melody. Musikpsychologie *12*, 28–41 (1995)

Forte, A., and Gilbert, S. E.: An Introduction to Schenkerian Analysis. New York: Norton 1982

Fraisse, P.: The Psychology of Time. New York: Harper & Row 1963

Gabrielsson, A., and Lindström, S.: Strong experiences related to music. A descriptive system. Musicae Scientiae *7*, 157–217 (2003)

Gibson, E. J.: Improvement in perceptual judgments as a function of controlled practice or training. Psychological Bulletin *50*, 401–431 (1953)

Gjerdingen, R. O.: Categorization of musical patterns by self-organizing neuronlike networks. Music Perception *7*, 339–370 (1990)

Hébert, S., and Peretz, I.: Recognition of music in long-term memory: Are melodic and temporal patterns equal partners? Memory & Cognition *25*, 518–533 (1997)

Huron, D.: The melodic arch in Western folksongs. Computing in Musicology *10*, 3–23 (1996)

Huron, D.: Tone and voice: A derivation of the rules of voice-leading from perceptual principles. Music Perception *19*, 1–64 (2001)

Huron, D., and Parncutt, R.: An improved model of tonality perception incorporating pitch salience and echoic memory. Psychomusicology *12*, 154–171 (1993)

Huron, D., and Royal, M.: What is melodic accent? Converging evidence from musical practice. Music Perception *13*, 489–516 (1996)

Jones, M. R.: Dynamic pattern structure in music: Recent theory and research. Perception and Psychophysics *41*, 621–634 (1987)

Juslin, P. N., and Persson, R. S.: Emotional communication. In: Parncutt, R., and McPherson, G. E. (Eds.): Science and Psychology of Music Performance; pp. 219–236. New York: Oxford University Press 2002

Kramer, L.: Music as Cultural Practice, 1800–1900. Berkeley: University of California Press 1993

Krumhansl, C. L.: Cognitive Foundations of Musical Pitch. New York: Oxford University Press 1990

Krumhansl, C. L., and Kessler, E. J.: Tracing the dynamic changes in perceived tonal organization in a spatial representation of musical keys. Psychological Review *89*, 334–368 (1982)

LARGE, E. W.: On synchronizing movements to music. Human Movement Science *19*, 527–566 (2000)
LERDAHL, F., and JACKENDOFF, R.: A Generative Theory of Tonal Music. Cambridge, MA: MIT Press 1983
MARIN, C. M. H., and MCADAMS, S.: Segregation of concurrent sounds. II: Effects of spectral envelope tracing, frequency modulation coherence, and frequency modulation width. J. Acoust. Soc. Amer. *89*, 341–351 (1991)
MEYER, L. B.: Emotion and Meaning in Music. Chicago: University of Chicago Press 1956
PALMER, C., and KRUMHANSL, C. L.: Independent temporal and pitch structures in determination of musical phrases. J. Experimental Psychology: Human Perception & Performance *13*, 116–126 (1987)
PANTEV, C., HOKE, M., LUETKENHOENER, B., and LEHNERTZ, K.: Tonotopic organization of the auditory cortex: Pitch versus frequency representation. Science *246*, 486–488 (1989)
PAPOUSEK, M., PAPOUSEK, H., and SYMMES, D.: The meanings of melodies in motherese in tone and stress languages. Infant Behavior and Development *14*, 415–440 (1991)
PARNCUTT, R.: Revision of Terhardt's psychoacoustical model of the root(s) of a musical chord. Music Perception *6*, 65–94 (1988)
PARNCUTT, R.: Harmony: A Psychoacoustical Approach. Heidelberg: Springer 1989
PARNCUTT, R.: Pitch properties of chords of octave-spaced tones. Contemporary Music Review *9*, 35–50 (1993)
PARNCUTT, R.: A perceptual model of pulse salience and metrical accent in musical rhythms. Music Perception *11*, 409–464 (1994a)
PARNCUTT, R.: Template-matching models of musical pitch and rhythm perception. J. New Music Research *23*, 145–168 (1994b)
PARNCUTT, R.: Pränatale Erfahrung und die Ursprünge der Musik. In: JANUS, L., und HAIBACH, S. (Eds.): Seelisches Erleben vor und während der Geburt. S. 225–240. Neu-Isenburg: LinguaMed. 1997
PARNCUTT, R.: Accents and expression in piano performance. In: NIEMÖLLER, K. W. (Ed.): Perspektiven und Methoden einer Systemischen Musikwissenschaft. S. 163–185. Frankfurt (Main): Peter Lang 2003
PEPER, C. E., BEEK, P. J., and VAN WIERINGEN, P. C. W.: Multifrequency coordination in bimanual tapping: Asymmetrical coupling and signs of supercriticality. J. Experimental Psychology: Human Perception and Performance *21*, 1117–1138 (1995)
POPPER, K. R., and ECCLES, J. C.: The Self and Its Brain. Berlin: Springer 1977
POVEL, D. J., and ESSENS, P.: Perception of temporal patterns. Music Perception *2*, 411–440 (1985)
RANDEL, D. M.: Emerging triadic tonality in the fifteenth century. Musical Quarterly *57*, 73–86 (1971)
RIEMANN, H.: Vereinfachte Harmonielehre. London: Augener 1893
SANO, H., and JENKINS, B. K.: A neural network model for pitch perception. Computer Music J. *13*(3), 41–48 (1989)
SCHREINER, C. E., and LANGNER, G.: Laminar fine structure of frequency organization in auditory midbrain. Nature *388*, 383–386 (1997)
SLOBODA, J. A.: The communication of musical metre in piano performance. Quarterly J. Experimental Psychology *35A*, 377–396 (1983)
SLOBODA, J. A.: Music structure and emotional response: Some empirical findings. Psychology of Music *19*, 110–120 (1991)
TEMPERLEY, D.: The Cognition of Basic Musical Structures. Cambridge, Massachusetts: MIT Press 2001
TERHARDT, E.: Pitch, consonance, and harmony. J. Acoust. Soc. Amer. *55*, 1061–1069 (1974)
TERHARDT, E.: Akustische Kommunikation: Grundlagen mit Hörbeispielen. Berlin: Springer 1998
TERHARDT, E., STOLL, G., and SEEWANN, M.: Pitch of complex tonal signals according to virtual pitch theory: Tests, examples and predictions. J. Acoust. Soc. America *71*, 671–678 (1982)
TERHARDT, E., STOLL, G., SCHERMBACH, R., und PARNCUTT, R.: Tonhöhenmehrdeutigkeit, Tonverwandschaft und Identifikation von Sukzessivintervallen. Acustica *61*, 57–66 (1986)
VOS, P. G., and LEMAN, M. (Eds.): Tonality induction [Special issue]. Music Perception *17*(4) (2001)

Prof. Dr. Richard PARNCUTT
Karl-Franzens-Universität
Institut für Musikwissenschaft
Mozartgasse 3
8010 Graz
Austria
Phone: +43 316 3802409/2405
Fax: +43 316 3809755
E-Mail: parncutt@uni-graz.at

Academia 350
Die Leopoldina-Feiern in Schweinfurt und Halle 2002

Vorträge der Festveranstaltungen aus Anlaß des 350jährigen Gründungsjubiläums der Deutschen Akademie der Naturforscher Leopoldina am 17. und 18. Januar 2002 in Schweinfurt und vom 18. bis 20. Juni 2002 in Halle (Saale)

Nova Acta Leopoldina N. F. Bd. *87*, Nr. 325
Herausgegeben von Benno Parthier (Halle/Saale)
(2003, 248 Seiten, 19 Abbildungen, 2 Tabellen, 24,80 Euro, ISBN 3-8047-2000-5)

Die Deutsche Akademie der Naturforscher Leopoldina feierte im Jahre 2002 ihre Gründung vor 350 Jahren mit zwei Festveranstaltungen. Im Januar in der Gründungsstadt Schweinfurt standen die historischen Wurzeln der Akademiegründung im 17. Jahrhundert im Mittelpunkt. Nach der Begrüßung durch Akademiepräsident Benno Parthier untersuchte Lorraine Daston (Berlin) das Thema „Die Akademien und die Neuerfindung der Erfahrung im 17. Jahrhundert“. Richard Toellner (Rottenburg) nannte seine Ausführungen zu den Quellen der Akademiegründung „Im Hain des Akademos auf die Natur wißbegierig sein: Vier Ärzte der Freien Reichsstadt Schweinfurt begründen vor 350 Jahren eine Naturforscherunternehmung“. Der Schweinfurter Festakt brachte nach der Begrüßung durch Frau Oberbürgermeisterin Gudrun Grieser und einer Folge von Grußadressen (u. a. vom bayerischen Ministerpräsidenten Edmund Stoiber) abschließend eine Standortbestimmung der ältesten deutschen Akademie in der Gegenwart von Präsident Parthier („Die Leopoldina heute“). Außerdem wird die im Rahmen der Feierlichkeiten erfolgte diesjährige Verleihung des Carus-Preises der Stadt Schweinfurt dokumentiert. Die Juniveranstaltung in Halle (Saale) widmete sich nach Grußworten des Bundespräsidenten Johannes Rau und des sachsen-anhaltinischen Ministerpräsidenten Wolfgang Böhmer den internationalen Aspekten des Leopoldina-Wirkens mit einem Symposium „Science and Society“, das gemeinsam von Vertretern der ältesten europäischen Akademien, der Royal Society (Lord Robert May, London), der Acadèmie des Sciences (Jean-Pierre Kahane, Paris), der Accademia Nazionale dei Lincei (Sergio Carrà, Rom) und der Leopoldina (Hans Mohr, Freiburg i. Br.), getragen wurde. Die Beiträge behandeln das gesamte Spannungsfeld von Wissenschaft, Politik, Gesellschaft und Demokratie. Darüber hinaus dokumentiert der Band den von der Jungen Akademie, einer Tochterinstitution von Leopoldina und Berlin-Brandenburgischer Akademie, im Rahmen der Leopoldina-Jubelfeier veranstalteten Workshop „Science und Society: Science Goes Pop?“, der versuchte, der Popularisierung von Wissenschaft und dem Bild des Wissenschaftlers in der Öffentlichkeit nachzugehen.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Nova Acta Leopoldina NF *92*, Nr. 341, 49–61 (2005)

(Dis-)Harmonie

Manfred Stahnke (Hamburg)

Mit 10 Abbildungen und 2 Tabellen

Zusammenfassung

Die Möglichkeit einer neuen harmonischen Denkweise wird vorgestellt anhand von Analysen musikalischer Werke des Autors. Dabei werden Bezüge zu dem U.S.-amerikanischen Komponisten Harry Partch (1901–1974) hergestellt, aber auch zu nicht-europäischen harmonischen Denkweisen wie bei den ‚Are'are von Malaita (Salomon-Inseln). Ferner werden neue harmonische Möglichkeiten in Beziehung gesetzt zu den im Innenohr messbaren „kubischen" und „quadratischen" Differenztönen.

Abstract

Possibilities of new ways of thinking in musical harmony are presented by ways of the analysis of musical works of the author. Connections to U.S. American composer Harry Partch (1901–1974) are shown, as well as to harmony thinking of the ‚Are'are from Malaita (Solomon Archipel). Furthermore are the new harmonic possibilities related to inner ear difference tones, specifically the "cubic" and "quadratic".

Hier wird es um harmonische Forschung gehen. Ich werde von einem älteren Werk her meine Forschungsposition beschreiben.

Manfred Stahnke 1987–1989
PARTCH HARP
Harfe in Skordatur und mikrotonaler Synthesizer

Für mich ist „Mikrotonalität" – ähnlich der alten „Tonalität" – ein ganzheitliches Phänomen aus Harmonik/Melodik und Zeitstrukturen. Vielleicht bin ich dabei, besonders dieses Eine aus ethnischer, nicht-notierter Musik zu lernen (oder aus einer Musik, wie sie Harry Partch erdachte und rudimentär notierte): Welche erzählende Kraft hat Musik, wenn sie mit all ihren winzigen Unregelmäßigkeiten leben kann und nicht durch Schrift „begradigt" gedacht wird. Ich versuche, mich dieser Qualität zu nähern durch die „Tricks" des Umstimmens und des Hoquetierens (das ist das sehr schnelle Ablösen der Instrumente, so daß als Summe ein Supersignal einheitlicher Melodie und Harmonik entsteht).

Harry Partch (1901–1974) war ein amerikanisches Original, ein Instrumente bastelnder Außenseiter, erst jetzt allmählich auch in Europa erkannt als ein Meilenstein im Feld der heutigen Komposition (Partch 1974, Stahnke 1981 und 2001). Mein Werk PARTCH HARP, angelehnt an die Harry-Partch-Denkweise in naturreinen Intervallen, wurde 1987–1989 geschrieben für eine speziell in „naturreinen" großen Terzen und kleinen Septen gestimmte Harfe – sowie für einen mikrotonal gestimmten Yamaha Synthesizer DX 7-II FD, dessen Grundstimmung ebenfalls diese Terzen und Septen enthält, im Gegensatz zur Harfe aber nirgends Oktaven. Das ist allerdings meine Spezialerfindung, sehr unüblich in Europa und auch nicht „Partchistisch“, da in beiden Fällen die Oktave stets als unumstößlicher Ausgangspunkt gedacht wurde. Übrigens ist dieser mikrotonale Synthesizer von Yamaha wesentlich von György Ligeti mitinitiiert worden – durch Ligetis Kontakt zu dem „Erfinder“ der kommerziell verwendbaren FM-Synthese, John Chowning, Stanford.

In PARTCH HARP werden zwar viele naturreine Intervalle benutzt. Aber ebenso häufig sind „seltsame“ Intervalle, die sich aus Verkettungen von diesen Naturintervallen zwangsläufig ergeben. Die Synthesizerstimmung verkettet bis zu den Grenzen des Stimmumfangs reine Terzen und Septen, wodurch sich „seltsame“ Oktaven und Quinten ergeben, man denke nur an die Naturterz 5/4: Dreimal übereinandergeschichtet ergibt sie eine seltsame „Oktave“ (meine PARTCH-HARP-Oktave), der ca. 40 Cent fehlen, also fast ein Viertelton. Mit der

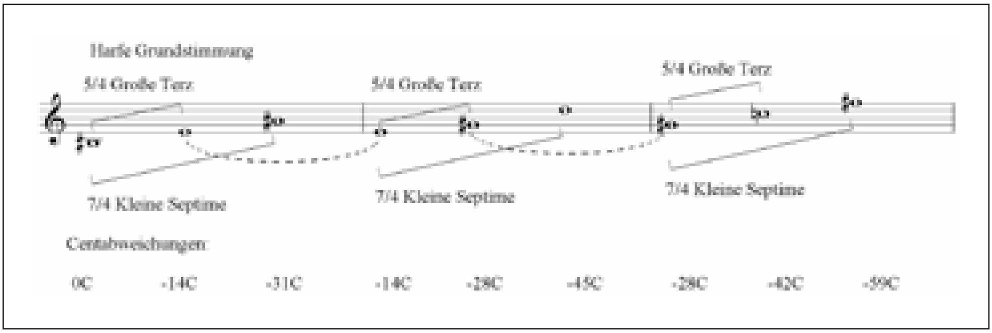

Abb. 1

Harfenstimmung, die oktavidentische Töne enthält, ergibt sich eine driftende Harmonik. Sie besteht aus einem völlig asymmetrischen Tonvorrat (Abb. 1).

Wenn wir bedenken, daß die Harfe durch ihr Pedalspiel jede der sieben diatonischen Tonstufen auf drei chromatischen Transpositionen bringen kann (also Ces, C, Cis, sodann Des, D, Dis etc.), bekommen wir ein reiches Feld von ganz asymmetrisch zueinander stehenden Tonhöhen (Abb. 2).

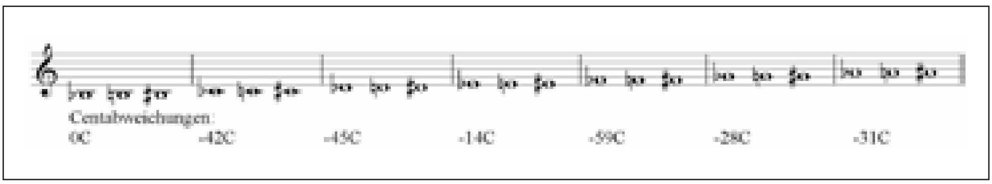

Abb. 2

Skalenmäßig angeordnet ergibt das die in Abbildung 3 dargestellte Abfolge.

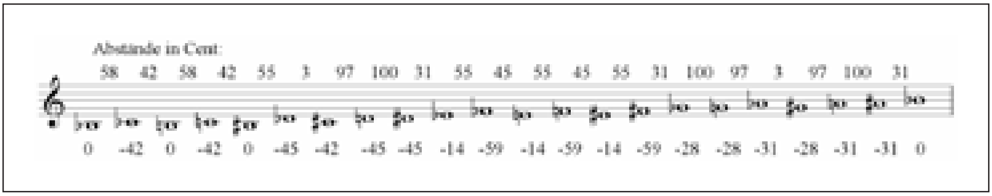

Abb. 3

Dazu steht die Synthesizerstimmung von $\sqrt[12]{1{,}956}$ um das mittlere c1 (exakt habe ich den Wert 1,9560685 ermittelt). Sie enthält konstante „Halbtonschritte" von jeweils 96,8 Cent und verliert nach 12 Schritten ca. 38,5 Cent pro Oktave. Diese Stimmung erfand ich, um eine Verkettung von reinen 5/4-Terzen und 7/4-Septimen von jedem Ton aus zu erzielen (der Fehler ist jeweils nur 0,8 Cent!). Im mittleren Tonbereich decken sich die reinen großen Terzen und reinen kleinen Septimen von Harfe und Synthesizer (exakt: nur die Töne im ersten Harfenbeispiel oben plus einiger Umstimmöglichkeiten durch das Harfenpedal, abgesehen von der eher theoretischen 0,8C-Abweichung beim Synthesizer). In den „Außenbezirken" des Tonumfangs jedoch driftet der Synthesizer immer weiter von diesen Tönen ab wegen seiner zu engen „Oktave" von 1161,5 Cent. Harfe und Synthesizer bewegen sich in einer wie „flüssig" erscheinenden Harmonik um reine Terzen und Septen. Diese flüssige, stets ambivalente Harmonik ist das Charakteristische auch der Musik Harry Partchs. Als „Zugabe" erscheint übrigens in Synthesizer und Harfe stark angenähert der 11/8 „Naturtritonus", ein Intervall, das Partch innerhalb seines „11 limit" stets mitbedacht hat. Die Synthesizerstimmung erlaubt außerdem eine Spiegelung von 5/4 und 7/4, so daß im Synthesizer auch Partchs „Utonality" andeutbar ist, also hier 4/5 und 4/7, gewissermaßen aus einer „Untertonreihe" (Abb. 4)

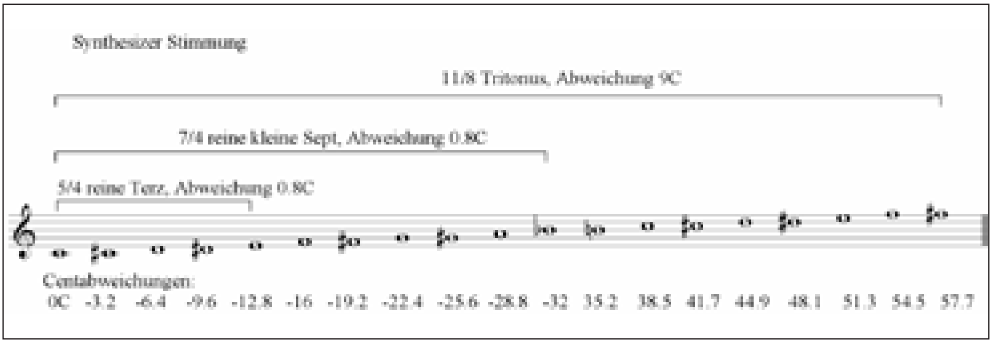

Abb. 4

Harry Partch lebte teils als Tramp in den USA, besonders in der „Great Depression" in den 30er Jahren, und baute/spielte oft herb klingende, skurrile Instrumente, die er „naturrein" stimmte, nicht zwölftontemperiert. Seine Philosophie sammelte er in dem Wort „corporeality". Tatsächlich ist nichts abgehoben oder spinnert an diesem Mann gewesen. Im Gegenteil bot Partch eine faszinierende Idee des Anfangs einer Musik an. Er baute seine Musik mit den

Händen, sang sie mit seiner Stimme und tanzte sie mit seinem Körper. Das meint „corporeality". Seine Musik erzählt in aller Reinheit von sich. Sie hat ein unschuldiges Land gefunden.

Die Sätze von PARTCH HARP heißen:
1. Zwiegesang, 2. Partch Harp, 3. Partch Bourdon, 4. Partch en ciel.

Einige Betrachtungen zu PARTCH HARP

Unsere musikalische Welt ist voller unentdeckter und entdeckter Mikrotöne, das wären Töne, die zwischen unseren gar so sehr theoretischen temperierten 12 Tönen liegen. Jeder Geiger kann ein Lied davon singen, jeder Trompeter. Nur die Tastler haben vielleicht ein festes Bild von Tonschritten, in dem sie sich so sicher bewegen, daß sie gewisse Abgründe nicht sehen. Wären sie verpflichtet, ihre Instrumente selbst zu stimmen – was unsere arbeitsteilige Welt nicht wünscht –, öffneten sich ihre Ohren. Es geht auch nicht um Mikrotöne. Sie sind nur ein Teil einer vielleicht neuen Denkweise, bei der es mir aber egal ist, ob sie neu sei. Sogar ist es mir egal, wie stark sie sich an irgend andere Denkweisen anlehnt – in Raum oder Zeit. Gar bin ich sicher, daß sie schon einmal da gewesen sein muß! Die außerzentraleuropäische Welt ist voll von für uns (noch) fremdartigen Skalen. Allerorten, allerzeiten ersinnen Menschen Tonfolgen, die sie mögen. Es gibt viele Arten von Gesetzen. Oft sind es sehr kleine Menschengruppen, die sich solche eigentümlichen, stammesspezifischen Gesetze auferlegen. In Afrika stimmt praktisch jedes Dorf anders. Ähnlich ist es im fernöstlichen oder pazifischen Raum. Uns ist bekannt der je eigenartige Skalenraum verschiedener Gamelanorchester. Fast nirgends ist großräumig das Tonhöhendenken streng fixiert – außer bei uns. Westliche Theoretiker klammern sich gern an die Vorstellung, daß hinter all den verwirrend vielfältigen Erscheinungen zumindest einfache Ideenwelten lägen wie Äquidistantialität. Jedoch: Allein daß die Europäer anderen Musikkulturen ein abstraktes „Skalen"-Denken aufpfropfen, gar noch in einem stillschweigend vorausgesetzten oktavidentischen System, Musikkulturen, die vielleicht räumlich-visuell denken (Abstände der Bohrungen auf einer Flöte), oder taktil-ergonomisch (Länge der Sanza-Zungen) oder anatomisch (Fingerdicke als Maß für die Balaphonlamellen) oder wie immer sonst – das sollte uns schwer zu denken geben. Vielleicht stecken wir hier gar noch in einem kolonialistischen Denken. Was las ich neulich: Die Musik der ‚Are'are von den Salomon-Inseln solle äquidistant-heptatonisch sein? (Zemp 1973, 1981) Ich prüfte das nach an meinem DX7-II, und was stellte ich fest? Nicht einmal die Oktave gibt es. Der Meßraum für Heptatonik löst sich damit ins Nichts auf. Oder sollten wir Oktaven mit einem Fehler von 20 Cent als Oktaven akzeptieren? Ganz konsequent vermeidet diese Flötenmusik den Quasi-Oktaven-Zusammenklang. Dahinter muß ein Prinzip stecken. Nun, bei näherer Analyse lassen sich schnell Terzenketten herausziehen. Der Begriff „Terz" ist aber wieder so ein „Kolonialismus", der mir unterschlüpft. Denn was sollen wir zu „Terzen" sagen, deren Größe zwischen 320 und 363 Cent schwankt? (Im Vergleich dazu ist unsere kleine Terz 300 und unsere große 400 Cent groß.) Wer partout bei der Terz bleiben will, konstruiert sich gern den Begriff „neutrale" Terz.

Aber ich muß noch mal auf die äquidistant-heptatonische Schauweise zurückkommen: Tatsächlich liebt das Volk der ‚Are'are ganz offenbar das Zusammenklingen der jeweils benachbarten Töne einer „Skala". Das bildet sozusagen eine Gegenharmonik zu jener Terzenwelt, die ich eben ansprach. Ganze Lieder bewegen sich in – wir würden sagen – „parallelen Sekunden". Diese Sekunden sind zwischen 198 und 134 Cent groß. Mag da noch jemand von

„Äquidistanz“ sprechen? Dies soll ein kleiner Hinweis sein darauf, was mich so fasziniert: Es gibt Kulturen, die mit Tonhöhen spielen wie wir vielleicht mit anderen Tondimensionen, etwa Klangfarben.

Mir fiel immer auf, daß weder Wyschnegradsky noch Hába noch auch Partch (drei bekanntere Namen im mikrotonalen Bereich) auf der wirklichen Höhe des Handwerks waren. Der erste blieb nebelhaft-spätromantisch-wolkig, der zweite blieb rhythmisch-formal in den Kinderschuhen stecken, der dritte baute in einem denkbar vertrackten Tonsystem seine Privatwelt. Der erste blieb im alten 19. Jahrhundert und „mikrotonalisierte“ nicht die Zeitachse, der zweite wählte neue temperierte Systeme, aber dazu auch eine neoklassizistische Rhythmik und Formgebung. Der dritte kümmerte sich verbissen um seine Skala in reinen Intervallen, baute seine Instrumente – und schimpfte auf die westliche Musikkultur, um die er sich aber kaum bekümmerte (Ausnahme: die alten Griechen). Er ist mir trotzdem der sympathischste. Übrigens bin ich über Ben Johnston (heute Prof. emeritus in Urbana, Illinois) der Enkelschüler Harry Partchs.

Welche Wege öffnen sich? Seit ein paar Jahren habe ich das Gefühl, mein Weg sei mir klar. Ich liebe Proportionsrhythmik, das bedeutet für mich ein erlebbares Über- und Hintereinanderblenden von einfachen rhythmischen Proportionen, die in verrückte Komplexitäten wachsen: Ich liebe seltsame Großproportionierungen wie etwa 33/32, das würde bedeuten, daß ein Instrument 33 Viertel spielt, während das andere im gleichen Zeitraum nur auf 32 kommt, also etwas „langsamer“ spielt. Das probiere ich auch für Klavier solo – und es geht wunderbar, wenn man auf neue Weise sanft und biegbar wird. Überhaupt reizt mich die „Seltsamkeit“ hinter dem Einfachen. Mein Wunsch ist, an der Oberfläche das Einfachste zu zeigen (mit Partch und Johnston liebe ich die einfachen Intervalle der reinen 5/4, 6/5, 7/6 Terzen, der reinen 7/4 Septime, des 11/8 Tritonus). Mein Wunsch wächst weiter und zieht aus der „Just Intonation“ deren „strangeness“, die bei Partch immer vorhanden ist, auf die er aber leider nicht genug Gedanken verschwendet hat.

Machen wir einen Sprung zu einem neuen mikrotonalen Werkstück aus meiner Werkstatt:

Manfred Stahnke 2003
Partota VIII – regio dissimilitudinis
Disklavier oder midifiziertes akustisches Klavier und Computer – ein Versuch über Harmonik in Ganzen Zahlen.
Für Jennifer Hymer, August 2003

„Das Reich der Unähnlichkeit“: „In der seit Augustinus so benannten *regio dissimilitudinis* existiert die menschliche Figur nur in ihrer schuldhaften Defiguration und unter der ständigen und buchstäblich tödlichen Bedrohung ihrer Dekomposition. Schon bei Plotin, der den Begriff *regio dissimilitudinis* von Platon übernimmt, wird dieses monströse Reich nicht nur Synonym für den Schlamm des Hades, sondern bezeichnet ein materiell konditioniertes Böses, welches sich in der christlichen Adaption mit der Erbsünde verschränken wird.“ (Ebeling und Meister 2003, S. 28.)

Wir sehen bei Partch und auch bei dem Franzosen Gérard Grisey (1946–1998), wie das Konzept einer vorgestellten primären „Reinheit“ (bei Partch: „Just Intonation“, bei Grisey die Zahleneinfachheit des „Spektralismus“) zu sekundären Monstrositäten während der tatsächlichen Arbeit gerät. Andere Komponisten, etwa LaMonte Young, suchen tatsächlich das

Verharren auf der *einen* Naturtonreihe, die nicht verlassen wird – und geraten zu einer autistischen Monstrosität. Es bleibt uns, diesen Zustand zu akzeptieren. Die *aequiformitas* des Paradieses haben wir verloren. Wir bauen an Kommentaren zu unserem Sehen und Hören, und wir stehen in einer Welt, die wir uns bauen, und von diesem Bau erzählt jeder Einzelne.

Die *Partota VIII* erzählt vom Hören auf eine extreme Weise. Sie befaßt sich mit dem Selbsterzeugen von Tönen im Ohr, wenn ein musikalisches Intervall interpretiert wird. 65 verschiedene Muster dieser Differenztonakkorde werden verwendet, wobei sehr einfache Intervallverkettungen und auch sehr verschrobene benutzt werden. Der erste Akkord steht in den Intervallproportionen 7/8/9/10/11/12/13. Das Intervall 12/13 (die oberen Töne des Akkords) kann als Primärintervall angesehen werden, welches in der kubischen Differenzton-Kaskade die unteren Töne 11, 10, 9, 8, 7 erzeugt. Bis zum 65. Akkord vergrößere ich die Intervalle sukzessiv. Dabei gelange ich immer wieder zu Intervallen, die uns aus der älteren Musik bekannt sind. Mit diesen Bekanntheiten spiele ich.

Die gesamte Schau der Akkorde 1–65

Erklärung zur Tabelle 1

1. Spalte:
   „1“: Diese erste Zahl bezeichnet den Akkord (Index).
2. Spalte:
   „12“: Die zweite Zahl oder Zahlenkombination bezeichnet den tatsächlich gespielten Griff auf der Tastatur. „12“ meint: „Eine Oktave (12 Halbtöne) wird gleichzeitig gegriffen.“ Bei zwei Zahlen wie etwa bei Akkord-Index 3: „5, 2“ heißt das: „Eine Quarte (5 Halbtöne) und darüber eine große Sekunde (2 Halbtöne) werden gleichzeitig übereinander gegriffen.“
3. Spalte:
   „7“ meint: „Ab dem 7. Naturton den synthetischen Akkord (aus insgesamt immer sieben Tönen) aufbauen.“
4. Spalte:
   „1“ meint: „Erzeuge ein Spektrum im Teiltonabstand 1.“
   (Also bei tiefstem Naturton 7 ist das Auswahlspektrum „7 8 9 10 11 12 13“.) Der tiefste gegriffene Ton ist immer der tiefste des Auswahlspektrums.

Die ersten drei Akkorde in Noten: Pfeilakzidentien weisen hin auf Sechsteltöne, ca. 33C, „+“ und „–“ weisen auf Zwölfteltöne, ca. 17C: eine Annäherung an die Naturtonverhältnisse (Abb. 5).

Tab. 1

Index	*Gegriffenes* Intervall in **Halbtönen**, bei 2 Zahlen: 2 Intervalle übereinander	Tiefster **Naturton** für *synthetischen Akkordaufbau*	Intervallabstand im synthetischen Akkord in **Naturtonabständen** (je 7 Töne pro computererzeugtem Akkord in diesem Abstand).
1	12	7	1
2	10	19	3
3	5, 2	6	1

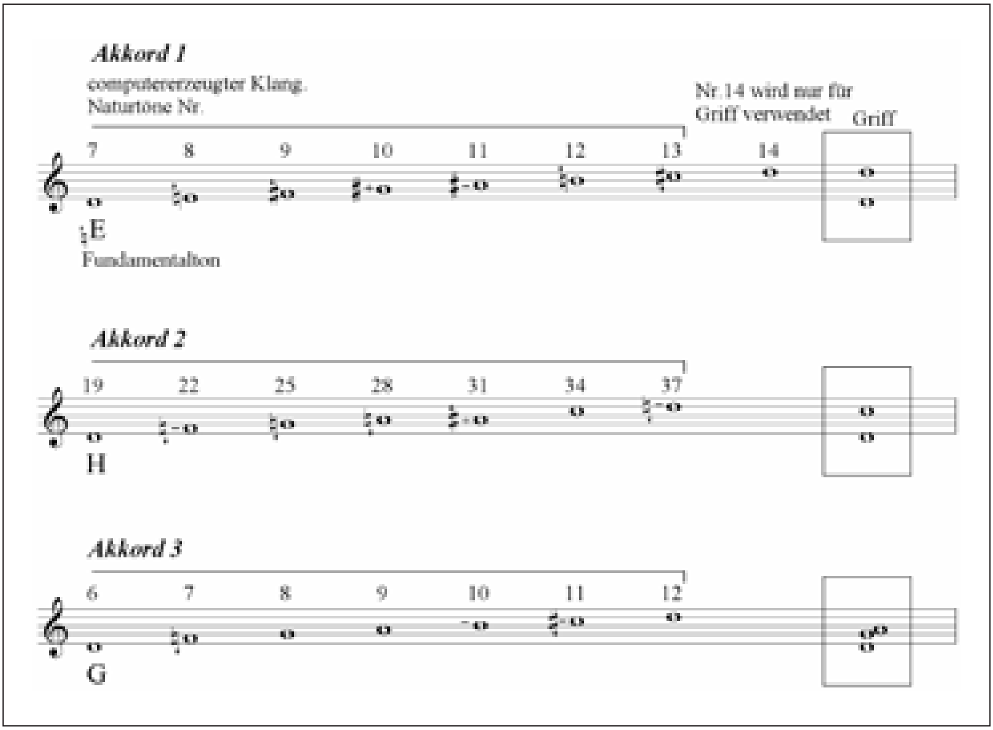

Abb. 5

Der weitere Verlauf des Systems ist in Tabelle 2 dargestellt.

Für die Computerprogrammierung:

Um die **Proportionen der Naturtonreihe** darzustellen, genügt eine Auflösung von 72 temperierten Tonschritten pro Oktave (1/12-Tonauflösung). Die **Gleichzeitigkeits-Toleranz** ist ca. 100 ms. Ist der gespielte Zeitabstand größer, erzeugt das Piano eine Melodie ohne die Differenztonkaskade.

Jeder **synthetische Akkord** besteht aus sieben Tönen, deren Dynamik sich nach dem lautesten gespielten Ton richtet: Der **zweitunterste Ton** des synthetischen Akkords soll dynamisch hervorgehoben sein. Seine Lautstärke richtet sich nach der Lautstärke des stärksten tatsächlich gespielten Tons, er sollte gleichlaut oder eventuell sogar etwas lauter sein. Der **unterste Ton** sollte praktisch ganz unterdrückt werden – er wird immer vom akustischen Klavier gespielt. Der **dritte bis siebente Ton** sollte ein (allerdings gut wahrnehmbarer) Schatten sein, beispielsweise ein Klavierton-Sample, dessen Einschwingvorgang weggeschnitten ist.

Um diese „Differenzharmonik" näher zu erläutern, wende ich mich jetzt einem weiteren Werk zu:

Tab. 2

Index	*Gegriffenes* Intervall in **Halbtönen**, bei 2 Zahlen: 2 Intervalle übereinander	Tiefster **Naturton** für *synthetischen Akkordaufbau*	Intervallabstand im synthetischen Akkord in **Naturtonabständen** (je 7 Töne pro computererzeugtem Akkord in diesem Abstand).
4	11	17	3
5	3, 10	16	3
6	12, 7	5	1
7	6, 8	24	5
8	11, 2	9	2
9	17, 4	17	4
10	7, 7	4	1
11	4, 6	19	5
12	18, 3	34	9
13	19	7	2
14	8, 3	17	5
15	14	16	5
16	20, 2	54	17
17	5, 14	3	1
18	9, 6	32	11
19	25, 1	17	6
20	13	8	3
21	10, 16	18	7
22	19, 6	32	13
23	6	17	7
24	22	54	23
25	20	16	7
26	27, 1	64	29
27	21, 6	17	8
28	29	27	13
29	12, 12	2	1
30	16	57	29
31	30	19	10
32	20, 6	24	13
33	13, 18	16	9
34	28	19	11
35	8, 18	12	7
36	32	27	16
37	18, 13	18	11
38	31	27	17
39	25	17	11
40	19, 11	3	2
41	9	19	13
42	23, 3	36	25
43	26, 5	27	19
44	29, 7	19	14
45	24, 3	4	3
46	32, 2	17	13
47	10, 20	9	7
48	21	24	19
49	25, 3	16	13
50	17, 14	6	5
51	22, 7	27	23
52	26	8	7
53	11, 21	19	17
54	35	32	29
55	18	12	11
56	27	17	16
57	33	24	23
58	41	34	33
59	19, 5	1	1
60	34	48	49
61	40	81	83
62	37	16	17
63	25, 4	27	29
64	38, 2	19	21
65	13, 27	9	10

Manfred Stahnke 2000–2002
ORPHEUS KRISTALL
Eine Oper in zwei Medien
(Bühne mit Internet)

Angesichts dieses Projekts dachte ich spontan: Wenn schon der Apparat „Internet“ mit seinem unsteuerbaren Spielcharakter in den Apparat Oper einbrechen soll (das war der Auftrag), müßte als starkes Gegengewicht ein sehr präzis gebautes „Kristall“ auf die reale Opernbühne gestellt werden. Meine Überlegung: Differenzharmonik könnte zu einem umfassenden meloharmonischen Konzept für die Oper werden. Um die Differenztongebilde handhaben zu können, wollte ich ausgehen von den Ganzzahl-Proportionen der Naturtonreihe.

Was ist „Differenzharmonik“? Im Innenohr entstehen spontan beim Zusammenklang mindestens zweier Töne Zusatztöne („Kombinationstöne“), welche nicht im Signal enthalten sind. Unter diesen Zusatztönen sollen uns hier vordringlich zwei verschiedene Arten von „Differenztönen“ interessieren. Der sogenannte „quadratische“ Differenzton ist der bekannteste: f1 – f2. Der sogenannte „kubische“ ist 2*f2 – f1. Letzterer ist bei kleinem Frequenzabstand sogar weitaus prägnanter als der quadratische, der durchgehend eine recht starke Amplitude der Primärtöne erfordert. Die Wahrnehmbarkeit des kubischen Differenztones nimmt schnell ab, wenn sich der Intervallabstand der Primärtöne vergrößert. Der interessante und wichtige Unterschied zwischen quadratischem und kubischem Differenzton ist die Tatsache, daß der quadratische nur eben dieser eine virtuelle Ton ist, daß aber der kubische je noch weitere Differenztöne initiiert. Die Entstehung dieses Phänomens können wir in etwa folgendermaßen anschaulich machen:

Der quadratische Differenzton könnte durch ein sogenanntes „peak picking“ im Innenohr erzeugt werden (Gelfand 1990, S. 406f.). Siehe dazu Abbildung 6. Die Hörmembran folgt der Schwingungskurve, die sich aus dem Zusammenklingen der beiden Primärtöne ergibt (im folgenden Beispiel im Schwingungsverhältnis 9/8 stehend), und rechnet sie zu einem einfachen „Ton“ um (9 – 8 = 1).

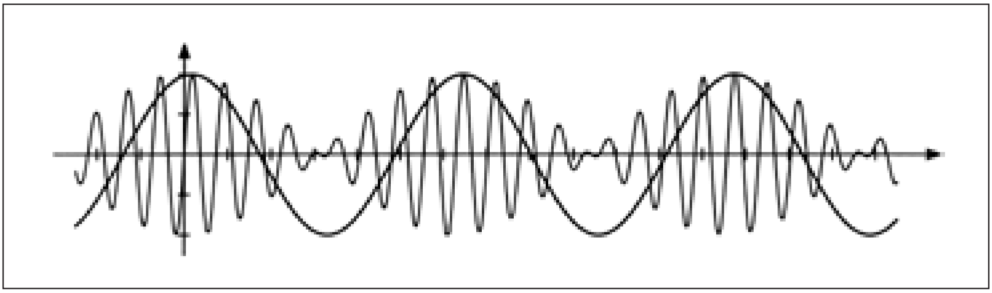

Abb. 6 Quadratischer Differenzton, zugehörige Sinus-Kurve überhöht

Anders sieht es beim kubischen Differenzton aus. Die Primärtöne erzeugen eine ganze Kaskade von sekundären Kombinationstönen (nach Pickles 1992, S. 107, Abb. 7).

Derzeit wird die Erklärung z. B. im sogenannten »cochlearen Verstärker« gesucht, d. h. in der Eigenaktivität der äußeren Haarzellen auf dem Cortischen Organ (welches auch die

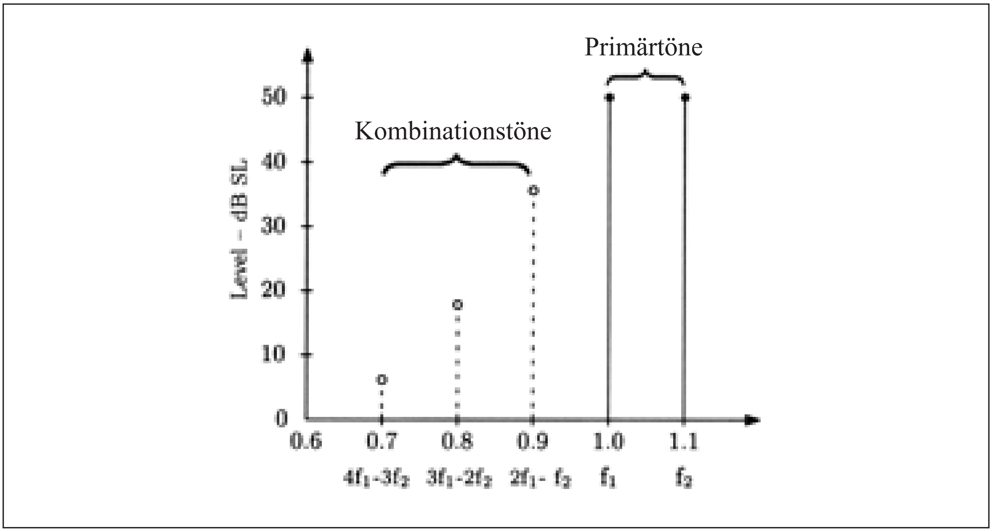

Abb. 7 Kaskade von sekundären Kombinationstönen

Basilarmembran enthält) (Pickles 1992, S. 157). Diese äußeren Haarzellen greifen aktiv an die Tektorialmembran, welche über dem Cortiorgan liegt, versetzen die Tektorialmembran in eine Schwingung, die abhängig vom Abstand der Primärtöne ist. Seit Längerem ist bekannt, daß das Innenohr beileibe kein passives Aufnahmeorgan ist, sondern selbst meßbare Töne erzeugt. Diese Eigenaktivität des Innenohres läßt sich grob so beschreiben, daß „Teiltöne" von „Naturtonreihen" eigenerzeugt werden, z. B. werden fehlende Fundamentaltöne ergänzt. Denken wir an das Telefon, das den Eindruck einer „Männerstimme" erzeugt, obwohl die tiefen Frequenzen gar nicht übertragen werden. Natürlich ist das Innenohr hierfür nicht allein verantwortlich. Auch nachgeschaltete Verarbeitungen bis hin zum *brain processing* spielen hinein und ergänzen die Aktivität der Membranen im Innenohr.

Wie können wir uns die meloharmonischen Wirkungen dieser Differenztöne anschaulich machen? Wenn wir von Intervallen in ganzzahligen Proportionen ausgehen, ergeben sich einfach zu beschreibende Differenztöne (Abb. 8). Nehmen wir eine große Terz 5/4 („Naturterz"). Das Minuszeichen vor h1 indiziert den Unterschied zum temperierten h1: ca. –15 Cent (1 Cent = 1/100 temperierter Halbton).

Der quadratische Differenzton „Q" ist 5–4 = 1, der kubische „K" ist 2*4–5 = 3.

Bilden wir in der Folge eine Anzahl stetig wachsender Naturintervalle und prüfen die Entwicklung der Differenztöne K und Q. Dabei meinen „+" und „–„ ca. 15 Cent, die Pfeilakzidenzien ca. 30 Cent Differenz zur Temperierung und das „halbe" Kreuz ca. 50 Cent (= ein Vierteltón), das sind auf 5 Cent genau gerundete Werte (Abb. 9).

Wir finden verschiedene Grade von harmonikaler „Komplexität". Der erste Akkord enthält die folgenden ganzzahligen Proportionen:

Primärtöne: 24 (h1) und 19 (g1).
Sekundärtöne: K 2*19 – 24 = 14 (♮ d1)
Q 24 – 19 = 5 (♯ – Gis)

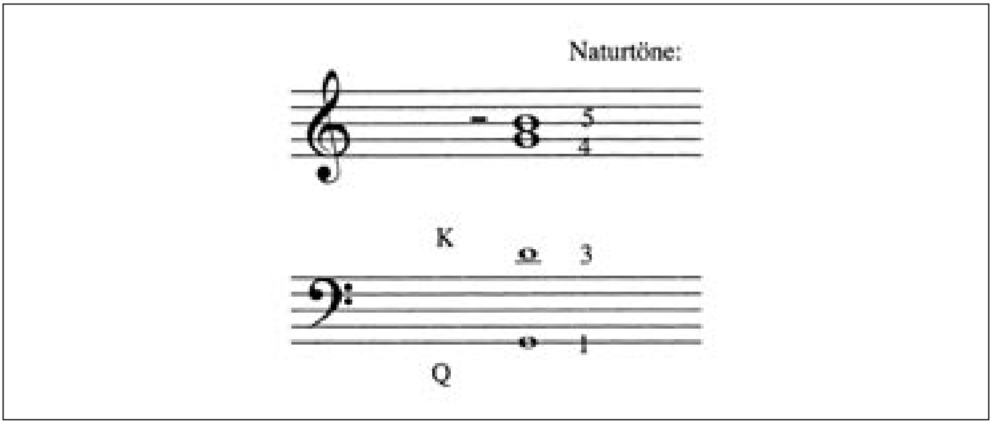

Abb. 8

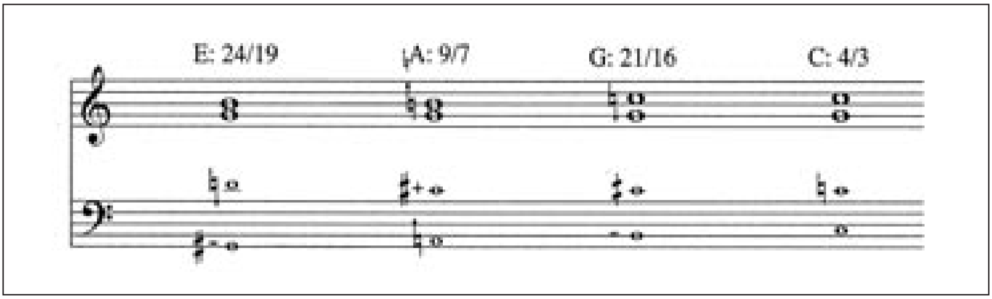

Abb. 9

Der Gesamtakkord ist also, in Intervallproportionen ausgedrückt: 24/19/14/5. Gegenüber diesem uns unvertrauten Akkord, der bei 19/14 eine „zu große“ Quart für unser Normalverständnis enthält, ist der letzte Akkord „einfach“: 4/3/2/1, ein „naturreiner“ Quintoktavklang. Der zweite Akkord ist ein nur graduell komplexerer Akkord, er enthält die „Natursept“, die wir immerhin von Blechbläsersätzen her kennen dürften: 9/7/5/2.

Alle vier Akkorde baut das Ohr im Prinzip selbsttätig, wenn es die Primärtöne hört. Eine Fourieranalyse würde keinerlei Energie bei den Sekundärtönen zeigen. Allerdings sind in den meisten Fällen die Sekundärtöne kaum bewußt wahrzunehmen. Wenn wir sie aber den Primärtönen hinzufügen, entsteht der Eindruck einer sehr speziellen „Konsonanz“ oder Stimmigkeit. Die Primärtöne „passen“ mit den Sekundärtönen zusammen.

Wie erwähnt (siehe Abb. 2), erzeugt das Innenohr *via* K (kubischer Differenzton) eine Kaskade von Differenztönen, die wir kurz anhand von ganzzahligen Proportionen untersuchen wollen: Bei der Eingabe des Primärintervalls 9/8 entsteht (Abb. 10).

K1 ist dabei 16 – 9 = 7
K2 ist 24 –18 = 6
K3 ist 32–27 = 5
K4 ist 40 –36 = 4

Abb. 10

Wir erhalten also einen „Formanten“ mit den Naturtönen 7, 6, 5 und 4. Übrigens gibt es eine viel einfachere Rechnung für den kubischen Differenzton, wenn wir ganzzahlige Verhältnisse annehmen wie oben: Nimm einfach den Abstand der Primärtöne und verlängere die Reihe: Primär 9/8 gibt den „Abstand 1“. Dieser erzeugt die kubischen Töne 7, 6, 5, 4 ...

Nun wäre es für einen Komponisten durchaus problematisch, ausschließlich mit Naturtonreihen zu arbeiten. Das war ein Problem etwa bei Gérard Grisey und den Pariser Spektralisten. Grisey baute sich konkurrierende Modelle, nämlich z. B. gedehnte und gestauchte Spektren, von denen er dann Ausschnitte nahm, die einen eindeutigen „Fundamentalton“ nicht mehr erkennen ließen (Stahnke 1999). Dadurch erreichte er eine perzeptive Mehrdeutigkeit seiner Strukturen. Das Gehör müßte springen zwischen möglichen „Interpretationen“, etwa: Bin ich im Feld 12/11/10/9 oder doch eher 11/10/9/8? Aus der Residualtonforschung wissen wir, daß das Ohr tatsächlich „gestaltlich“ zum „Einfachen“ hin interpretiert. Der Residualton, ein tiefer als die Primärtöne liegender Quasi-Fundamentalton, ist eine Gehörvermutung des Naturtonaufbaus der Primärtöne, auch wenn diese nicht exakt auf eine Naturtonreihe fallen (dazu z. B. Gelfand 1990, S. 410 ff.).

Wie wäre es, wenn wir eine plurale meloharmonische Welt akzeptierten und eine „perzeptiv informierte“ Meloharmonik daraus bauten? Offenbar könnten wir ein Feld aufbauen zwischen „Einfachheit“ (Harmonizität, auch im Sinne dessen, was ich oben „Stimmigkeit“ nannte) und „Mehrdeutigkeit“. Was aber wäre „Einfachheit“? Es gibt sie nicht absolut, sondern nur in Relation zu dem von uns Gelernten, und in Relation zu dem Umfeld, in dem die postulierte „Einfachheit“ erscheint. Wie wir oben sahen, ist in der an sich „einfachen“, weil naturtönigen Intervallik 24/19/14/5 mit 19/14 als „zu großer“ Quart schon Mehrdeutigkeit enthalten: Zählt hier die „Quart“ oder nicht? Immer mißt das Ohr an dem einfachen Intervall, wenn es ein komplexeres hört, oder allgemein an der einfacheren Gestalt.

Vielleicht ist gutes Komponieren dort, wo wir zum „Tanzen auf erinnerten Gestalten“ gezwungen werden. Und sehr gutes Komponieren würde ins Neuland der „unbekannten Gestalten“ aufbrechen. In Meloharmonik könnte dies ein Land der fremden Intervalle sein unter Einschluß der Naturtöne 7, 11, 13 etc. Aber wir haben gesehen, daß dies nicht reicht, weil auch diese Intervalle gemessen werden an den bekannten. Erst wenn eine „stimmige“ Meloharmonik entwickelt ist und konfrontiert wird mit einer dazu „nicht stimmigen“, würden wir am Abgrund tanzen: Nur dort ist das beste Komponieren angesiedelt: ohne feste Haut. Differenzharmonik braucht – wie jedes Konzept – die Tür ins Exterritoriale. Und da weht ein kalter Wind.

Literatur

EBELING, K., und MEISTER, C.: Postsäkulare Paradiese – Kunst im Reich der Unähnlichkeit. In: FLÜGGE, M., und MESCHEDE, F. (Eds.): Warum! Bilder diesseits und jenseits des Menschen. Ostfildern 2003

GELFAND, S. A.: Hearing. An Introduction to Psychological and Physiological Acoustic. 2nd edition. New York, Basel: Marcle Dekker Inc. 1990

PARTCH, H.: Genesis of a Music. 2. erw. Aufl. New York: Da Capo Press 1974

PICKLES, J. O.: An Introduction to the Physiology of Hearing. 2nd edition. London etc.: Academic Press 1992

STAHNKE, M.: Gedanken zu Harry PARTCH. In: HENCK, H. (Ed.): Neuland. Ansätze zur Musik der Gegenwart. Jahrbuch Band 2, S. 243–251. Bergisch Gladbach 1981/1982

STAHNKE, M.: Die Schwelle des Hörens: „Liminales“ Denken in „Vortex temporum“ von Gérard Grisey. ÖMZ *6*, S. 21 (1999)

STAHNKE, M.: Partchenogenese. Harry Partch – wie ein Komponist sich selbst erfand. Hörstück für den WDR, Sendung 21. Juni 2001. Redaktion HILBERG, F. In: STAHNKE, M. (Ed.): DEN TON FINDEN – Schriften zur Musik. II. Abteilung, S. 54 – 65. Hamburg 2004. (Darin auch: PARTCH, H.: Ein kleines Tutorium zu seiner Harmonik. I. Abteilung, S. 10. Zu bestellen bei Stahnke-Verlag, www.manfred-stahnke.de [2001])

STAHNKE, M.: Partch Harp, Orpheus Kristall, Partota VIII. Alle Werke sind erschienen im Stahnke-Verlag, www.manfred-stahnke.de

ZEMP, H.: Échelles équiheptatoniques des flutes de pan chez les ‚Are‘are. Yearbook of the International Folk Music Council *5*, 94 –95 (1973)

ZEMP, H.: Melanesian Solo Polyphonic Panpipe Music. Ethnomusicology *25*, 408 (1981)

Prof. Dr. Manfred STAHNKE
Kupferdamm 12
22159 Hamburg
Germany
Tel.: +49 40 6682970
E-Mail: ms@manfred-stahnke.de

Uwe Pörksen: Was spricht dafür, das Deutsche als Naturwissenschaftssprache zu erhalten?

Vortrag in der Sitzung der Deutschen Akademie der Naturforscher Leopoldina am 12. Dezember 2000 in Halle (Saale)

Nova Acta Leopoldina N. F. Bd. *87*, Nr. 326
Herausgegeben von Benno Parthier (Halle/Saale)
(2001, 31 Seiten, 9,95 Euro, ISBN 3-8304-5106-7)

Die atemberaubende Entwicklung auf zahlreichen Feldern der Naturwissenschaft und der Medizin hat zu beeindruckenden Ergebnissen, aber ebenso auch zu Ängsten in Teilen der Bevölkerung, insbesondere den dem modernen Wissenschaftsbetrieb ferner stehenden Kreisen geführt. Nicht nur das Unverständnis für die fachlichen Details, sondern auch die immer häufigere Verwendung des Englischen als die *lingua franca* der Naturwissenschaften, erschweren die Propagierung von neuen wissenschaftlichen Erkenntnissen und das Verständnis für den erreichten wissenschaftlichen Fortschritt. Auf der einen Seite belegen Statistiken eindeutig den Vormarsch und die Vorzüge der englischen Sprache als Naturwissenschaftssprache. Andererseits erscheint die von Uwe Pörksen diskutierte Frage: „Was spricht dafür, das Deutsche als Naturwissenschaftssprache zu erhalten?" durchaus als berechtigt. Der Autor unternahm in einem öffentlichen Vortrag vor der Deutschen Akademie der Naturforscher Leopoldina im Dezember 2000 den Versuch, die verschiedenen Argumente mit Augenmaß und unter Aufzeigung der gegensätzlichen Standpunkte zu diskutieren und zu wichten.

Die Wissenschaftsgeschichte beweist: Zweisprachigkeit oder Mehrsprachigkeit war der Normalfall: das Gegenüber von Deutsch und Latein (800–1800), Deutsch und Französisch (1600–1800), Deutsch und Englisch (1960–?) belegt diese Aussage. Nur zwischen 1800 und 1960 war Deutsch die allein vorherrschende Sprache unserer Naturwissenschaft.

Die Dominanz des Englischen in den Naturwissenschaften führt zu einer Verwendung dieser Sprache als einer schmalen Funktionssprache (Englisch II), die verbunden mit der visuellen und mathematischen Zeichensprache als ein rasches internationales Verständigungsmittel fungiert. Unter der aktuellen ökonomisch-technischen Entwicklung und der jüngsten elektronischen Medienrevolution hat dieser Code beachtliche Vorteile. Trotzdem sind der Anwendung von Englisch II bei anspruchsvollen wissenschaftlichen Aufgaben Grenzen gesetzt, da im Ergebnis „blinde Flecken" bleiben und der Selektion von Denkmodellen aufgrund der reduzierten Ausdrucksmöglichkeiten Vorschub geleistet wird. Das Fazit des Germanisten Pörksen kann deshalb nur heißen: „Nur das differenzierte Englisch (Englisch I) und eine differenzierte Ausarbeitung der Naturwissenschaften in der eigenen Muttersprache, entwickelte Ein-, Zwei- und Mehrsprachigkeit dürften der wachsenden Komplexität der Forschungsaufgaben und Erkenntnisprobleme gewachsen sein. Die Naturwissenschaftssprache ist nicht nur Erkenntnisinstrument, sondern ebenso ein öffentliches, ein kulturelles, gesellschaftliches Phänomen."

Nova Acta Leopoldina NF *92*, Nr. 341, 63 – 89 (2005)

Research and Technology in the Opera *Der Sprung*

Georg Hajdu (Hamburg)

With 20 Figures and 5 Tables

Abstract

In this paper the opera *Der Sprung – Beschreibung einer Oper* is being dicussed in light of its biographical, historical, musical and technological contexts. The opera is the result of a unique collaboration between librettist Thomas Brasch and the author. Its harmonic and formal structure is entirely generated from a short motto by Brasch, using advanced technology for spectral analysis and computer composition. Historically, the opera could be characterized as a late example of the exploratory phase in computer music.

Zusammenfassung

Dieser Aufsatz diskutiert die Oper *Der Sprung – Beschreibung einer Oper* in ihren biographischen, historischen, musikalischen und technologischen Kontexten. Die Oper ist das Resultat einer außergewöhnlichen Zusammenarbeit zwischen dem Librettisten Thomas Brasch und dem Autor. Ihre harmonische und formale Struktur wurde mit fortgeschrittenen Verfahren zur Spektralanalyse und Computerunterstützter Komposition aus einem kurzen Motto Braschs abgeleitet. Geschichtlich kann die Oper als spätes Beispiel der explorativen Phase in der Computermusik bezeichnet werden.

1. Introduction

The opera *Der Sprung – Beschreibung einer Oper* was the result of several intersecting lines – lines of biographical, historical, technological and scientific relevance with aspects of serendipity and hard work. In the following I will trace these lines and reconstruct the making of this piece, which took a decade to conceive and 4 years to complete.

The years 1984 to 1998 mark the beginning and end of this process, in which I mutated from a molecular biologist with a second major in music into a professional composer and music-school professor with continuous strong interests in computer technology and science. Moreover, these years also witnessed technological advances, which went from the development of the first Apple Macintosh computer to the introduction of affordable computers that were fast enough to enable users to perform complex tasks such as DSP in real time with novel software.

Finally, these years also brought about a dramatic development of the areas of cognitive psychology and neurology, which elucidating the mechanisms of perception and cognition, are increasingly re-shaping the fields of music theory and composition.

2. The Story

In 1992, when I decided to write an opera (at that time I lived in California as a recipient of a DAAD scholarship) I resorted to an article by Viennese journalist Erika Wantoch, which had been published in the Austrian magazine *Profil* in March of 1984. She had written an impressive account of a philosophy student who in a mad fit had killed a professor and wounded his colleague a few weeks earlier. I had a clear recollection of the incident since it happened in my former hometown Cologne: My brother had almost witnessed this terrible crime committed in a university seminar he took for credit, but he had already shown more interest for his acting than for his Hebrew lessons.

The next step was to find the ideal author with an interest in twisted stories. Again, it was my brother Daniel who played a crucial role in finding this very person, since as an actor he knew numerous theater people. He got me in touch with Thomas Brasch and, in 1993, I had the opportunity to meet and work with him twice for several weeks in San Francisco. I didn't know at the time though, that Brasch (1999) was THE specialist for morbid topics (which he demonstrated with novels such as *Mädchenmörder Brunke*.)

Besides my personal interest in the topic, it was apparent that the story also had a historical relevance. In West Germany, in the 1980s the society slowly opened up to facing the implications of the 3rd Reich and the Jewish holocaust (mainly triggered by a Hollywood film named *Holocaust*), while in the 1970s any curiosity was typically met with a wall of silence. These were the grounds off which the protagonist's mind had been feeding. Identifying with the Jewish trauma and even converting to Judaism, she had increasingly retreated into a state of paranoia, convinced that she had to eradicate the source of her discomfort: The German Christian professors who had been teaching Jewish studies at the Cologne Martin-Buber institute. She thus became some sort of lonely Ulrike Meinhof, fighting for the Jewish cause.

3. The Making of *Der Sprung*

3.1 The Libretto – Result of a Unique Interaction

Thomas Brasch, a rebel and notorious celebrity in East Germany, author, poet and filmmaker, was born in 1945 in England to Jewish communist parents and grew up in the East-German nomenclatura. He protested the Soviet invasion of Prague in 1968, was thrown in jail and finally forced to leave his country in 1973; he died in 2001 at the age of 56. Brasch had an instant knack for the story. He was impressed by its depth which reached from a Dostoyevskian murder novel, aspects of guilt and redemption in post-war Germany (East and West), the mad woman opera topos to questions of Jewish and German identity and the Rolling Stones singer Mick Jagger as the personified devil.[1]

Thomas Brasch also embraced my approach to base the opera on a computer-generated process, which was consistent with the fact that the protagonist had felt remote-controlled by

1 Obviously, there are also interesting neurological implications in *Der Sprung*. The protagonist may have suffered from an imbalance called Fregoli's delusion (Carter 1999). With this type of delusion the sufferers usually lose the ability to tell foreign faces from familiar ones, which can lead to a highly paranoid state of mind.

Fig. 1 Thomas Brasch (on the right) and the author standing at a street corner in Berkeley, California (picture taken in 1993).

a computer in the period leading up to the assault. During his stay in San Francisco and the months afterwards, we had a fruitful exchange in such manner that every step in the creation of the opera was the prerequisite for a new step.

While in traditional operas, the librettist delivers the text to the composer which he or she turns into a musical score (a two-layer process), seven consecutive steps can be distinguished in the making of *Der Sprung* (Fig. 1 – Fig. 8):

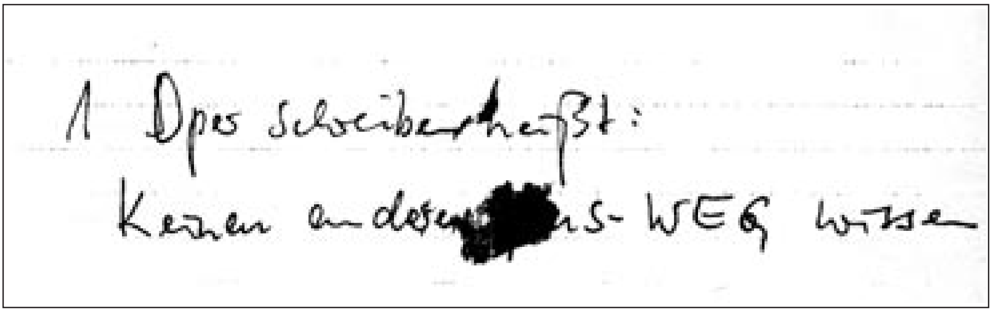

Fig. 2 Level *A*: A written Motto (Brasch)

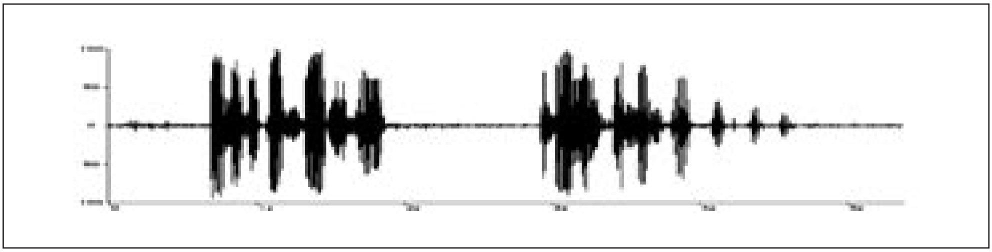

Fig. 3 Level *B*: The recording of the motto onto an answering machine (Brasch)

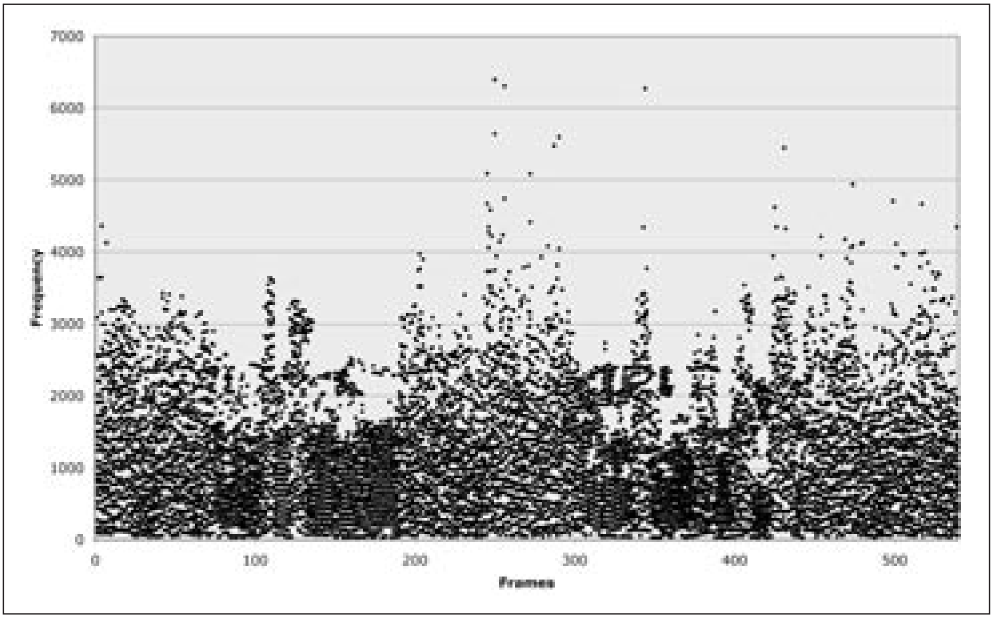

Fig. 4 Level *C*: Frequency and temporal analysis of the sample (Hajdu)

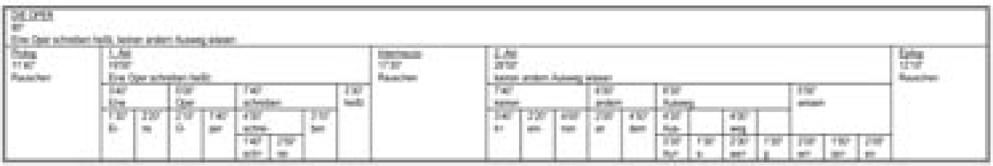

Fig. 5 Level *D*: The formal plan derived from the analysis (Hajdu)

Prolog	1. Act	Internezzo	2. Act	Epilog
Jetzt würde sie es schaffen...	Ich kannte sie, Herr Kollege...	Jetzt ist der Scheitelpunkt endlich erreicht...	Die Zuschauer wollten eine Erklärung...	Ich stürze ab...
	Wir hatten immer ein gutes Verhältnis zu ihr...		Sie habe mich schon früher gekannt...	
	Heute habe ich beschlossen...		Eine andere Sprache sprechen...	
	Die Waffe soll eine aus dem Mittelalter sein...		Die Grenze überschreiten...	

Fig. 6 Level *E*: The libretto derived from the formal plan (Brasch)

Ja, das bin ich, Georg. Schade, dass Du das nicht aufzeichnest, aber ich versuch's trotzdem:

Als wär' das Singen aller Menschen gut,
als könnte man doch wirklich eine Oper neu erfinden,
als könnte man wie schon früher singen,
als könnte man sagen: „Das ist eine Handlung!",
und so als wäre es eine große stumme Wandlung,
als wäre es immer noch, als wär'n die Noten so gehetzt,
als müsste man von einer Frau, die schießt - und nicht genau -
so sagen: „Das ist zu schnell, das ist zu schnell!"

Fig. 7 Level *F*: Improvisation of "answering machine poetry" (Brasch)

Fig. 8 Level *G*: The score based on the libretto (Hajdu)

3.2 A Word on Contemporary Opera

Since Morton Feldman's *Neither* the notion of opera is open to dispute. As a composer I wondered: Why not writing an opera in which the scenery is created in the mind of the listener, facilitated by the use of videos and audio samples; an opera that doesn't even need singing? I imagined the writing of an evocative music – a music that was able to tell a story solely by using stylistic allusion similar to John Zorn's *Kristallnacht*. I asked Brasch explicitly to not write a text in dialog form. But in the end, it was due to the evocativeness of the human voice that I didn't do away with singing after all there are even allusions to the operatic genre. For instance, I wanted to keep the differentiation in recitative and aria. Only, the recitatives were turned into radio plays framing the two acts. It is the radio plays that advance the opera by yielding information. The acts with its two times four numbers create atmosphere and ambience. Though, I did abandon the unity between the singer and his/her role: Since, as I stated before, the opera was supposed to be created in the mind of the listener, a singer was allowed to personify several roles (Hüppe 1999).

While composing the scenes, I was confronted with a particular difficult task: Giving each scene its own stylistic identity, while keeping the coherence of the whole. I solved the problem by deriving an omnipresent, time-stretched stream of sound from Brasch's recorded motto: "Writing an opera means having no other way out." In the next step I adapted the spectral harmony (i.e. chords derived from the overtones of Brasch's speech) to the compositional requirements of the scenes in question: In the first scene of the first act, I approximated the sounds to a microtonal scale wich subdivides the perfect twelfth into 13 equal steps. In the second scene I employed bird songs – sampled songs and melodies stylized by Messiaen, which I approximated to the spectral harmonic progression. In *Intermezzo*, the spectral chords, enriched by scalar pitches, serve as the basis for an algorithmic, interactive process, in which the choir is treated like an acoustic synthesizer. In the second scene of the second act, following an episode with Klezmer music, a surreal waltz is built out of transposed spectral pitches. In the third scene, the pitches of an ever-descending 19-tone scale collide with and are subsequently harmonized by overtones, while, at the end of the fourth scene, motives of the preceding scenes are recapitulated – once again adapted to the corresponding notes of the spectral chord progression. Hence, Brasch's motto, which is heard in fragmented form during the last scene's electronic episode, permeates inaudibly almost every compositional detail – very much like Stockhausen's formula composition technique.

3.3 Spectral Analysis

The total duration of the sentence Brasch spoke onto my answering machine was 5.4 s. The sample was subject to a McAulay-Quatieri[2] type of Fourier analysis (McAulay and Quatieri 1986).

A FFT frame size of 10 ms yielded 540 continuous spectra with 100–200 partials. Their temporal succession was expanded by a factor of 1000 to *Der Sprung's* total duration of 90

2 "Using overlapping windowing methods similar to standard short time analysis, the MQ method computes Fourier transforms of the individual windows. The peak frequencies of each window (the partials) are found and their amplitudes and phases are extracted. The partials for each window are linked to those in the following window in order to develop a trend in the progression of frequencies (their amplitude and phases). We call each progression a track." (www.owlnet.rice.edu/~elec301/Projects02/ lorisFor/mqmethod2.html).

min. Of the over 200 spectral components, only the 24 strongest were retained and used as pitch material. After time stretching, each frame's duration is 10 s. Thus, the succession of the 540 frames, i.e. 540 chords, determined the harmonic rhythm as well as the formal structure of the entire opera.

Frequency analysis also revealed the existence of two types of spectral material, which had far-reaching structural consequences:

(*i*) Phonetic material (deterministic) based on vowels and consonants was worked into two acts with 4 scenes each. These scenes are characterized by operatic gestures, quotations and pastiches.

(*ii*) Statistic material (derived from answering-machine noise; indeterministic) was worked into radio plays (*Prolog*, *Intermezzo*, *Epilog*).

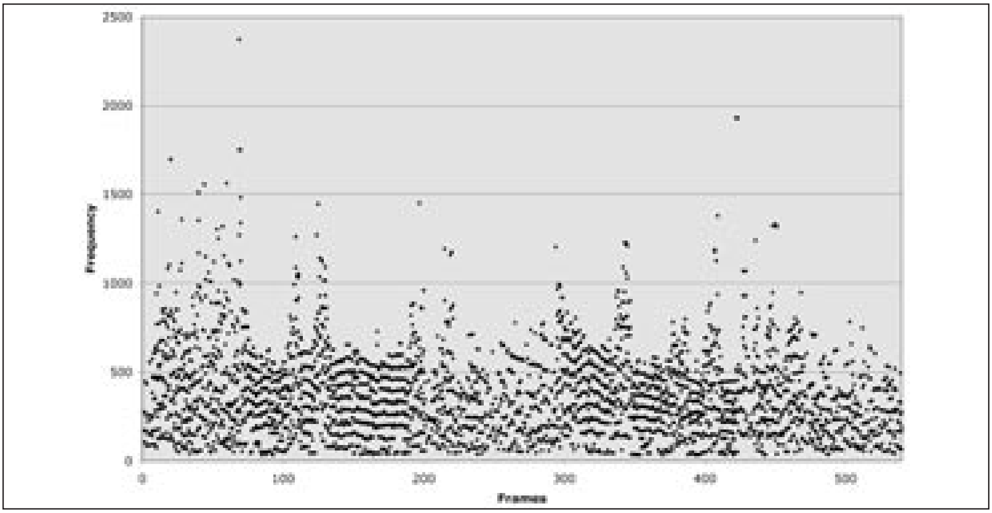

Fig. 9 Spectrogram of the eight strongest components. Notice the nearly perfect alignment of the partials in segments with harmonic content (vowels).

Brasch (2002) wrote his libretto strictly adhering to the given structure: The texts entitled A., B. and C. (see appendix) differ from the rest in that they feature the inner monolog of the protagonist, whereas the other eight texts are more descriptive.

Before subjecting the harmonic material to a composition process, the numerical data had to be translated into musical notation in three steps: Frequencies and amplitudes were converted into MIDI cents[3] and key velocities and finally into (eighth-note) notation. The translation was achieved by using applications I wrote in the programming environment Max and modeled after the composition environment PatchWork (later renamed to OpenMusic).

Table 1 lists typical spectra from five different regions (format: index, frequency amplitude).

3 MIDI cent values are derived by combining absolute MIDI key numbers with the relative cent scale, by multiplying key numbers by 100 and adding an offset in cents.

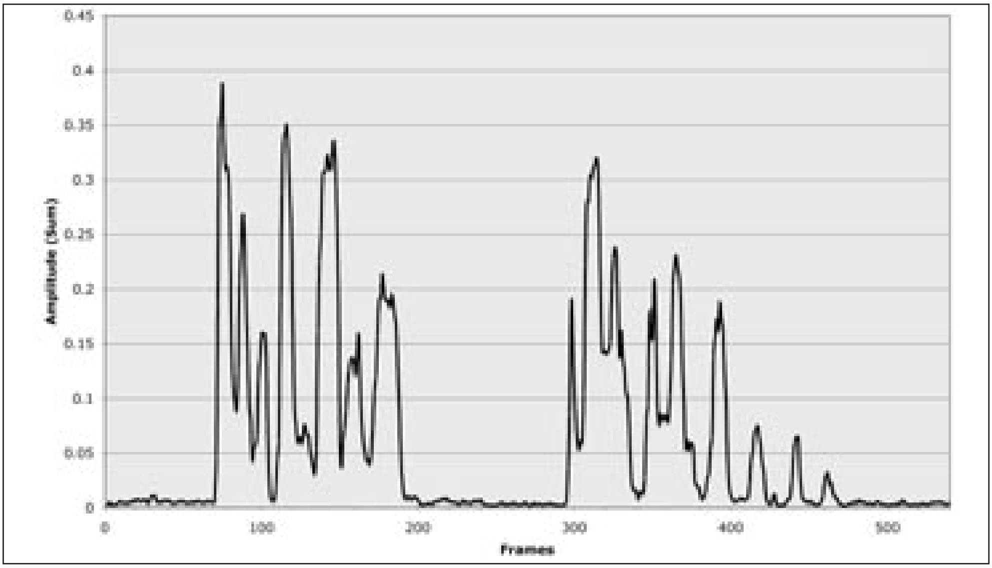

Fig. 10 Summing up the amplitudes for the partials shows the boundaries between the sonic events. These events were turned into parts, scenes and sections. The flat areas correspond to the answering machine noise.

Tab. 1 Typical spectra from five different regions (format: index, frequency amplitude)

Spectrum # 27	Spectrum #150	Spectrum #200	Spectrum #299	Spectrum #501
1, 102.73 0.000406;	1, 42.32 0.002289;	1, 56.15 0.002908;	1, 189.11 0.002685;	1, 99.36 0.000246;
2, 189.54 0.000287;	2, 161.38 0.001966;	2, 159.42 0.00169;	2, 286.35 0.008844;	2, 236.98 0.000443;
3, 247.48 0.000388;	3, 240.71 0.010502;	3, 229.97 0.000474;	3, 411.55 0.009397;	3, 298.09 0.000206;
4, 325.56 0.000149;	4, 281.04 0.019742;	4, 319.48 0.000824;	4, 509.98 0.02783;	4, 356.08 0.000239;
5, 402.96 0.000556;	5, 393.35 0.006564;	5, 497.84 0.000304;	5, 599.31 0.005647;	5, 546.65 0.000311;
6, 515.69989 0.000255;	6, 461.66 0.004629;	6, 614.63 0.000134;	6, 691.43 0.0057;	6, 577.84 0.000107;
7, 588.77002 0.000127;	7, 510.61 0.00339;	7, 623.52 0.000237;	7, 815.32 0.010416;	7, 732.05 0.000123;
8, 664.969971 0.000114;	8, 614.600.001719;	8, 700.92 0.00012;	8, 920.34 0.005869;	8, 830.30 0.000073;
9, 741.520.000261;	9, 672.340.001289;	9, 784.03 0.000063;	9, 942.91 0.005315;	9, 905.47 0.000065;
10, 898.90 0.000138;	10, 746.16 0.001492;	10, 851.21 0.000117;	10,1056.310.006888;	10, 976.90 0.000082;
11, 1074.25 0.000335;	11, 819.02 0.000481;	11, 959.19 0.00022;	11, 1202.61 0.004601;	11, 1085.23 0.000093;
12, 1080.84 0.000185;	12, 918.42 0.000719;	12, 1054.93 0.00011;	12, 1353.10 0.009476;	12, 1317.03 0.000038;
13, 1208.52 0.000104;	13, 980.44 0.000744;	13, 1107.14 0.00004;	13, 1439.47 0.003693;	13, 1397.47 0.000047;
14, 1243.73 0.000142;	14, 1035.26 0.000924;	14, 1304.76 0.000122;	14, 1530.75 0.021652;	14, 1504.69 0.000072;
15, 1384.01 0.000168;	15, 1115.85 0.001549;	15, 1418.68 0.000059;	15, 1558.65 0.004553;	15, 1598.52 0.000066;
16, 1491.96 0.000103;	16, 1211.43 0.001399;	16, 1481.14 0.00006;	16, 1683.80 0.003261;	16, 1690.39 0.000029;
17, 1578.68 0.000113;	17, 1265.98 0.001934;	17, 1644.00 0.000039;	17, 1749.76 0.003415;	17, 1933.15 0.000064;
18, 1640.39 0.000176;	18, 1353.09 0.000955;	18, 1890.64 0.000038;	18, 1830.10 0.002067;	18, 2104.56 0.000037;
19, 1857.25 0.00009;	19, 1522.85 0.000251;	19, 1993.53 0.000054;	19, 1917.61 0.001172;	19, 2435.38 0.000036;
20, 2215.92 0.000108	20, 1579.85 0.000252;	20, 2065.57 0.000039;	20, 2076.85 0.003231;	20, 2668.31 0.00003;
21, 2293.81 0.000117;	21, 1657.92 0.000465;	21, 2335.64 0.00004;	21, 2169.67 0.00357;	21, 2782.48 0.000034;
22, 2294.10 0.000103;	22, 2232.92 0.000277;	22, 2797.28 0.000039;	22, 2248.68 0.002475;	22, 3123.71 0.000035;
23, 2696.56 0.000101;	23, 2254.14 0.000577;	23, 3122.45 0.00005;	23, 2326.06 0.002285;	23, 3792.86 0.000031;
24, 2766.48 0.000097;	24, 2326.82 0.000346;	24, 3260.09 0.000038;	24, 2874.72 0.001436;	24, 4111.43 0.000029

Translation into MIDI cents and key velocities, a logarithmic scale such as dB, yields the Table 2 (negative key velocities belong to partials below the hearing threshold; data format: index, MIDI cent velocity):

Tab. 2 Negative key velocities belong to partials below the hearing threshold; data format: index, MIDI cent velocity

Spectrum #200
1, 3336 41;
2, 5143 33;
3, 5777 14;
4, 6346 23;
5, 7114 8;
6, 7479 –3;
7, 7504 4;
8, 7706 –5;
9, 7900 –14;
10, 8042 –5;
11, 8249 3;
12, 8414 –6;
13, 8498 –21;
14, 8782 –5;
15, 8927 –15;
16, 9001 –15;
17, 9182 –21;
18, 9424 –22;
19, 9516 –17;
20, 9577 –21;
21, 9790 –21;
22, 10102 –21;
23, 10293 –18;
24, 10367 –22;

And finally, MIDI cents data are converted into musical notation[4] (Fig. 11).

Fig. 11 MIDI cents data are converted into musical notation.

4 Although this spectrum was extracted out of the answering-machine noise, it shows the typical characteristics of a harmonic spectrum: Large intervals in the lower frequency region and increasingly smaller ones towards the higher region. This is due to a desired artifact of the analysis program.

4. Excursion I: A new Approach to Composition

4.1 Spectral Composition

At this point, it seems necessary to open up a parenthesis in order to further elucidate the compositional and theoretical contexts of *Der Sprung*. The term *spectral composition* is usual associated with the names of French composers Gérard Grisey and Tristan Murail, who founded the new music ensemble *L'Itineraire* in 1973 (Dufourt 1979). Grisey and Murail, among others, were searching for novel ways to organize music harmonically, deriving harmonies from harmonic and inharmonic spectra of instrumental sounds and re-orchestrating them for acoustic and occasionally electronic instruments, thus the term *spectral composition*. Among the major pieces written in this technique are *Les Espace Acoustiques* (1973–1985) for ensembles of varying size by Gérard Grisey, and *Gondwana* (1980) for large orchestra by Tristan Murail. Spectralism is rooted in the tradition of French music going back to Messiaen and Debussy.

Clarence Barlow took a slightly different approach in his ensemble composition *Im Januar am Nil* (1984) in which he orchestrated spectra derived from speech. For this, he invented a number of nonsense phrases limiting his choice of phonemes to vowels and consonants, avoiding fricatives and plosives – phonemes with high-frequency noise components.

4.2 IRCAM

The *Institut de Recherche et Coordination Acoustique/Musique* was founded by Pierre Boulez in 1974 as a place where musical and acoustic research and artistic creation were supposed to form a symbiosis. Since its foundation it attracted many great minds, which have invented, designed and composed groundbreaking works. Among these inventions are the *4X* (1981), one of the first real-time sound processors, the *IRCAM Signal Processing Workstation ISPW* (1990) and the programming and patching environment Max, written by Miller Puckette in 1986, for the purpose of controlling the *4X* computer. Other important developments are the *OpenMusic*, *Modalys*, *Diphone* and *Audiosculpt* software applications. One of IRCAM's outstanding researchers is Xavier Rodet who has been working on countless projects involving analysis and resynthesis of sound. His residency at CNMAT (UC Berkeley) has spurred the development of sound analysis tools, which were the basis of *Der Sprung*. His collaboration with CNMAT's Adrian Freed (Wright et al. 1998) also led to the creation of the flexible *Sound Description Interchange Format* (*SDIF*).

OpenMusic is a visual music programming environment developed by Carlos Agon and Gérard Assayag (Assayag et al. 1999) on top of the programming language *LISP*. Despite its similarity to *Max/MSP*, it is a non-real application mainly created to facilitate the design of compositions. It disposes of numerous libraries for spectral and algorithmic composition, a constraints library and the *maquette* patching window for modeling compositional processes. *OpenMusic* also possesses a number of import and export functions which make it an ideal interface between different applications such as *Diphone*, *Max/MSP*, and the music notation program *Finale*.

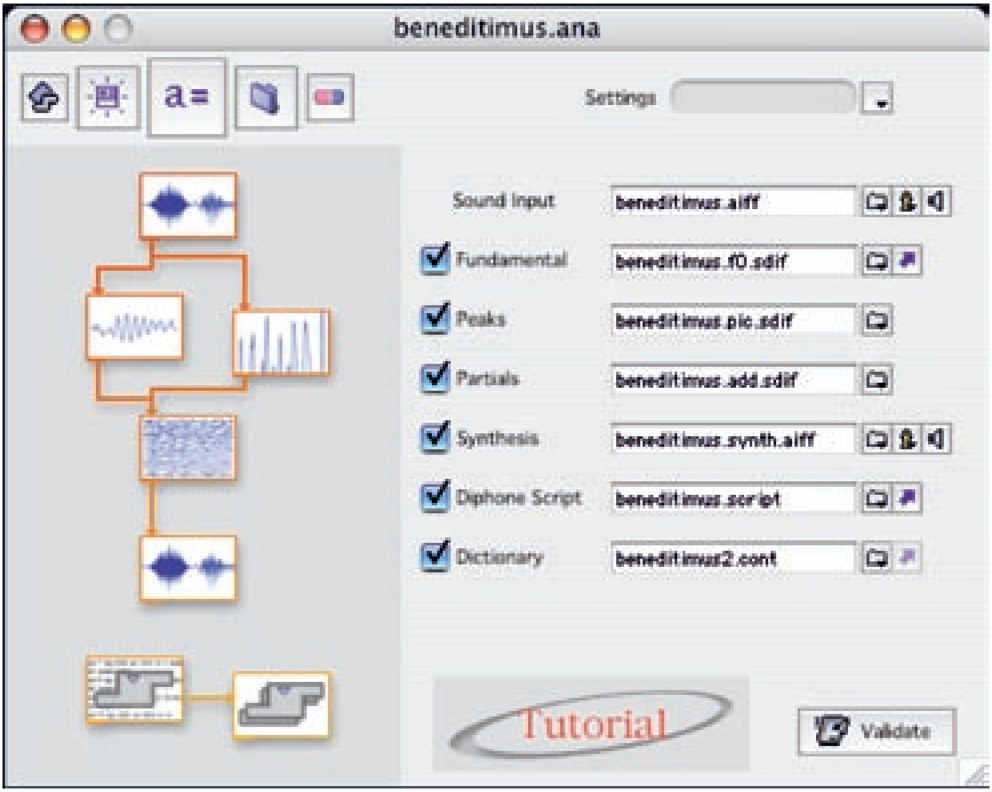

Fig. 12 Screen shot of *AddAn*: The *Diphone* release contains *AddAn*, an application similar to the program employed in 1994 for spectral analysis of Brasch's sentence.

4.3 Max/MSP

As mentioned before Max was originally designed to control the IRCAM *4X*. It's ingenious open architecture and graphical user interface proved to be an ideal development tool for real-time music applications and has become a sort of lingua franca of computer music with its two dialects *PureData* and *jMax*. The environment consists of numerous internal and external objects and can be expanded by third-party development. There are countless objects for MIDI control, signal processing, matrix operations, neural network simulation, network communication, and, most recently, interfaces to programming languages such as LISP and Java.

4.4 Microtonality

Spectral composition refocused the attention to higher, "out-of-tune" overtones such as the 7^{th}, 11^{th} and 13^{th} partials. Notating such sonic events requires higher resolution than traditional notation of pitches. For instance, in his piece *Prologue* (1974), Grisey employs eighth-tone notation to approximate the partials to 48-tone equal temperament (48TET), a notation with a maximum error of 12.5 cents (a 16^{th} tone). In my paper "Überlegungen zu einer neuen

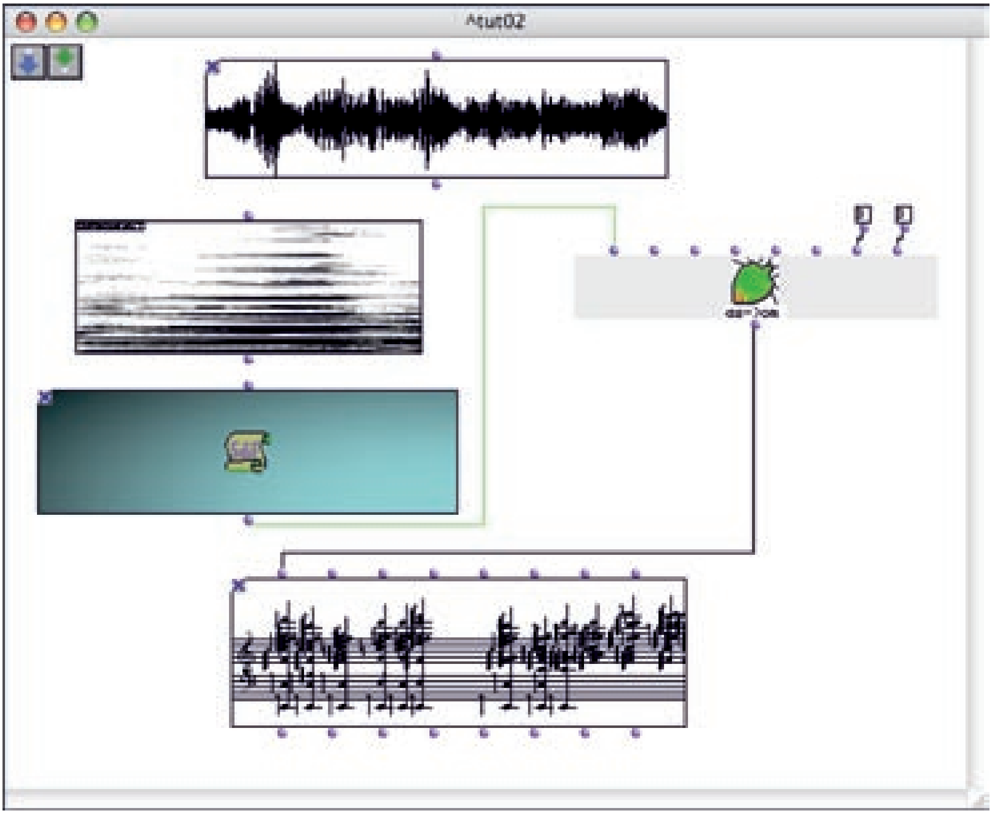

Fig. 13 Screen shot of an *OpenMusic* SDIF tutorial window demonstrating its built-in music notation capabilities.

Musiktheorie" (Hajdu 2004) I described the use of three grids for composing and notating microtonal music:

1st grid: Pitches of arbitrary frequencies such as harmonic or inharmonic spectra.
2nd grid: A filter to approximate these pitches to a stable set of pitches such as 19TET or the rather exotic Bohlen-Pierce scale.
3rd grid: A filter to approximate and notate the pitches yielded by the second grid; the first scene of the first act of *Der Sprung* being an example of this strategy.

My preference for scales and tuning in *Der Sprung* was driven my theoretical reasoning I elaborated in my paper "Low Energy and Equal Spacing" (Hajdu 1993). This paper also describes how the application of quantitative methods to the problem of interval concordance yields results that are in sync with the "hard facts" of music history and theory.

4.5 Neural Networks

Another fascinating technology introduced to music research, theory and composition is neural network simulation. Originally invented in the 1940s to mimic the behavior of nerve cells, it was first abandoned in favor of Artificial Intelligence and expert systems before it made its re-entry into the academic realm. Michael LEE (LEE et al. 1991), a graduate student at CNMAT in the early 1990s, wrote a *MaxNet* neural net object for the Max programming environment (later renamed to MLP, which stands for Multi-Layer Perceptron). During my time at CNMAT, I was involved in developing a number of applications using the mlp's pattern recognition and interpolation capabilities.

5. In-depth Analysis of Selected Moments

In the following I will analyze selected scenes of the opera in light of the methods and strategies outlined earlier.

5.1 Spectral Mapping

The first scene of the first act features a fictitious dialog between the two professors who were shot by the philosophy student; one is fatally wounded – the other survives. The latter, puzzled by her crime, praises her intellectual accomplishments while his moribund colleague tries to get his attention.

The scene was written entirely in the Bohlen-Pierce scale, a consonant scale that subdivides the interval of a twelfth in thirteen equal steps. As this scale, not having any octaves, is an intellectual achievement in itself, it symbolizes the abstract, academic world of a university department.

This part is based on the syllables "Ei-ne" and consists of mainly two parts, a short instrumental overture and a duet in which the professors are accompanied by two microtonal keyboards followed by a short coda.

Tab. 3 The Bohlen-Pierce scale described independently by German engineer Heinz BOHLEN (1978) and Stanford professor John PIERCE (MATHEWS et al. 1984) is characterized by an extraordinary number of unusual, yet consonant intervals in close approximation to small odd integer ratios.

Stufe	Reine Stimmung			Gleichschwebend temperierte Stimmung		
n	f_n/f_0	cent	hekt	f_n/f_0	cent	hekt
0	1/1	0	0	1,0000	0	0
1	27/25	133	91	1,0882	146	100
2	25/21	302	206	1,1841	293	200
3	9/7	435	297	1,2886	439	300
4	7/5	583	398	1,4022	585	400
5	75/49	737	504	1,5258	732	500
6	5/3	884	604	1,6604	878	600
7	9/5	1018	696	1,8068	1024	700
8	49/25	1165	796	1,9661	1170	800
9	15/7	1319	902	2,1395	1317	900
10	7/3	1467	1003	2,3282	1463	1000
11	63/25	1600	1094	2,5335	1609	1100
12	25/9	1769	1209	2,7569	1756	1200
13	3/1	1902	1300	3,0000	1902	1300

As in my piano composition *Fingerprints* (1993), I experimented with the ratio 3:5:7:9 on a metric level, creating an analogy between meter and harmony. I decided to base the overture on 3 different elements:

A fast ascending melodic figure was based on the "strong" intervals of the scale. A kind of crescendo was achieved by asymmetrically subdividing the theoretical time span between successive entries of this motive – with 6 occurrences as the result of the interpolation between 3 and 9; a slow trill between a and b quarter tone flat with a rhythmic counterpoint (5 occurrences); and spectral chords derived from Brasch's sentence and approximated to the Bohlen-Pierce scale, in chronological order, mostly arpeggiated (7 occurrences).

Other elements are sampled sounds of breaking glass and pouring water (symbolizing the injury of the human body) and a short sample from Monteverdi's *Orfeo* ("Tu se morta ...").

In the ensuing duet, the tenor and bass lines of the two professors as well as the keyboard accompaniment were first written in standard tuning based on triadic harmony, stylistically somewhere between Kurt Weill and Alban Berg. This texture was then translated into the Bohlen-Pierce scale by mapping the voice and keyboard lines to the closest scale steps of the approximated speech spectra (which were used in free order).

The coda closes this part with a harmonic and melodic ascent followed by the sound of a flushing toilet.

Fig. 14 An intuitively composed line was mapped to spectral pitches in Bohlen-Pierce tuning in the 1st scene of the 1st act. The circled numbers refer to spectra within the 540 spectral-chord progression.

While the first act deals more with the events leading up to the crime, the second act introduces a new element: the element of contemplation and self-reference, thus the subtitle *Beschreibung einer Oper*. In the first scene of the second act Brasch describes the unsympathetic reaction of fictitious spectators being exposed to the very same opera that is unfolding in front of the real audience.

For this scene, I invented eight short comments and exclamations (partially based on reactions I received from opera people and radio editors before the opera was finished). In analogy to the composition method applied to the entire opera I performed spectral analysis on the texts spoken by mezzo-soprano Annette Kleine and myself. Again, I derived the rhythmic and melodic material from these analyses, albeit without time stretching.

The material was translated into musical notation using a cascade of algorithmic processes. Two types of textures are discernible: One using the spectral content in a quantization of 62.5 ms, and another employing the rhythmic structure formed by the temporal envelope of the spoken texts.

Since playing 32^{nd} notes at ♩=120 seemed an almost impossible task I removed the shorter pauses from the music and asked the musicians to quasi improvise their parts.

The rhythmic sections performed by the two percussionists grant even more freedom: the choice of instruments and the exact rhythmic elaboration of the music written in space notation are up to the performers themselves.

The scene is based on the syllables “k-ei-nen” and, therefore, consists of three parts. The first part carries over from the real intermission by using the recorded sounds of background chatter, interspersed with the rendering of those eight comments by professional actors, so that the real intermission seems to continue well into the opera. The second part features the libretto whispered (and thus made unintelligible) by the choir, whereas the third part consists of a succession of the “spectators’ utterances” orchestrated for orchestra, percussion and electronics. The singers, now acting as if they were the audience, react to this by clapping, laughing and cheering.

5.2 Neural Composition

In the third scene of the first act which features excerpts from a fictitious diary (including a section with four female voices signifying the multiple personalities of the protagonist) two compositional approaches were taken and their results transformed into a popular musical idiom: A spectral one, utilizing further analysis material, and a connectionist one, featuring a set of neural networks. In the latter approach the networks were trained to either quotations from historical or popular sources or to the spectral material itself.

This scene is based on the syllables “sch-rei-ben”, “sch” representing an independent sonic event. Since “rei” is further divided in two distinctive parts, the overall form is quaternary.

The first part consists of the playback of the same word “schreiben” stretched by a factor of 220 accompanied by saxophone, electric guitar, double bass and percussion. The gigantic expansion of the short sample reveals microscopic details such as the long *portamento* from c# to g and thus yields the pitch material for the acoustic instruments.

After a short transition, a fast section unfolds featuring slowly arpeggiated spectral chords in ascending motion. The spectral pitches are reached by suspensions that resolve either upwards or downwards.

Fig. 15 Excerpt from the 1st scene of the 2nd act.

The third part and fourth parts are composed using neural networks for melodic interpolation employing melodies from the opera itself (H), from a CD with Sephardic songs from the middle ages (S) and a piece by the Rolling Stones[5] (R).

Inspired by the idea of seamless melodic interpolation (exemplified in Clarence Barlow's composition *1981* for piano trio), I trained a whole battery of Max *mlp* objects to these melo-

5 Mick Jagger was an important figure in the protagonist's personal mythology, remarkably playing the role of a modern reincarnation of Jesus Christ. There is even an account of her visit to Jagger's mother and inquiring about a scar on his stomach (Wantoch 1984). The religious implications are even more outlandish considering Jagger's occasional self-stylization as devil, and the fact that she had left out the words "Jesus Christus" in a paper she had been asked to copy.

dies with their respective accompaniments which allowed me to move freely through melodic space, thus generating countless new melodies (with varying similarity to the originals).

Melodic interpolation is far from being a trivial problem (Polansky 1992). The intervallic space in which interpolation is performed is characterized by at least two distinctive properties: pitch distance (magnitude) and harmonic distance. While pitch distance is usually a function of the frequency ratio of the two fundamentals, harmonic distance is more complicated to formalize and depends a great deal on intuition and experience.

I found that the circle of fifths represents a viable compromise between the two principles, in which the circularity of the chroma circle (Shepard 1964) is preserved and harmonic relationships are allowed to come into play.

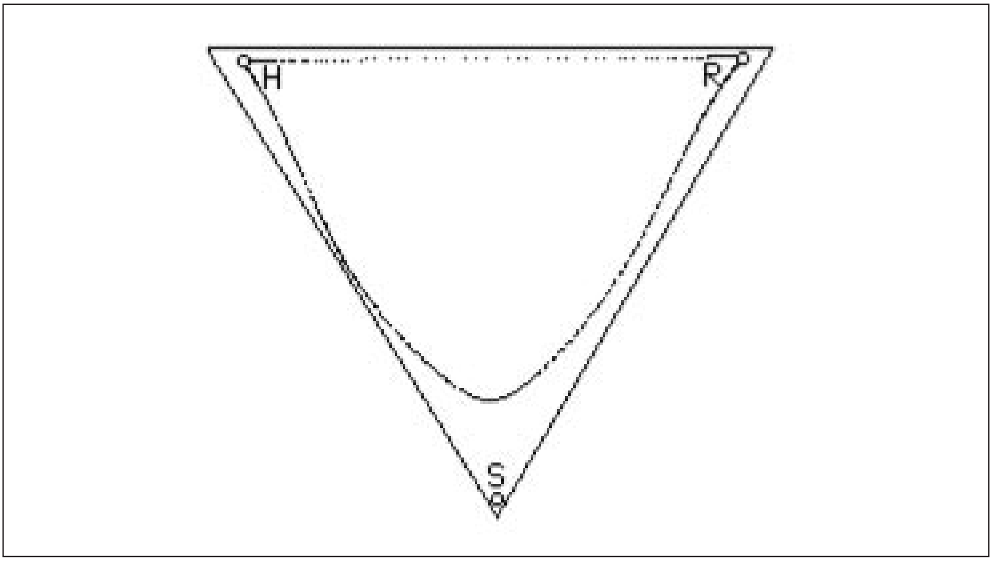

Fig. 16 The actual interpolation involved three melodies (H, S and R) located at equal distance in the corners of a triangular melodic space and was performed over a total period of three minutes. The graph shows the interpolation path at a resolution of 1000 sample points. For the graphical plot, another network was trained to translate the input data into spatial coordinates.

My paper “Circularity in neural computation and its application to musical composition” (Hajdu 1995) offers a concise explanation of the mathematical methods and the training process pursued.

5.3 Machine-man Interaction in Intermezzo

„Wobei es eine schöne Form ist, eine Sache nicht aufzuschreiben, die einen Ton haben muß.“ (Thomas Brasch)

Intermezzo is scored for keyboard, “wired” choir, narrator and electronics. The term “wired” refers to the interaction between the computer and the choir (the singers reproduce the pitches they hear in headphones). Spectral analysis determined this part of the opera to last 17.5 min-

Fig. 17 The last part of the 3rd scene composed with neural net simulation

utes; and being its longest part, it represents the psychological climax of the opera. It covers the moment when the protagonist "snaps" which is symbolized by the plunge she's about to take.

17.5 minutes equals 105 frames, which, by chance, is the product of 3 × 5 × 7 – numbers already used in the first scene. In analogy, I based the scene on a macro rhythm that was characterized by the equally spaced occurrence of three ascending events (glissandos or ascending clusters), five text events (answering machine texts or live narration of the libretto) and seven choral entries.

As in the previous scenes the material consisted of spectral chords (pseudo-harmonic spectra extracted from answering machine noise) consisting of the 24 strongest partials.

105 different scales containing up to 130 pitches were derived from these chords by a pseudo-equidistant subdivision of chord intervals, based on 17 TET. This was achieved by filling the gaps between partials with additional pitches at a mean interval size of approximately 71 cents.

Brasch's quote "While it's a nice form not to write down something that ought to have a sound" indeed set the tone for this part of *Der Sprung*. The goal was to compose the entire score non-symbolically, i.e. without music notation. This was accomplished by means of real-time composition: Using the programming environment Max/MSP to send its output to a sampler as well as to the eight singers.

The real-time processes are listed in the Tables 4 and 5.

Tab. 4 Real-time processes (electronics)

Electronics	
Type	Description
random	Stochastic control of pitches, dynamics, durations and onsets.
arpeggios	Arpeggiated chords, pitch range and delta time is controllable.
glissandos	Chordal pitches determine beginning and ending of glissandos.
swarm	Ascending clusters; successive scale tones.
patterns	Metric hierarchies for meters with 3, 5 and 7 pulses and their products are stored in tables and used as indices for scale tones. Tempo, range and the amount of silent notes can be controlled in real time.
melodies	A melody generator using scales as input material. Rhythm and meter are influenced by event density and event length.
RandSeg	In contrast to the generators described above, RandSeg is a modifier. It receives its input either directly from the keyboard or from the generators. The input data are stored and recalled by a random walks.
thru	In addition, it's possible to play the chordal and scalar pitches directly from the keyboard using the thru setting. The keyboard range can be devided in three zones each with a different timbre.

The choir performs (fixed, i.e. non-randomized) variants of the instrumental processes. The eight singers receive their input from headphones on eight different audio channels using the multi-channel audio system.

5.4 *Quintet.net*

Upon completion of *Der Sprung* in 1998, I was increasingly intrigued by the idea of network composition, i.e. having musicians perform under the control of a central server. The rise of the Internet and its associated protocols provided the tools to realize the interactive, networked performance environment *Quintet.net*. The ongoing development started in the

Tab. 5 Real-time processes (choir)

Choir	
Type	Description
chords	analogous to thru for the "instrumental" processes
random	fixed pitched with random character
glissandos	upward and downward portamentos
patterns	short composed patterns
arpeggios	eight-part arpeggios of spectral harmonies

summer of 1999. *Quintet.net* extends ideas present in *Intermezzo*, but adds a symbolic layer facilitating the interaction of performers over large distances. Being an open environment, several pieces or parts thereof have been realized with it, the Munich Biennale opera *Orpheus Kristall* by Manfred Stahnke among them (Hajdu 2003).

6. Conclusion

One interesting question remains to be discussed: How to situate *Der Sprung* in its historical context and to extrapolate future developments in the field of computer composition. In retrospect, three stages can be discerned, which I will call the *speculative*, the *exploratory* and *interactive* stages.

The *speculative* stage (from 1950 to 1970) was characterized by a lack of knowledge in psychoacoustics and cognitive psychology as well as a serialist stance towards the treatment of musical parameters such as timbre and meter. The early electronic works of Stockhausen and algorithmic works by Xenakis were typical for this approach. Recognizing that certain parameters evaded successful formalization and serialization, a phase of intense research ensued leading to important discoveries in cognitive psychology and the development of groundbreaking tools for computer composition. Researchers and composers would typically meet at interdisciplinary institutions such as CCRMA (Stanford) or IRCAM and commonly work on realizing a piece. An example for this *exploratory* phase (from 1970 to 2000) is Clarence Barlow's piano piece *Çogluotobüsisletmesi* (1978) and my opera *Der Sprung*. In the most recent stage, the interactive stage, we are witnessing the rise of a different type of artist disposing of the most highly developed tools (*Max/MSP/Jitter*, *Pure Data*, *OpenMusic*, *Reason* and *Reaktor* just to name a few) enabling them to work intuitively and interactively without deep knowledge of what's behind scenes, i.e. the graphical user interface. The large research studios also had to respond to this shift of paradigm: Anyone can now own equipment many times as powerful as the most advanced gear available in the early 1990s at a small fraction of the cost. IRCAM for instance gets considerable revenues by selling software through its user groups. Open source software is available to anyone over the Internet. Hence, music development tools are no longer confined to certain universities or research centers but are distributed freely and mixed at will by artists. The increasing importance of real time also leads to a disappearance of the distinction between composition and improvisation, or composer and performer. On the other hand, we are also observing a similar paradigm shift among music researchers who are more and more intrigued by the findings of neurological

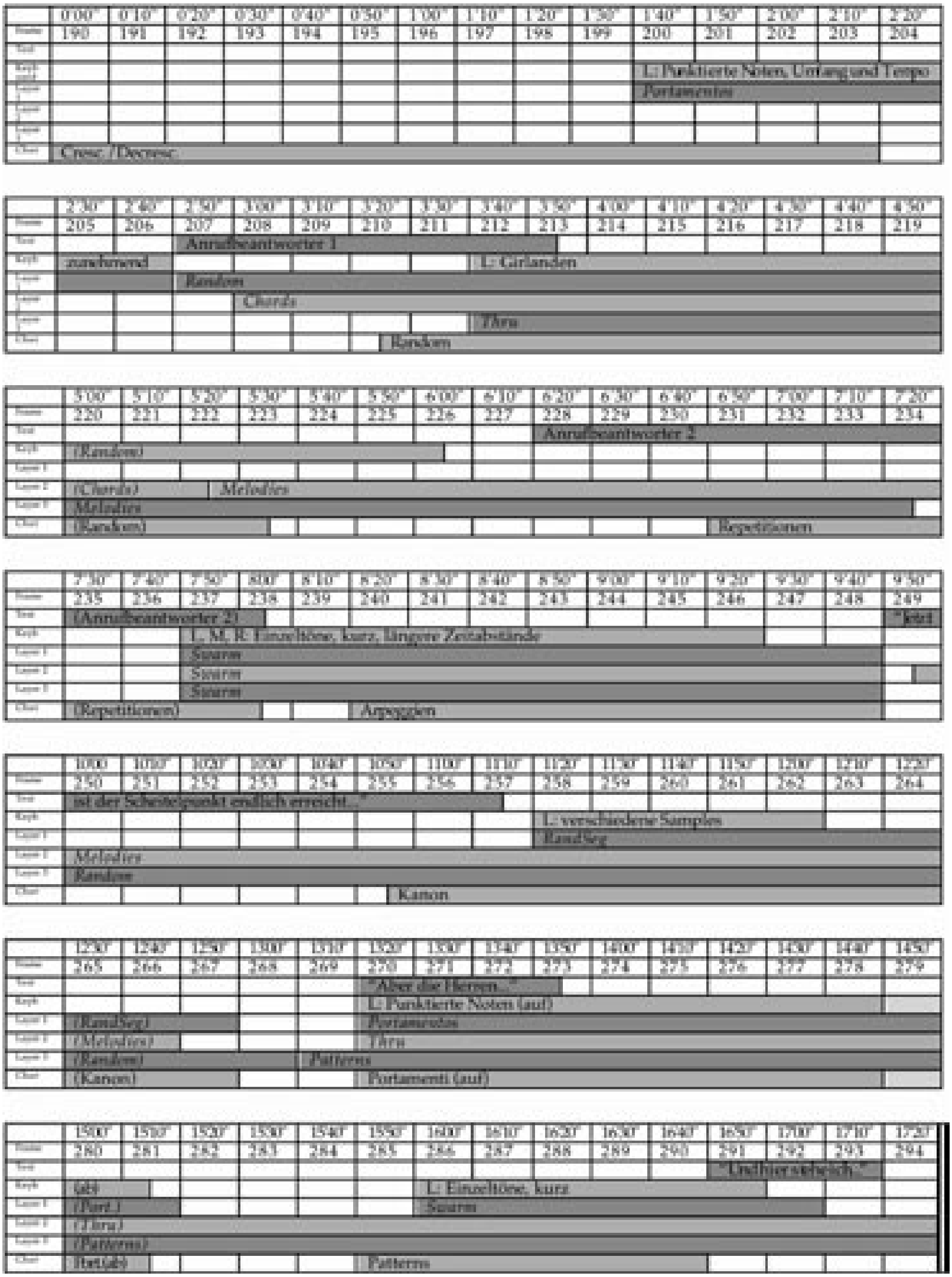

Fig. 18 The temporal structure of *Intermezzo*

research and imaging techniques allowing a glimpse of a musician's or listener's brain at work – in real time.

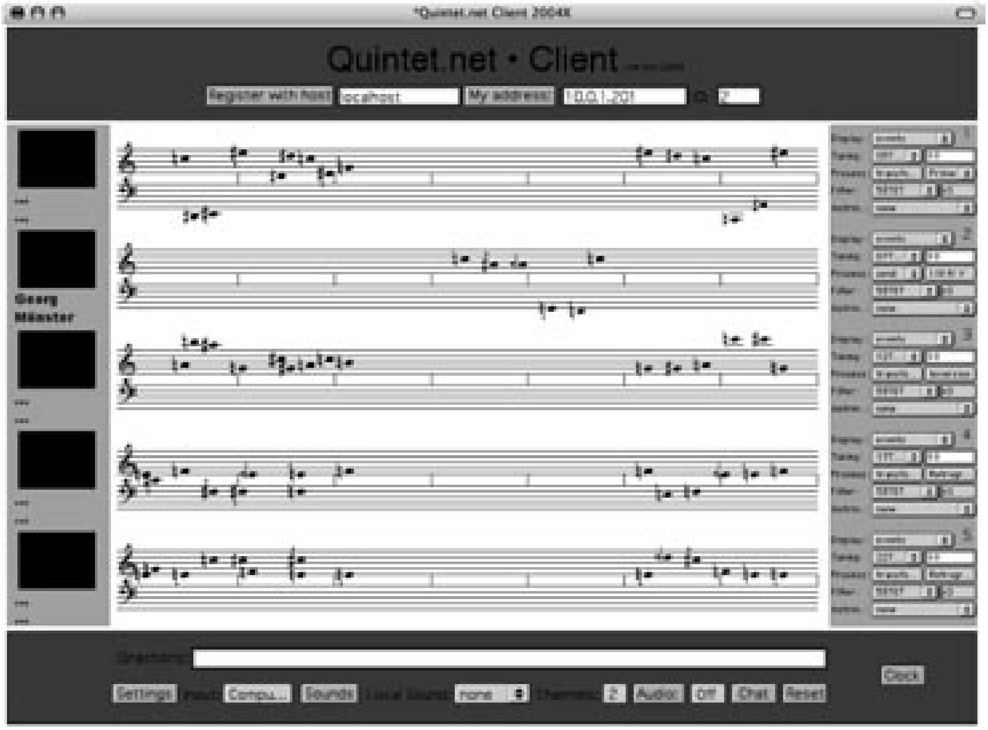

Fig. 19 Screen shot of the Quintet.net Client's graphical user interface.

While we will still see collaborations between researchers and musicians in the future, they will probably not be as typical as in the *exploratory* stage. On the other hand, I expect a dramatic change of what constitutes music theory in pedagogical institutions: A more general and quantitative theory based on the findings of psychoacoustics and cognitive psychology will finally replace the constrained and historical theories developed in and for the Golden age of tonal music.

7. Appendix

7.1 Newspaper Article (from the Jerusalem Post, January 26, 1984)[6]

Woman kills professor in German 'Buber centre'

COLOGNE (AP). – A woman armed with 16 pistols fatally shot a 49-year-old professor and wounded the director of Cologne University's Martin Buber Institute of Jewish Studies, police reported yesterday.

The shooting occurred on Tuesday afternoon, but was announced by the police only after professor Hermann Greive, an expert on Theodor Herzl, died yesterday morning in a Cologne hospital.

The 32-year-old assailant, identified only as Sabine G., was a student at the institute. She was held for murder and two counts of attempted murder.

Dieter Fricke chief of the Cologne police homicide division, said the motive for the shooting was under investigation. He told reporters yesterday that the woman had not given a statement to police.

The assailant took a master's degree in philosophy and Jewish studies at the institute two years ago and had worked since then as an archivist at Cologne University, police said.

Police sources said earlier that investigators were probing reports of a possible religious conflict between the woman and the professor.

Greive was shot in the left temple while giving a course in basic Hebrew to 12 students.

Fricke said the woman then ran out into the hallway and fired at institute director Johann Maier, 51, when he tried to intervene. The shot grazed his skull, and he was able to overpower her after she fired at and missed another professor in the hallway.

Maier, who is one of Europe's best-known experts on Judaism, was treated at a hospital for the wound and released.

In addition to the murder weapon, police confiscated 11 more muzzle-loader pistols from a toilet at the institute. The weapons, calibre 35 to 45 millimetres, were found in four plastic bags and a briefcase.

The police found five more muzzleloaders and a gas pistol in a van parked outside the institute. They said the assailant had rented the vehicle.

The pistols - replicas of old weapons - can be purchased in sporting-goods stores and do not require a licence. The police said a Cologne dealer said the woman bought several of the pistols at his shop last week.

A psychiatric examination of the assailant yesterday morning failed to turn up evidence that she was mentally deranged, the Cologne prosecutor's office said.

A political motive in the shooting has been ruled out, the office said.

Police sources said the woman was living alone following a divorce.

She was believed to be Jewish, but it was not clear if her parents are Jews or whether she adopted the religion, the sources said.

They said the woman reportedly had complained to fellow students about non-Jewish professors' teaching at the Institute. Neither Greive nor Maier are Jewish, the sources said.

Itim last night identified the woman suspected in the slaying as Sabine Gerhardt, aged 32.

Quoting Kol Yisrael radio's correspondent in Bonn, Itim said Gerhardt was a convert to Judaism and had studied in Israel.

One of Gerhardt's grandmothers was Jewish and her parents were Christians.

Fig. 20 Newspaper article

6 The much longer and more accurate article by Erika Wantoch states the correct name of assailant and claims that no member of her family was actually Jewish.

7.2 Libretto (English Translation by Susanna Spiro)

A.

Now she would do it: Standing here above, observed by all those below, who had not believed her capable of it: of leaving this ridiculous GDR, where no one understood, neither at school nor at the gym, that she had it in her to surpass them all, of leaving this ridiculous GDR and starting anew, they had not thought her capable of it, of abandoning her place as a pitied, average high-diver at this tiled provincial swimming pool, which those below take to be the world, and they will not venture onto the 11-meter diving board, because they believe that 10 meters would be the limit, only because they can't see what she sees, these spectators of their own lives, who had not thought her capable of this, of becoming the star, of leaving her position as an animal caretaker and becoming a doctor of philosophy, of proving, as the best student, to these Germans, who believed she was one of them, just because she was German, of proving to them who Kant is, of proving to this professor, whom she had loved, that she would be perfectly capable of forsaking love and going over to hatred, as easily as going from East to West, as if there were no wall, these Catholics who thought she was Catholic, just because father and mother were, who believed her incapable of becoming a Jew, one of the community of victims, she also wanted to become one of them. Now she would do it, from her 11-meter diving board, after she had left behind her name, her profession, her character, her place of residence, her religion, her sex, her desire for the other sex, for the answer-after she had finally left all of that behind her, like the gaping spectators down below, now after she had ascended from being a spectator to being the star, ascended this tower of glory, ever higher and farther beyond reach, with this plunge.

1.

I knew her, my dear colleague, as a brilliant thinker, her conclusions concerning virginal nature in Hegel and its parallelism to the commonwealth, my dear colleague, were unsurpassed; how can such an intellect become so deranged, I knew her, my dear colleague, as a logical reasoner, how can such sense in a woman deteriorate so completely, I knew her, my dear colleague, as a helpful assistant, how can charity become so distorted into hate, I knew her, my dear colleague, as an animal-loving creature, she could not know enough about every lab rat and parted painfully from each one.

I, my dear colleague, have been struck dead by her fucking gun, for you it was only life-threatening, you will survive, I thought so, you always had a better relationship with the dean, you, my dear colleague.

2.

We always had a good relationship with her, here in the house, until she brought the turtles home with her, the frogs, the amphibians, the sod, the wading pool, until she had made her apartment into a terrarium and an aquarium as well, until the water began to come through the ceiling and the television was destroyed, until every night up there she began to quack like a duck, bark like a dog, snort like a horse, until she began to shriek in a voice like an unknown bird and we could no longer get any sleep, which had left her, we always had a good relationship with her, here in the house.

A schoolteacher moved into her apartment, who looks a little bit like her, with the big glasses and the thin mouth. Sometimes we think that it's really her, she's back, but that cannot be, she is in jail or in the madhouse now.

The schoolteacher often sings at night.

3.

May 16
Yes, today I decided to begin my career as a high-diver at the "Mermaid" swim club, which will take me to the Tokyo Olympics.
September 22
Yes, today I decided to learn to knit or, better, to perish from an unknown disease.
July 4
Yes, today I decided never to speak another word to Mick JAGGER, to throw away my Rolling Stones albums, and to become a Jew or a drug addict.
May 9
Yes, today I decided to publicly revoke my dissertation and to inform my aunt that there is not a single Jew in the Institute for Jewish Studies.
December 3
Yes, today I decided to renounce language and practice only deeds.

4.

The weapon should be from the Middle Ages, the weapon should be symbolic, the weapon should be deadly, the weapon should be an enigma, the seller of the weapon should be a Jew, the seller of the weapon should be unsuspecting, the seller of the weapon should be a swindler, the buyer of the weapon should be a student, the buyer of the weapon should be educated, the buyer of the weapon should be innocent, the murderer should be the weapon, displaced from the Middle Ages into the present moment, from the outskirts of the ordinary into the center of fear.

B.

Now the climax has finally been reached: To escape their stares with this plunge, how could she do that, they will say, buy a gun and go into the university, where they presume to stain my Jewish identity with their stares, where they presume to continue to call me by my old name instead of saying Sara, where they presume to doubt that I am the true wife of Mick JAGGER and have seen the scar on his stomach, the scar, the healed stab wound, from which he unfortunately recovered, after I left him that night, but the professors will not recover from these two shots with which I shot them out of their unworthy German existence and shot myself upward into the heaven of EINSTEIN and FREUD, I, the new formerly German Anne FRANK, who did her deed for the Jewish people who cannot defend themselves against the appropriation of their history by uncircumcised professors of Jewish Studies, this people, to whom I have attached myself and now go before them, because they need someone who can lead them on the long journey through the darkness and here I stand on the 11-meter tower, in the spotlight of history, and yet suspended high up with my gun in my hand, in order to look down upon you, ever higher and ready to shoot, you two will be given over to the Dead Sea, through which we had to go, I am flying and destroying your construction and the newspapers will write about me, as though it were only in my head, not in the world, this plunge.

1.

The audience wanted an explanation for what they had to look at, to listen to, to report and gathered to consider whether this description of an opera was about the presentation of the documented case in which in the eighties a professor of Jewish Studies was killed and another badly wounded by a student, the audience did not come to any conclusion, except one: the observer, the listener sees and hears nothing, if he does not let himself go. So they went back into the viewing room of their history, to the person who was supposed to tell them what they could not understand, for the observer sees nothing.

2.

She had known me before, she said suddenly, no, no this is not our first encounter, didn't I remember, it was true that I had had a different appearance and a different name, but I had revealed myself to her, I had been her married Jewish lover and she had threatened to shoot my son if I would not immediately leave my wife, but fortunately I had exchanged my identity and had run to her, to the big shalom. Meanwhile I could never see her eyes. She seemed to me to have turned completely inward. So I ran out and never wanted to see her again. I sensed something.

3.

To speak another language, one that only the speaker understands, behind which he is completely concealed, behind which no one can discover him, to mingle the language of the victims and the perpetrators into a violently tender web, like that of men and women, of lunatics and children, of pale cowards and stony mummies, a language like a dance, that satisfies itself before an orchestra without instruments under a sky full of violins, disguised as machine guns, to learn to speak the language of a speechless protagonist, whom one did not encounter except on paper, on the piano. To learn to speak her scream.

4.

The boundary crossed from rage into coldness, from motive into action, from terror into paralysis, from eagerness into absence, the boundary crossed from ambition into decline, from intention into chance, from diligence into rest, from sentence into word, from melody into sound, from din into noise, from drawing into line, from history into moment, the boundary crossed with one leap, which stands still, one foot on this side, the other on the far side over the edge, with one leap, which leads no farther.

C.

I crash down, they lead me away, they transport the corpses away, they write me off in the newspapers, they take a picture of me at the prison doctor's, they pick me up like for a KZ, they dismiss me like a lunatic, they replace me as the star, they tear down my 11-meter tower, they bolt the door behind me, they pull the audience out, they reject my statement, they cut off my hair, they again take away my Jewish name, the Jews turn away from me, my body turns away from me, my classmates turn away from me, Papa and Mama turn away from me, they dismiss me, they tear up the swimming pool, they let the water out, I crash down, 11 meters deep I crash down, they turn off the music, they turn off my thoughts, they turn off the light, they stop my plunge, I crash into the sea of silence, my plunge, I am broken up. I will be broken up, after I had closed, I was treated and finally described. I don't want to go under, there's no water here, turn off these noises, turn off these words, I am crashing down, so short was the plunge, I am crashing and turning myself off.

References

Assayag, G., Rueda, C., Laurson, M., Agon, C., and Delerue, O.: Computer assisted composition at Ircam: Patch-Work & OpenMusic. Computer Music Journal *23(3)* (1999)

Bohlen, H.: 13 Tonstufen in der Duodezime. Acustica. *39/2*, 76–86 (1978)

Brasch, T.: Mädchenmörder Brunke. Frankfurt am Main: Suhrkamp 1999

Brasch, T.: Liebe Macht Tod: Der Sprung. S. 297–309. Frankfurt am Main: Suhrkamp. 2002

Carter, R.: Mapping the Mind; pp. 119–124. Berkeley, Los Angeles, London: University of California Press 1999

Dufourt, H.: Musique spectrale (1979). In: Musique, pouvoir, écriture; pp. 289–294. Paris: Christian Bourgois 1991

Hajdu, G.: Fingerprints. Score. Hamburg, New York: Peer 1993

Hajdu, G.: Low energy and equal spacing; the multifactorial evolution of tuning systems. Interface *22*, 319–333 (1993)

Hajdu, G.: Der Sprung. Score. Hamburg, New York: Peer 1994–1998

Hajdu, G.: Circularity in neural computation and its application to musical composition. In: Proceedings of the International Computer Music Conference 1995, Banff Centre for Arts, Banff, Canada, pp. 363–365 (1995)

Hajdu, G.: Quintet.net – an environment for composing and performing music on the Internet. Manuscript (2003)

Hajdu, G.: Überlegungen zu einer neuen Theorie der Harmonie. In: Stahnke, M. (Ed.): Mikrotöne und mehr – für György Ligeti. In Series: Heister, H.-W., and Wolfgang Hochstein, W. (Eds.): „Musik und". Hamburg 2004

Hüppe, E.: Fragmentarische Überlegungen zu Georg Hajdu's „Der Sprung". MusikTexte *81/82*, 135–36 (1999)

Lee, M., Freed, A., and Wessel, D.: Real-time neural network processing of gestural and acoustic signals. Proc. of the Int. Computer Music Conf., Montreal 1991

Mathews, M. V., Roberts, L. A., and Pierce, J. R.: Four new scales based on nonsuccessive-integer-ratio chords. J. Acoust. Soc. Amer. *75*, S10(A) (1984)

McAulay, R. J., and Quatieri, T. F.: Speech analysis/synthesis based on a sinusoidal representation. IEEE Transactions on Acoustics,Speech, and Signal Processing ASSP-*34(4)*, 744–754 (1986)

Polansky, L.: More on morphological mutation functions. Recent techniques and developments. Proceedings of the ICMC (San Jose); pp. 57–60 (1992)

Shepard, R. N.: Circularity in judgments of relative pitch. J. Acoust. Soc. Amer. *36*, 2346–53 (1964)

Wantoch, E.: Wahn, wo ist Dein Sinn. Profil. *10/5* (March 5), 56–60 (1984)

Wright, M., Chaudhary, A., Freed, A., Wessel, D., Rodet, X., Virolle, D., Woehrmann, R., and Serra, X.: New Applications of the Sound Description Interchange Format. Proceedings of the International Computer Music Conference, Ann Arbor, Michigan 1998

Prof. Dr. (USA) Georg Hajdu
Tornquiststraße 8
20259 Hamburg
Germany
Phone: +49 40 23517610
Fax: +49 40 428482770
E-Mail: hajdu@musikhochschule-hamburg.de

Das Leopoldina-Postdoc-Stipendium

Wir bieten in einem Förderprogramm ausgewählten **Wissenschaftlerinnen** und **Wissenschaftlern** aus Deutschland, Österreich und der Schweiz mit einem Postdoc-Stipendium Unterstützung in ihrer beruflichen Entwicklung. In das Förderprogramm werden herausragende **promovierte Nachwuchswissenschaftler** unter 36 Jahren aus naturwissenschaftlichen und medizinischen Fachgebieten aufgenommen. Die Förderung umfaßt:

– ein monatliches Stipendium während der Gastaufenthalte (orientiert an Sätzen und Zuschlägen der DFG bzw. der AvH-Stiftung),
– Beihilfe zu Reisekosten,
– beschränkte Mittel für Laborbedarf.

Sie wird von Zuwendungen des bmb+f (Bundesministerium für Bildung und Forschung) getragen.

Die Förderung ermöglicht die vollständige Bearbeitung eines eigenständigen Forschungsprojektes von zwei- bis dreijähriger zusammenhängender Dauer an renommierten Forschungsstätten im Ausland. Sie hat eine Vertiefung von Kenntnissen und Befähigungen in der jeweiligen Spezialdisziplin zum Ziel, nicht jedoch die Habilitation. Eine Bewerbung kann jederzeit durch ein Mitglied der Akademie, die Institutsleitung der Bewerber oder mit zwei Referenzen durch die Bewerber selbst eingebracht werden. Richten Sie diese an:

Deutsche Akademie der Naturforscher Leopoldina
Postfach 11 05 43
06019 Halle (Saale)

Eine Bewerbung sollte enthalten:

– die formlose Antragstellung an den Präsidenten der Akademie, Herrn Prof. Dr. Volker TER MEULEN,
– einen tabellarischen Lebenslauf,
– Ihre Zeugnisse und Referenzen,
– Listen Ihrer Publikationen, Vorträge, ...,
– gewünschte Gastinstitute und Betreuer,
– eine Projektskizze und den Arbeitsplan.

Die eingehenden Anträge werden von einer Vergabekommission unter Einbeziehung von Fachgutachten bewertet und entschieden. Ein Rechtsanspruch auf Förderung besteht nicht.

Weitere Informationen erhalten Sie bei:

Dr. Andreas CLAUSING,
Tel.: (03 45) 4 72 39 50, Fax: (03 45) 4 72 39 59,
E-Mail: stipendium@leopoldina-halle.de oder unter http://www.leopoldina-halle.de

Nova Acta Leopoldina NF *92*, Nr. 341, 91–103 (2005)

The Application of Physical Rules for a Perfect Musical Performance

Klaus WOGRAM (Braunschweig)

With 14 Figures

Abstract

The musical acoustics is a special part of the acoustics whenever there is a connection to music. Usually this discipline does not distinguish by a high preference of the more artistically interested musicians. But the knowledge of the physical operation of the conventional musical instruments can help the musician to get a better musical performance.

With some examples for a solid bass guitar, a tom-tom drum and a trumpet the common methods of investigation of the physical roles as the modal analysis are mentioned, and the musical effects which are relevant for the performance are explained.

Zusammenfassung

Die Musikakustik oder auch Musikalische Akustik ist ein Spezialgebiet der Akustik, wann immer sie mit der Musik in Verbindung steht. Normalerweise genießt diese Disziplin der Physik nicht immer die Vorliebe der mehr künstlerisch orientierten Musiker, doch kann die Kenntnis der physikalischen Funktionsweise der konventionellen Musikinstrumente auch dem Künstler helfen, eine bessere Aufführung zu erreichen.

Anhand einiger Beispiele für eine Baßgitarre, eine Trommel sowie eine Trompete werden Untersuchungsmethoden wie die Modalanalyse für die physikalischen Zusammenhänge aufgezeigt und die sich beim Spiel auf diesen Instrumenten ergebenden musikalisch relevanten Effekte erläutert.

1. Introduction

When playing a conventional musical instrument the musician has learnt during his study to control his instrument in that way that he is able to accept all kinds of challenges. The main purpose of a musical study is a sure and well-grounded playing technique and a distinct musical ear. One can say that the aim of a musical education is to train the players sense-organs especially his sense of hearing. But also the knowledge of the physical functions of musical instruments in which the mostly artistically interested musician is engaged hardly often can help him to get a better efficiency with his daily exercises. By means of some examples performance effects will be demonstrated and an explanation be done by help of the physical foundations. By that it may become clear that it is suggestive to ask for the reason of the performance effects.

2. Subjective Perceptions during Musical Performance

During the musical performance many of the player's senses will be activated. This may be explained with the example of a cartoon of Gerald HOFFNUNG which shows a female player on a so called Wagner tube (Fig. 1). Starting the performance the musician has a specific musical idea of the music to play. This is marked by the red brim of her helmet, her thoughts include the kind of music, the sound color, the intonation and the trained playing technique. Moreover she looks at the notes (eyes are marked in red), looks on the instrument with the typical engraving on the bell and sees her environment as there is the orchestra and the audience in the hall. Now when starting the performance she feels the contact of the mouthpiece at her lips (rim of the mouthpiece marked in red) and listens to the sound of her instrument with her red marked ears. Last she feels the contact with the instrument with her fingers and perceives by this the vibrations of the instruments body.

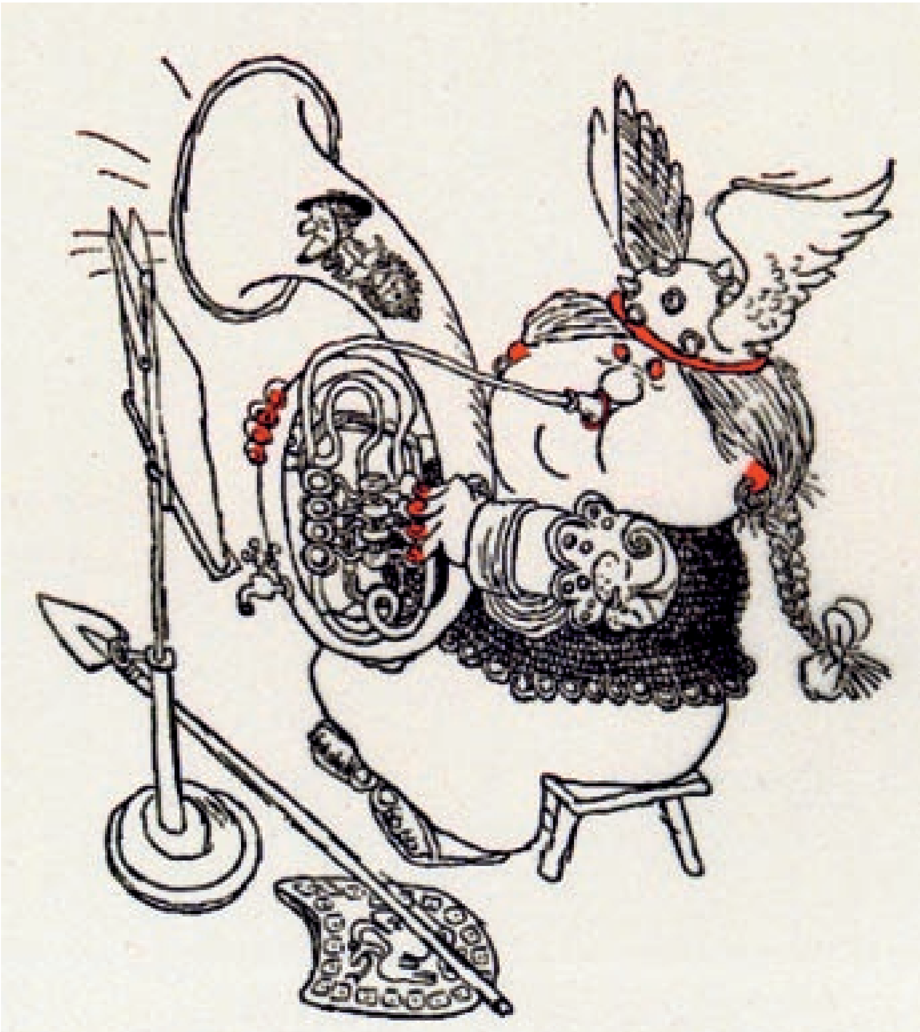

Fig. 1 Cartoon of Gerald Hoffnung: Female Player of a Wagner Tube

In the technical or physical view these senses and activities may be shown as interactions in a block diagram (Fig. 2). Before generating a sound the musician will compare his ideas with his inner reference which is mainly impressed by his experience and his individual taste. His personal attitude and the physical mode of operation of the sound generation tend to that sound product which the musician perceives with his senses and again compares with his inner reference. This is a feedback loop with which a perfect sound can be created in a shortest time.

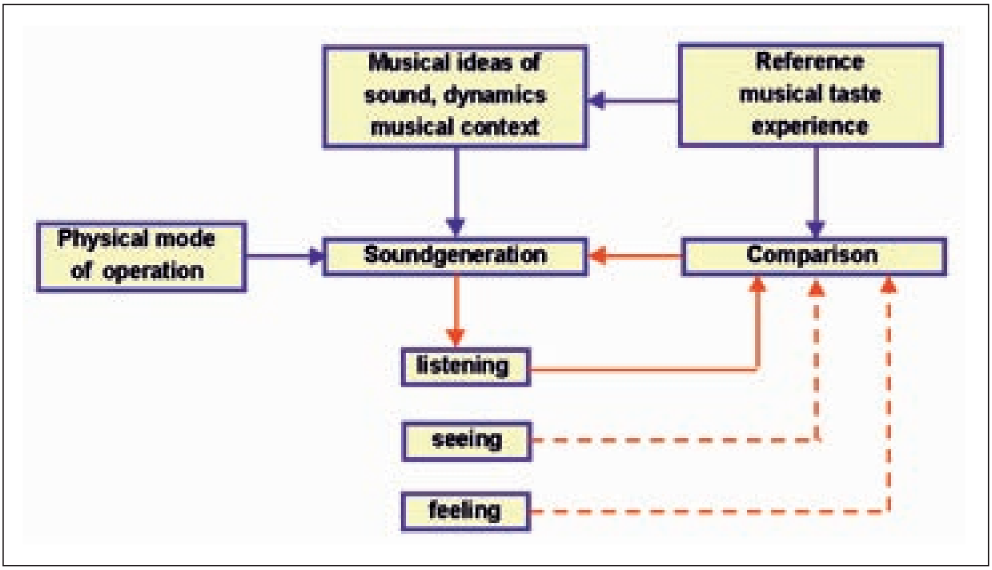

Fig. 2 Individual influences on musical performance

3. Musical Acoustics

When having a look on the physical or technical operations during the performance on conventional instruments we come to the subject of musical acoustics. It deals with the acoustics whenever there is a relation to music. As can be seen in Figure 3 the field of musical acoustics includes the three essential topics "physical rules" "human effects" and "room effects".

The pure physical part includes the physical function of the musical instruments where we want to have a more detailed look because of its importance for the performer, the sound generation the filtering effect of the resonators and the sound radiation into the room.

The human effect includes mainly the individual playing technique, his musical preference and his experience. But also his prejudices concerning the brand, the type and appearance or design of the instrument affect the result of his musical efforts. These prejudices may also be a question of the players aversion against the kind of music to be played, against the composer or the conductor.

The room effects concern the reverberation time of the room, that is that time interval between the start and the drop of a signal to an amplitude of 1/1000 of its beginning, the volume

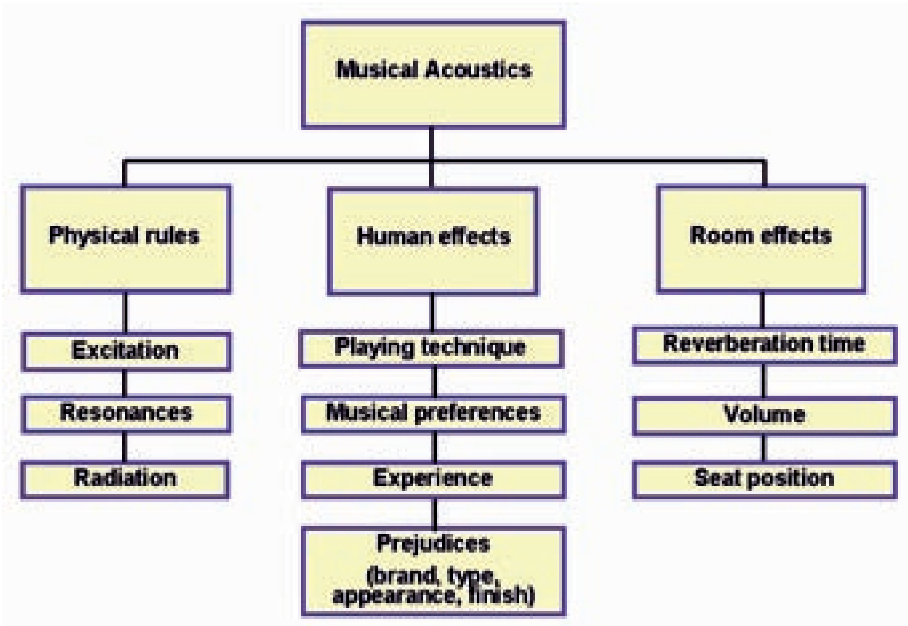

Fig. 3 Interactions in musical acoustics

of the room and the positions of the player and the listener. The reverberation time is given usually as T_{60} in s, because the decrease of the amplitude to 1/1000 corresponds to a decrease of the sound level of 60 dB.

4. Examples

Let's start with the play of a four-stringed bass guitar, its strings tuned to E_1 (41 Hz), A_1 (56,6 Hz), D_2 (73,4 Hz) and G_2 (98 Hz). The bass player complained that the timbre of the instrument at certain sounds left a lot to be desired. From the measured sound spectra no peculiarities could be discovered and the reverberation times of all playable sounds had to be determined. Figure 4 shows the result of this investigation. The decay rates T_{60} of the basic playable sounds of the 4 strings are applied in chromatic order on top of the fret marking of the guitar neck. It is to be seen, that reverberation times for all strings range around 20 s with exception of an excession at the low register on all strings as well as a reduction around the sound $D_3^{\#}$ with approximately 156 Hz on the G_2-string. This reduction to values around 4 s shows that this basic sound drops off much faster than all others and for that gives the sound a hollow and potty timbre. Now you can produce this sound with other strings of the instrument as well, selecting a higher fret number. Comparing the reverberation behavior of this sound $D_3^{\#}$ on the G_2-string (8^{th} fret) with the one on the D_2-string (13^{th} fret), we notice that the decay rate on the D_2-string is much longer and therefore better (Fig. 5). But how is this difference to explain?

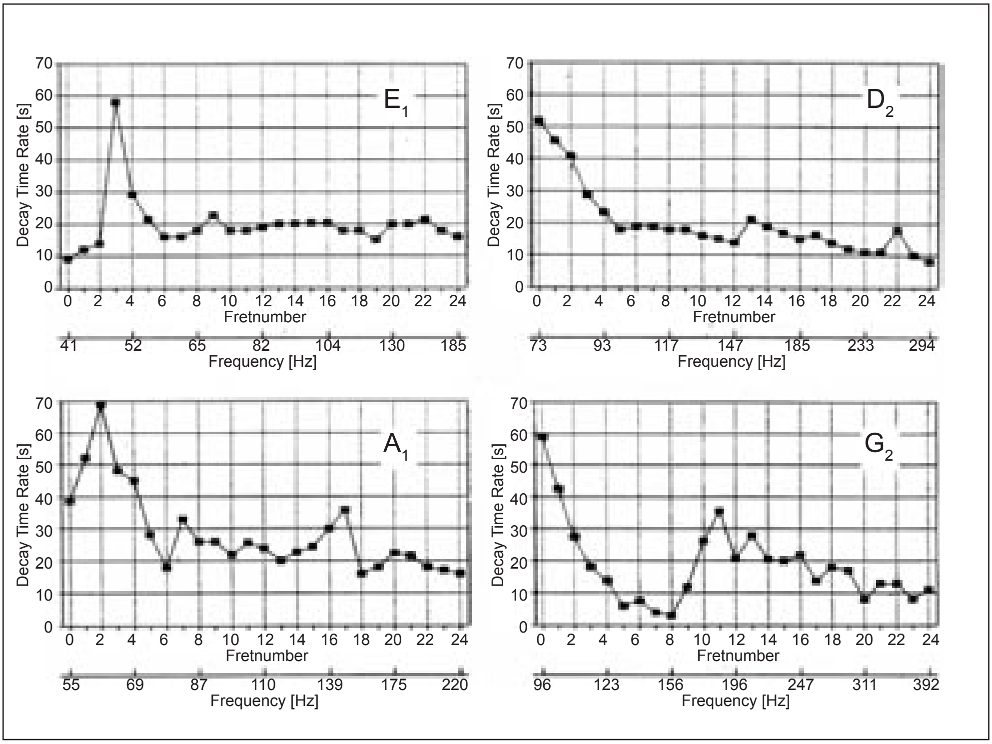

Fig. 4 Decay rates of the 4 strings of a solid bass guitar

By means of modal analysis the connections can be made clear. This measuring method (Wogram 1991) serves to find out separately all possible resonance conditions of body vibrations. In Figure 6 the modal analysis method is shown as circuit diagram. On the surface of the structure to investigate (in this case a grand piano sound board), a net of measuring points is created, and each single measuring point is hit by a small impulse hammer one after another. Inside the hammer a force sensor is locked, and its electrical signal is lead to one channel of a 2-channel-FFT analyzer. On one of the other measuring points a reference sensor is fastened for acceleration and its output signal is lead to the second channel of the 2-channel-FFT analyzer. Now all transfer functions from the single hitting points to the reference point are determined one after another with help of the FFT analyzer. These functions are factorized in its modal data by computing programs and finally the motion study at any mode (resonance) can be animated on a computer screen in slow motion. The result for the investigated mode at the sound $D_3^{\#}$ at 156 Hz is shown in Figure 7. It shows the maximal states of oscillation in between the animation moves back and forth. In addition the two spots of maximal (antinode) and minimal (node) deformations are marked on the finger-board. You can see at the 8th fret an antinode and at the 13th fret a node. Considering the physical law that the input impedance of an oscillator shows a maximum at its oscillation node and a minimum at its antinode, it gets clear that the sound energy moves fast from the string into the finger-board at generating the sound $D_3^{\#}$ on the 8th fret. This reduces the reverberation time, whereas on the 13th fret the

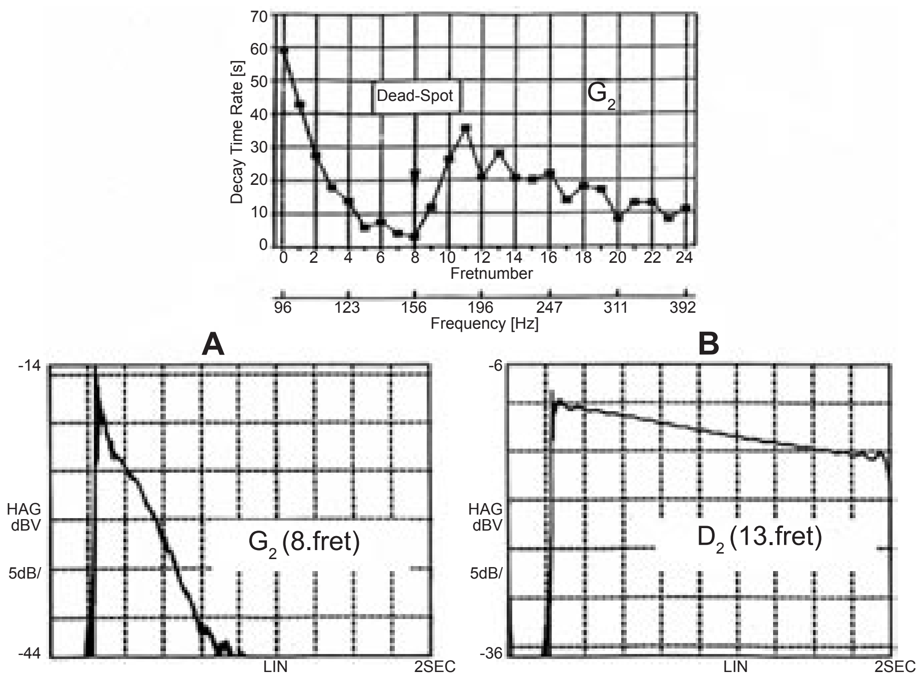

Fig. 5 Decay rates of the tone $D_3^{\#}$ at a bass guitar on (*A*) the G_2- and (*B*) D_2-string

sound energy can stay longer in the string. The knowledge of the physical behavior can help the musician to achieve a well-balanced sound on the bass guitar using alternative fingerings.

In the 2nd example we look at the sound of a drum, which was judged by several musicians very differently. It is a 12"-Tom-Tom and its sound was described as "strong and full" on one hand and as "thin and hollow" on the other. Why?

To detect under which conditions the varying judgments were given, it was investigated first how the drummers tuned the two heads (upper impact head and lower resonance head). Soon it showed that there were hardly any differences in tuning. All drummers tuned the head and the resonance head to the same frequency. Therefore the different judgments had to be caused by the individual mounting types of the tom toms.

To make out the drum clamping conditions, modal analytic investigations of the heads were carried out first. The heads were hit at the marked measuring points with the impulse hammer, and the vibrations were measured at the reference point by an optical path tracker. The results for the two lowest resonances (modes) are shown in Figure 8. At the first mode at 121 Hz both heads swing in phase. That is they move up and down uniformly, whereas at the second mode at 180 Hz they move in opposite direction. While the head swings down, the resonance head moves up at this second mode. In contrast to this mode, at which the force the heads exert on the shell is compensated, the simultaneous forces of the first mode

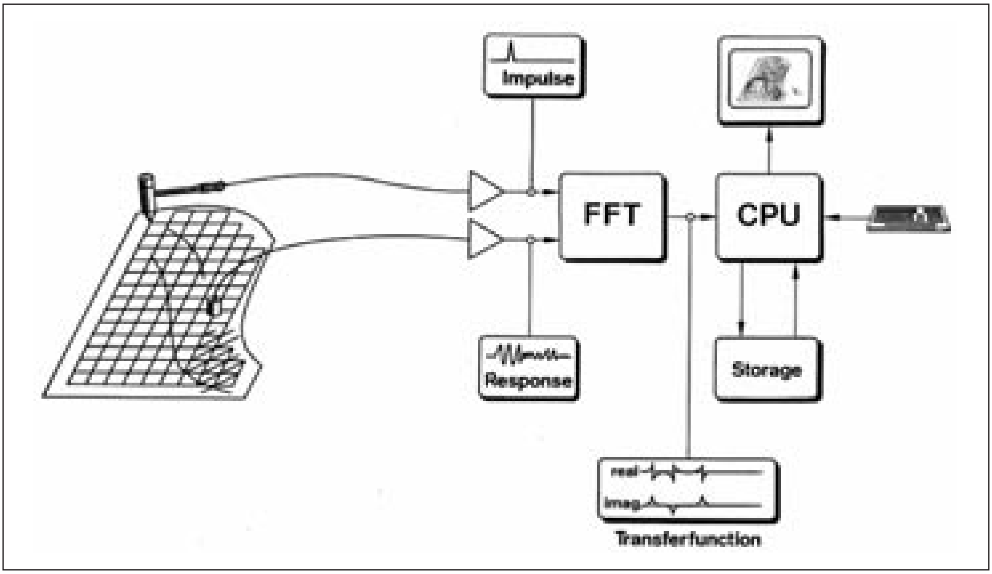

Fig. 6 Method of modal analysis of musical instruments

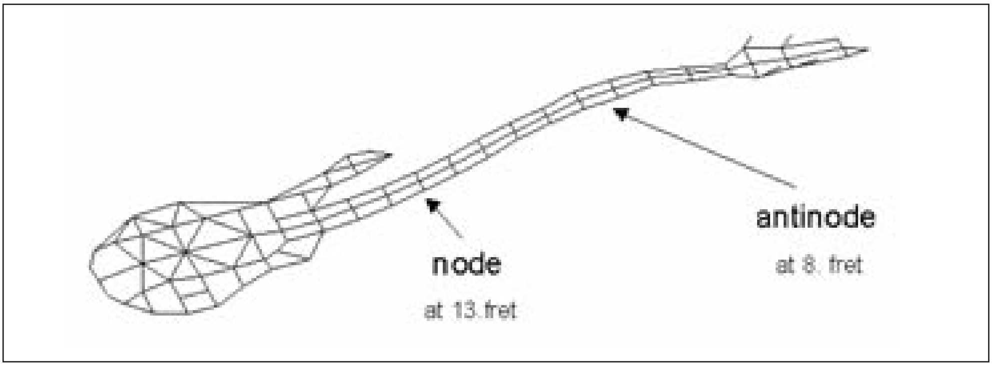

Fig. 7 Vibrational mode of the bass guitar at 156 Hz (tone $D_3^{\#}$)

add up and exert a force on the shell. This again is mounted on the stand, which can have its own resonances as well. Is this stand resonance identical with the one of the heads at the first mode, an energy transfer occurs from the heads *via* the shell into the stand and from there to the floor – as is with the bass guitar. Would the stand be tuned as described, that the combination stand/drum has the same resonance frequency as the heads by itself, the energy transfer should be stronger as if tuning the stand to another frequency.

Figure 9 shows the reverberation behavior of the looked at drums basic sound at different stand tunings. On the left the reverberation time is longer as on the right, where the stand resonance meets the head resonance. The vibration behavior of the whole stand and drum system shows the most unfavorable case in Figure 10.

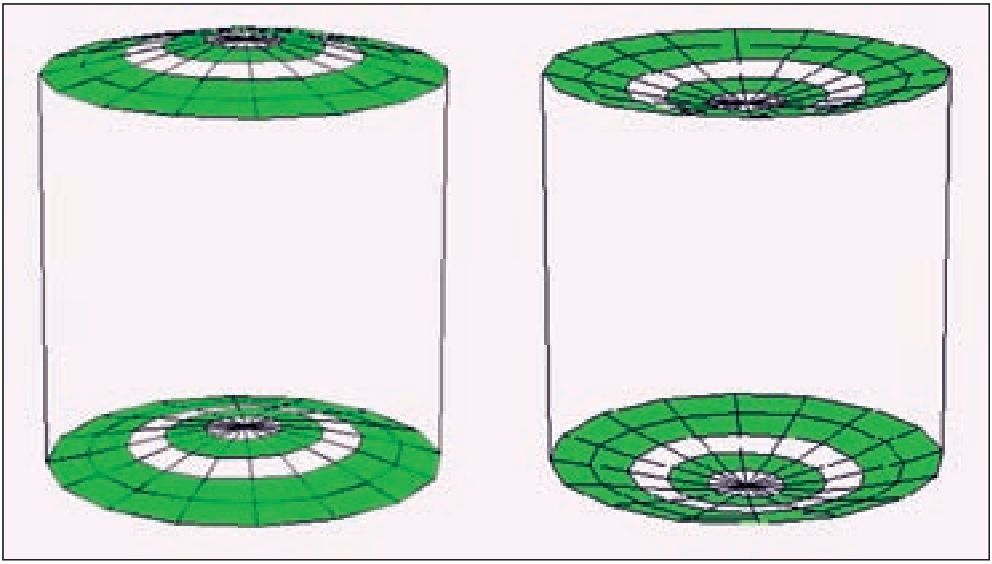

Fig. 8 Lowest vibrational mode of the tom-tom heads at 121 Hz

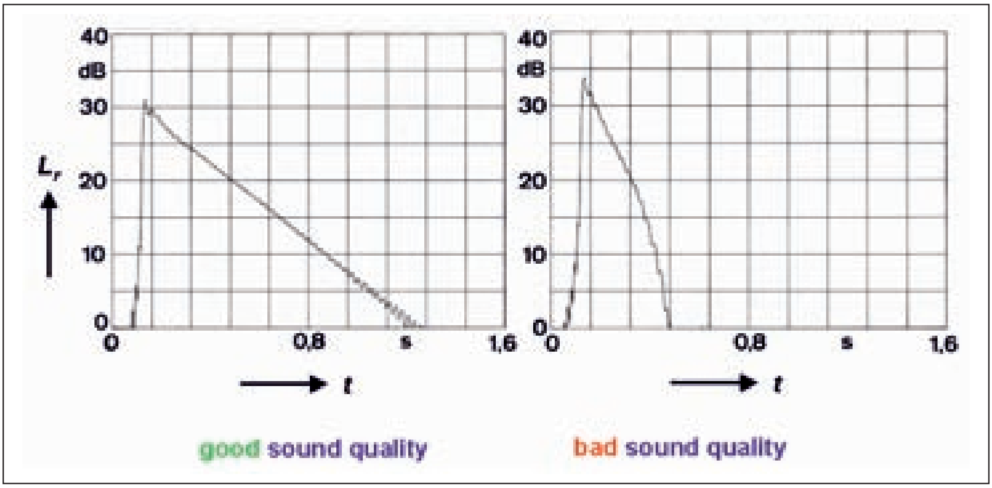

Fig. 9 Decay rates of the fundamental harmonic of the tone B_2 (121 Hz) of a tom-tom fixed differently at a normal stand.

We realize that it makes quite a difference how the tom-tom is mounted to the stand. At each new arrangement of the drumset the musician has to bear in mind that no similar resonances of head and stand occur because of the risk of an unsatisfactory timbre of the drum sound. This example again shows that knowledge about musical acoustic fundamentals can help the musician to reach a better musical result.

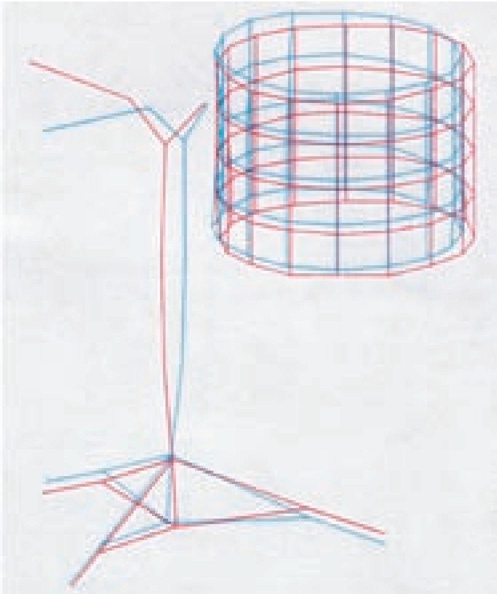

Fig. 10 Unfavorable vibrational mode of the total tom-tom at corresponding resonances of the heads and the stand

The last example deals with the tuning problems at playing the trumpet. A trumpet player complains that he can hardly control the tune of a sound on his trumpet while playing large differences in dynamic.

To clarify the problem we look at the function of the brass instruments sound generation first (Wogram 1972).

The actual sound generation occurs by lip vibrations of the brass player, which modulate the force of the outcoming air stream. The created sound signal represents a heavily distorted sine with many harmonics. This signal moves into the brass instrument and at correct resonance tuning stimulates the locked air column in the instrument tube. These resonances develop from traveling back and forth of the sound wave between the lips and the bell rim, because here the sound wave is partly reflected by the sudden change of the sound propagation. Because the sound propagation and reflection conditions inside the brass instrument depend on the shape of the air column, that is from the shape of the instrument tube, differently shaped brass instruments possess different resonance tunings. That means single resonances are not always sufficient for demands on harmonic connections of the musical practice. It is the art of the brass instrument maker to influence the instruments resonances by correcting the shape to correspond to expected musical values.

The used trumpet in the selected example has the measured resonance graph shown in Figure 11. It represents the instruments frequency dependent acoustic input impedance, measured with a specially developed measuring system (Wogram 1998). 10 clearly outstanding resonances with an amplitude drop above the 10^{th} resonance are obvious. That means the instrument is relatively easy to play up to sound D_6 (10^{th} resonance), above that the resonance effect decreases and complicates the response. The descant requires much higher lip strength, which is much the same with all brass instruments.

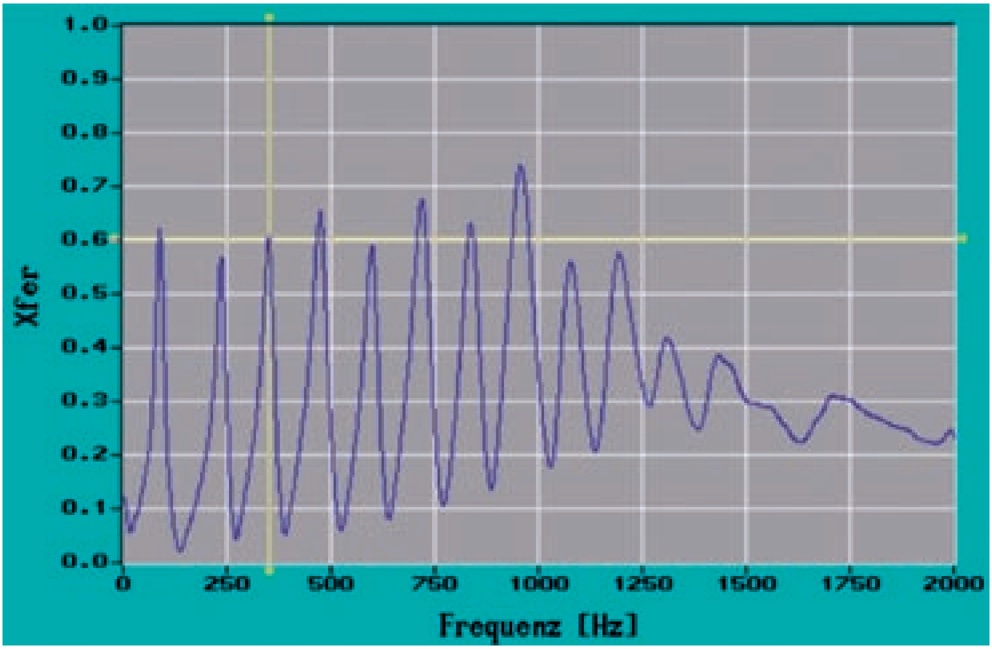

Fig. 11 Measured resonance curve (input impedance) of a B^b-trumpet

Investigating the frequency position of the single resonances and its deviation from the values of the most used equal tempered scale, we obtain the intonation curve shown in Figure 12. Here tuning deviations for each sound are marked in German notation. The cross marked sound f^1 corresponds to the faulty sound F_4 in English style. Its resonance is with about 6 cent very low compared to others, 100 cent are equivalent to the interval of a semitone! The medium tune of the trumpet orients itself mainly by the tune of the major sound, that is the resonance no. 4 or sound b^1 (B_4^b) marked by a circle. Compared to this value of about 30 cent the problematical 3rd resonance is 24 cent too low!

Plays the trumpet player this sound F_4 very soft, that is in *ppp* and suppresses every musical or harmonic context, intonation is given by the corresponding resonance, that is at 6 cent. To raise the sound to the demanded sound height of about 30 cent, the player has to change his embouchure and drive up the sound a lot. Because of his training he succeeds usually quite well, but it requires a lot of practice and concentration.

Has the player to play the same sound very loud (*fff*), he produces with his lip vibrations a sound containing a lot of harmonics. At very high levels the amplitude of the basic sound diminishes a lot and the amplitudes of the higher overtones are much taller than the one of the fundamental. At the synchronization of the lip frequency with the resonance of the trumpet the second harmonic of the stimulating sound gains an increasing importance, because after Wogram (1972) it should match best possible with the corresponding resonance of the trumpet as well. But since the second harmonic of the sound shows double the frequency of the basic sound, the corresponding resonance is also at an octave interval to the fundamental resonance. For the inspected sound F_4 it was the 3rd resonance. Now we have to look at the

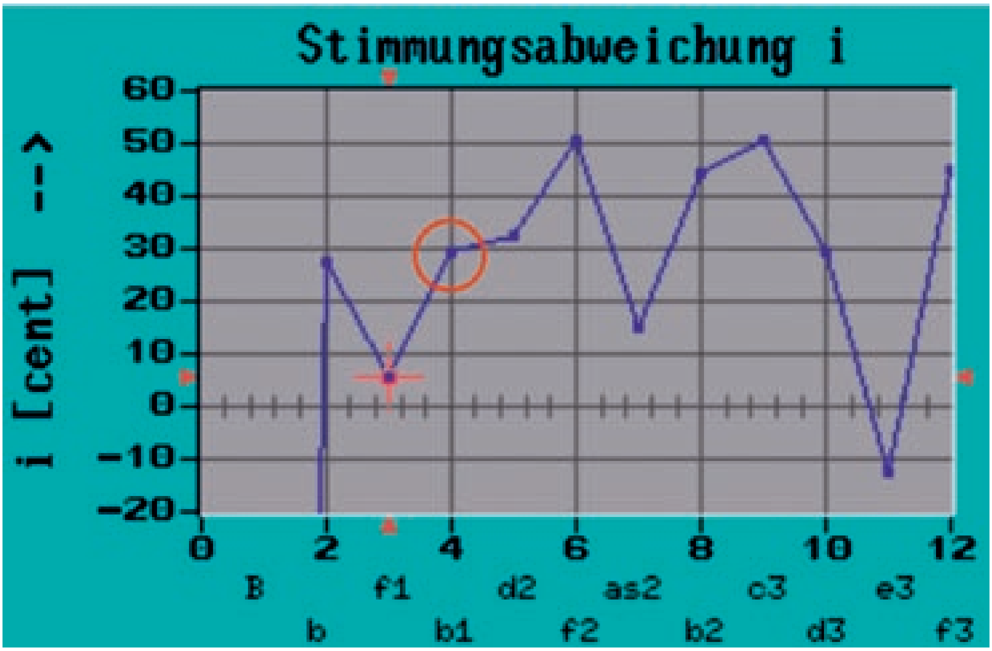

Fig. 12 Measured intonation curve of the B^b-trumpet

corresponding octave, that is the 6th resonance. But this has a tune deviation of 50 cent and is 44 cent higher than the 3rd resonance. To attain optimal synchronization of the sound F_4 at fortissimo, especially the second harmonic has to match with the 6th resonance and that is the case at 50 cent. Therefore the brass player will select an intonation of around 50 cent at *fff*, which is much higher than the one at a *ppp* sound.

To correct these intonation differences the brass player depends completely on his abilities to change the embouchure, which has a negative effect especially at crescendo or decrescendo. In case the player would not take into account his own mental reference as well as the intonation of his orchestra, the tune of the played sound F_4 would develop according to the function shown in Figure 13. Considering that the player is forced to keep a uniform pitch (in this case 30 cent), the efforts to achieve it with the investigated instrument are imaginable. In this case the knowledge of musical acoustic effects can lead faster to a satisfactory solving of the problem, especially since methods by Wogram (1998) are available now, to remove the described serious flaws constructively.

5. Influence of the Room

The sound of a musical instrument is influenced heavily on its way to the ear of a listener by the acoustical properties of the music room. That is illustrated by means of the ray tracing in Figure 14. The direct sound (Dir) reaches the listener first, passing through on the shortest way. Next are the parts reflected by the walls (W...), followed by the ceiling reflections

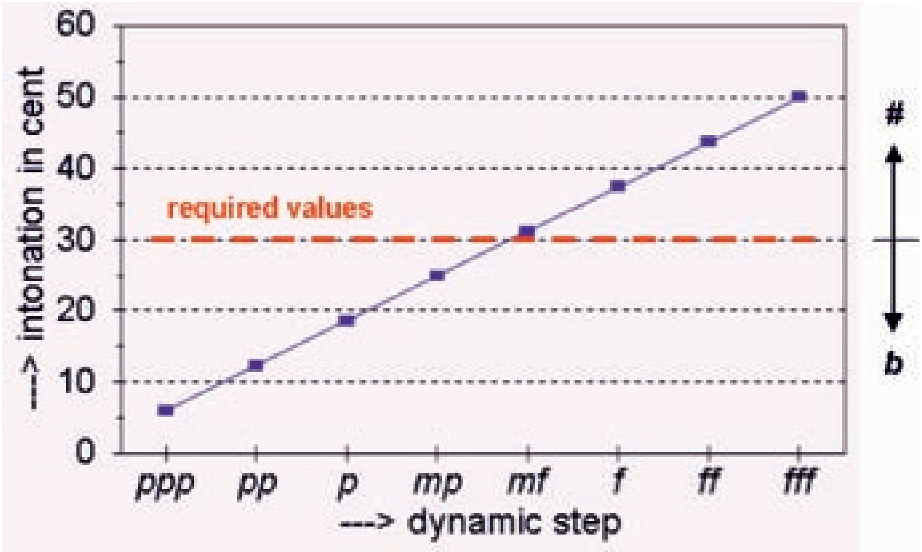

Fig. 13 Intonation of the tone F_4 of the B^b-trumpet as a function of dynamics

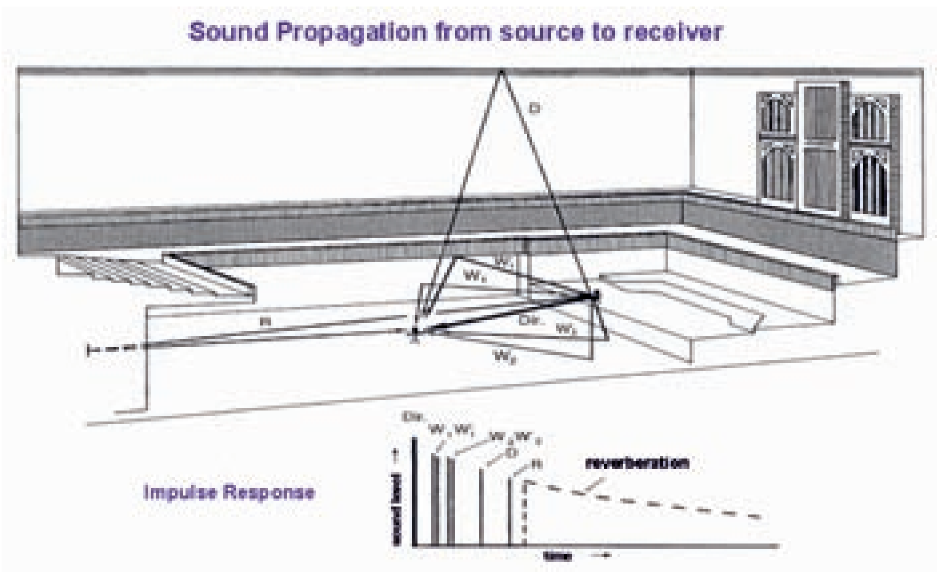

Fig. 14 Sound propagation in a performance room

(D) and last by the back wall reflections (R). Would the musician simply clap his hands and thereby generate an acoustical impulse, the successively arriving impulses could be summed up in the impulse response as shown in Figure 14. Here the latest arriving and in parts repeatingly reflected sound parts are combined to an exponentially abating reverberation due to its chronologically dense succession.

The impulse response structure depends on the design of the wall absorption as well as the players and the listener's position. That way the instruments sound effect is formed by the room. How the musician takes these influences into consideration at his performance is therefore of great significance. Exist low absorption values for the room, the reverberation time is longer as with high absorbent room limiting surfaces. A longer reverberation time leads to a larger sound volume, but blurs the contour lines of a fast played passage all the more. Because absorption and therefore reverberation time is frequency dependent, reverberation time changes the timbre. The musician has to prepare for these properties by adapting to the circumstances with his playing technique (embouchure, key attack, bowing etc.).

The presented examples show that the knowledge of the physical effect mechanisms at the play on classical music instruments can put the player in a position to perfect his musical performance beyond the degree attainable by pure practice. The field of musical acoustics supplies the necessary toolkit.

References

Wogram, K.: Ein Beitrag zur Ermittlung der Stimmung von Blechblasinstrumenten. Diss. TU Braunschweig 1972

Wogram, K.: Schwingungsuntersuchungen an Musikinstrumenten mit Hilfe der Modalanalyse. Instrumentenbau-Zeitschrift Part 1, Vol. *1*, 44–48, Part 2, Vol. *2/3*, 115–122 (1991)

Wogram, K.: Die Anwendung der Modalanalyse bei Musikinstrumenten. Instrumentenbau-Zeitschrift Part 1, Vol. *5*, 58–63, Part 2, Vol. *6*, 36–40 (1991)

Wogram, K.: Eine einfache akustische Meßmethode zur Beurteilung und Verbesserung von Intonation und Spielqualität bei Blechblasinstrumenten. Posaunen und Trompeten. Michaelsteiner Konferenzbericht Nr. *60*, 185–198 (1998)

Dr.-Ing. Klaus Wogram
Vor der Mühle 6
38551 Vollbüttel
Germany
Phone: +49 5373 330054
Fax: +49 5373 330242
E-Mail: klaus.wogram@t-online.de

„Bewahren und Verändern im Kontext biologischer und kultureller Evolution“
Gaterslebener Begegnung 2003

Gemeinsame Tagung des Institutes für Pflanzengenetik und Kulturpflanzenforschung (IPK) Gatersleben und der Deutschen Akademie der Naturforscher Leopoldina vom 22. bis 24. Mai 2003 in Gatersleben

Nova Acta Leopoldina N. F., Bd. *90*, Nr. 338
Herausgegeben von Anna M. Wobus (Gatersleben), Ulrich Wobus (Gatersleben) und Benno Parthier (Halle/Saale)
(2004, 244 Seiten, 49 Abbildungen, 10 Tabellen, 29,95 Euro, ISBN 3-8047-2170-2)

Zum nunmehr zehnten Mal trafen sich in Gatersleben Natur- und Geisteswissenschaftler, Schriftsteller, Künstler, Journalisten und Politiker zum interdisziplinären Dialog über Fragen, die sich aus den Entwicklungen von Naturwissenschaft und Technik für die Gesellschaft ergeben. Naturwissenschaftler und Biologen sind dem Erhalt der in der Evolution entstandenen biologischen Vielfalt, aber auch dem Anspruch verpflichtet, dieses Potential verantwortungsvoll zum Wohle des Menschen einzusetzen und zu gestalten. Der Band enthält neben den *Anfragen an Wissenschaftler* (diesmal von der Schriftstellerin Helga Schütz, Potsdam) Beiträge zur Evolutionsbiologie (Konrad Bachmann, Gatersleben, Evolution und Information; Jörg Hacker, Würzburg, Evolutionäre Infektionsbiologie), Ethologie (Wulf Schiefenhövel, Andechs, Vom Instinkt zur Kultur: Zur Evolution geistiger Fähigkeiten – Beispiele aus traditionalen Kulturen Melanesiens), Humangenetik (Peter Propping u. a., Bonn, Humane Reproduktionsbiologie: Eingriff in die natürliche Evolution des Menschen?), Kulturwissenschaft (Sigrid Weigel, Berlin, Evolution der Kultur oder Kulturgeschichte der Evolutionstheorie – Epistemische Probleme am Schnittpunkt der zwei Kulturen) und Ethik (Klaus Tanner, Halle/Saale, Zwischen „Heuristik der Furcht“ und Hoffnung auf Veränderung). Er spannt damit den Bogen von naturwissenschaftlichen Problemen über die Reflexion wissenschaftshistorischer und -philosophischer Zusammenhänge bis hin zur Debatte ethischer Standpunkte. Verbunden mit Gedichten der beteiligten Schriftsteller und Abbildungen der Werke der in Gatersleben zur Begegnung ausstellenden Künstler vermittelt der Band einen unkonventionellen Blick auf ein nach wie vor brisantes Thema.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Nova Acta Leopoldina NF *92*, Nr. 341, 105–111 (2005)

Brain Signatures of Musical Semantics[1]

Stefan Koelsch (Leipzig)

With 4 Figures

Abstract

Semantics is a basic dimension of language. Although many people think that music is capable of conveying semantic information, it has been elusive if listening to music can really activate brain mechanisms of semantic information processing. The processing of language- and music-semantic information was investigated using the so-called N400 component of the event-related brain potential (ERP). The N400 is a classical electrophysiological index of semantic processing. It was found that the semantic processing of words can systematically be influenced by preceding musical information: If a word is semantically related to a preceding musical context (e.g., the word *hero* following a passage of a Beethoven symphony), the N400 elicited by this word clearly differs from the N400 elicited by a word that is semantically not related to the musical context (e.g., *flea*). Results show that music can activate representations of semantic concepts, and that music can, thus, transfer considerably more meaning information than previously believed. Findings are in line with the assumption that the human brain processes music and language very similarly.

Zusammenfassung

Semantik ist eine basale Dimension der Sprache. Bisher war unklar, ob das Hören von Musik Mechanismen im menschlichen Gehirn aktivieren kann, die semantische Information verarbeiten. Die Verarbeitung sprach-semantischer und musik-semantischer Information wurde anhand der sogenannten N400-Komponente des ereigniskorrelierten Hirnpotentials untersucht. Die N400 ist ein klassischer elektrophysiologischer Index semantischer Verarbeitungsprozesse. Wir fanden, daß die semantische Verarbeitung von Wörtern systematisch durch vorhergehende Darbietung musikalischer Information beeinflußt werden kann: Die durch Wörter evozierte N400 variiert in ihrer Größe, abhängig von der Stärke der semantischen Beziehung zwischen dem Wort und einem vorher gehörten Musikstück. Die Ergebnisse zeigen, daß Musik Repräsentation semantischer Konzepte aktivieren kann, und daß daher Musik erheblich mehr semantische Information übermitteln kann als bisher angenommen. Die Befunde stimmen mit der Annahme überein, daß das menschliche Gehirn Musik ähnlich wie Sprache verarbeitet.

When listening to a sentence like *Hannah sings a song*, the word *music* is semantically stronger related, and thus more expected, than the word *pen*. This effect is the semantic priming effect, it refers to the highly consistent processing advantage seen for words that are preceded by a semantically related context (Osterhout and Holcomb 1995, Kellenbach et al. 2000).

An electrophysiological index of semantic priming is the N400 component of the event-related electric brain potential (ERP; ERPs are measured using electroencephalography, and inform about activity of mainly cortical neurons). The N400 usually emerges around 250–400 milliseconds (ms) after the onset of a word. The N400 elicited by words has reliably been shown to be highly sensitive to manipulations of semantic relations: The amplitude of the N400 is smaller if a word (e.g., *music*) is semantically related to a sentence like *Hannah*

1 A german translation of this manuscript will be published in the *Jahrbuch der Max-Planck-Gesellschaft* 2005.

sings a song, and larger if the word is semantically unrelated to the sentence (e.g., *pen*) (Kellenbach et al. 2000, Kutas and Hillyard 1980).

Meaning is most obviously a key feature of language, and the assumption that music is capable of transferring meaning information is not too common. However, music is a means of communication (Jones and Holleran 1992, Swain 1997, Raffmann 1993, Meyer 1956, Hevner 1937, Peirce 2002, Zbikowski 2002), and composers use music as a means of expression. Most theorists distinguish between different aspects of musical meaning:

(*i*) meaning which emerges from a connection across different frames of reference suggested by common patterns or forms: For instance, sound patterns in terms of pitch, dynamics, tempo, timbre, etc. can resemble the sound of an object (e.g., a bird), or features of objects (e.g., high, bright, rapid),
(*ii*) meaning which arises from the suggestion of a particular mood (e.g., happy),
(*iii*) meaning due to extramusical associations (e.g., any national anthem), and
(*iv*) meaning due to the interplay of formal structures in creating patterns of tension and resolution (e.g., surprise elicited by an unexpected chord).

Intuitively, it seems plausible that music can transfer meaning information: E.g., listening to certain passages of Beethoven's symphonies, we would rather think of the word *hero*, than of the word *flea*, and listening to certain passages of Mozart's symphonies, we would rather think of an *angel* than of a *scallywag*. However, so far it has been elusive how such semantic associations emerge during listening to music, and it has been unknown if the cognitive operations that decode meaning information during listening to music are identical with those that serve semantic processing during language perception.

We investigated this issue with a classical semantic priming paradigm in which (*i*) sentences, and (*ii*) musical excerpts were presented as prime stimuli (musical excerpts were recorded from commercially available CDs). The prime-stimuli were semantically either related, or unrelated to a target word that followed the prime stimulus (see example in Fig. 1, in which the target word *wideness* is semantically related to the sentence *The gaze wandered into the distance*, and semantically unrelated to the sentence *The manacles allow only little movement*). Target words ($n = 44$, e.g. *illusion*, *wideness*, *cellar*, *king*, *needle*, *staircase*, *river*, *male*) were half concrete, and half abstract words.[2]

Musical primes were chosen based on musicological terminology, and on self-reports of the composers. For example, the prime for the word *needle* was a passage of Schönberg's *String Terzett* in which he described stiches during his heart attack. In the excerpt from R. Strauss presented in Figure 1, intervals are set in open position (covering a wide pitch range), thus this excerpt was used as prime for the word *wideness*.

Some of the musical stimuli that primed concrete words resembled sounds of objects (e.g., *bird*), or resembled qualities of objects (e.g., low tones associated with *basement*, or ascending pitch steps associated with *staircase*). Some musical stimuli (especially those used as primes for abstract words) resembled prosodic, and possibly gestural cues that can be associated with particular words (e.g., *sigh*, *consolation*). Other stimuli represented stereotypic musical forms or styles that are commonly (that is, even by nonmusicians) associated with particular words (for example, a church anthem and the word *devotion*).

2 Examples of the stimuli are available at http://www.stefan-koelsch.de.

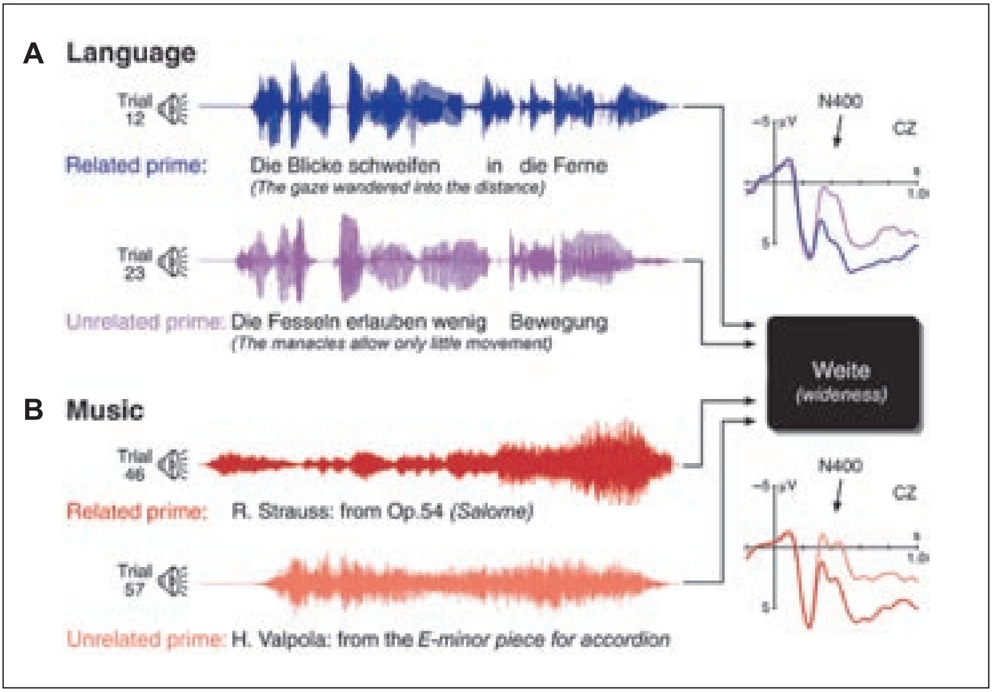

Fig. 1 Examples of stimuli and brain electric responses of the semantic priming experiment. (*A*) Language and (*B*) music (from Koelsch et al. 2004)

Figure 1 (*top right*) shows ERPs elicited by target words that were semantically either related (*brown line*) or unrelated (*lilac line*) to a preceding prime-sentence. Compared to semantically related words, unrelated words elicited a clear N400 (see arrows in Fig. 1). This is the classical semantic priming effect (target words that are semantically unrelated to a prime sentence elicit an N400); this effect reflects processes related to linguistic analysis that were dependent on the degree of fit between the semantic content of prime sentences and target words.

We were interested if such a semantic priming effect can also be observed when target words followed musical excerpts. ERPs elicited by target words that were semantically either related (*dark blue line*), or unrelated (*bright blue line*) to a musical prime-stimulus are shown in the bottom right of Figure 1. Interestingly, target words that were semantically unrelated to a preceding musical excerpt also elicited a clear N400 (compared to target words that were semantically unrelated to the preceding musical context). The N400 effect did not differ between the language condition (in which the target words followed sentences) and the music condition (in which the target words followed the musical excerpts), neither with respect to amplitude, latency, and scalp distribution. Figure 2 shows the results of a source analysis of the N400 effects. The neural generators of the N400 did not differ between the language condition (top of Fig 2, brown dipoles), and the music condition (bottom of Fig 2, blue dipoles). In both conditions, the main sources of the N400 were localized bilaterally in the posterior part of the medial temporal gyrus (Brodmann areas 21/37), in the close vicinity of the superior temporal sulcus. These regions are known for the processing of semantic information during language perception (for studies on the functional neuroanatomy of semantic processes at the word level see Friederici 2002, Démonet et al. 1992, Price et al. 1997, Friederici et al. 2000, for the sentence level see Friederici 2002, Ni et al. 2000, Kuperberg et al. 2000, Baumgaertner et al. 2002, Halgren et al. 2002, Helenius et al. 1998).

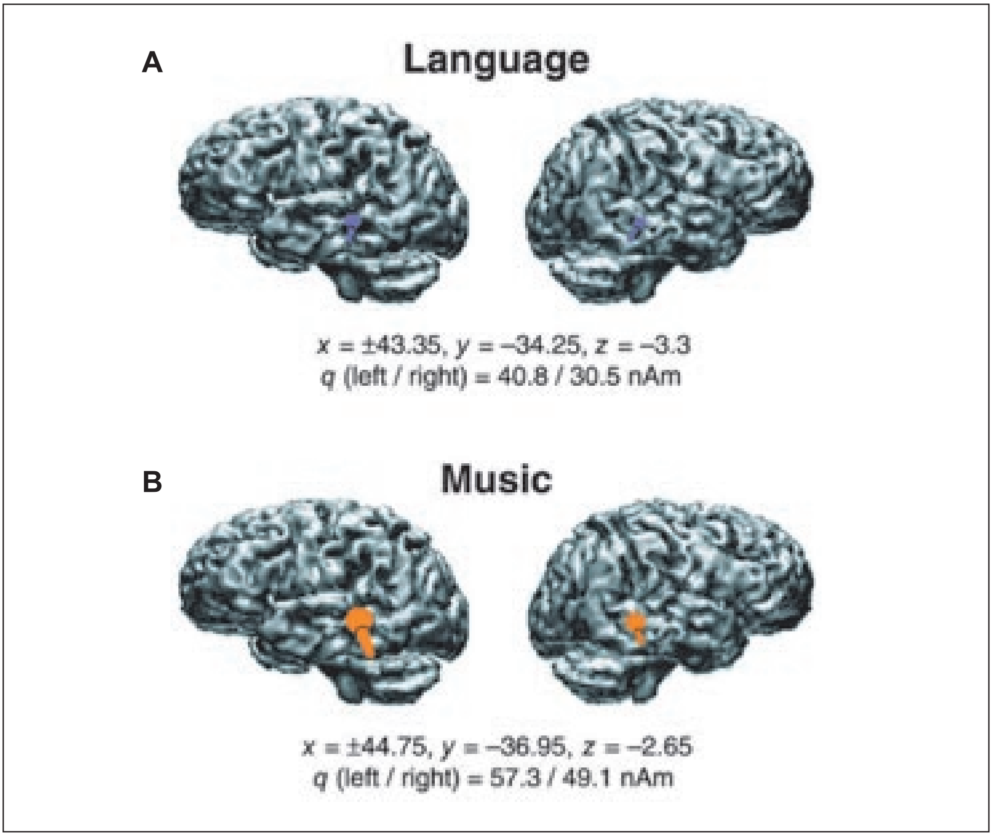

Fig. 2 Localization of the main neuronal sources of semantic processing, separately for (*A*) the language and (*B*) the music condition (from Koelsch et al. 2004)

The N400 effect in the music condition demonstrates that musical information can have a systematic influence on the semantic processing of words. The finding that the N400 effect did not differ between the language- and the music condition, indicating that musical information can even have the same effects on semantic processing as linguistic information. That is, the data demonstrate that music can activate representations of meaningful concepts, and that, thus, music is capable of transferring considerably more meaning information than previously believed.

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 relations between primes and target words were balanced, indicating that music can not only transfer emotional information.

The present findings support the assumption that the human brain processes music and language with overlapping cognitive processes, in overlapping cerebral structures (for a review see Koelsch and Friederici 2003, see also Patel 2003). This assumption is in line with findings showing that musical syntax is processed similarly as linguistic syntax. Using magnetoencephalography (MEG), it was found that a music-syntactically irregular chord (e.g., a *submediant* at the end of a chord sequence instead of a *tonic*) is processed in brain structures that are also involved in the processing of linguistic syntax (see Maess et al. 2001, Fig. 3: in the left hemisphere, the area in which the grand-average dipole is located is denoted as *Broca's area*). With functional magnetic resonance imaging (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), but also posterior temporal areas (Fig. 4, see also Koelsch et al. 2002). The latter areas are in the left hemisphere often denoted as *Wernicke's area*. Both Broca's area and Wernicke's region are crucially involved in the perception and the production of language; the interplay between these structures has for a long time been thought to be language-specific. The data presented in Figure 4 show that the cortical "language-network" also serves the processing of music (in the language domain, this network is often lateralized to the left hemisphere, in the music-experiment it was slightly right-lateralized).

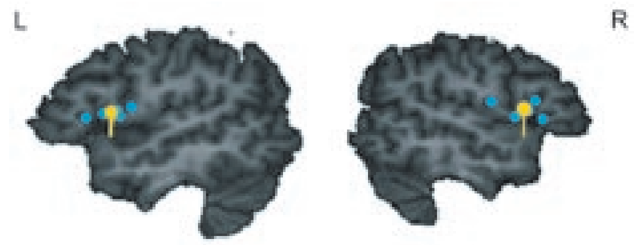

Fig. 3 Localization of the primary neuronal sources of music-syntactic processing (from Maess et al. 2001)

The presented findings indicate that the human brain does often make no essential difference between musical and linguistic information – or, in other words, that the brain takes music often as language, and *vice versa*. The finding of a cerebral network that is used for the processing of both music and language also explains why musical elements participate very early in the process of language development in children: it has been hypothesized (*i*) that music and speech are intimately connected in early life (Trehub et al. 2000), (*ii*) that musical elements pave the way to linguistic capacities earlier than phonetic elements (Papoušek 1996), and (*iii*) that melodic aspects of adult speech to infants represent the infant's earliest associations between sound patterns and meaning (Fernald 1989), as well as between sound patterns and syntactic structure (Jusczyk and Krumhansl 1993). Note that most people on earth speak tone languages, i.e., languages in which changes in pitch lead to changes in word meaning. Even in non-tonal languages, prosody (i.e., the musical information of speech such as melody and rhythm) is of crucial importance for the coding of the meaning of speech.

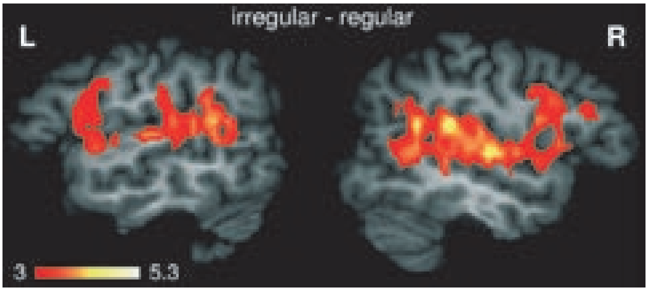

Fig. 4 Brain activations elicited by the processing of unexpected chords (contrasted to activations elicited by expected chords) (from KOELSCH et al. 2002)

Interestingly, all participants of the studies presented in this article were so-called “nonmusicians” (i.e., subjects without any formal musical training). The results show that even nonmusicians (who neither have explicit music-theoretical knowledge, nor special musical training) can process musical syntax, and understand musical semantics. The (implicit) musical knowledge is presumably acquired during listening experiences in everyday life. These assumptions are in line with studies showing that the acquisition of musical knowledge, and the processing of musical information according to this knowledge, is a general ability of the human brain. It is assumed that this general human musicality played a key phylogenetical role for the evolution of language, and that music making behavior covered important evolutionary functions such as group coordination and social cohesion (ZATORRE and PERETZ 2001). With this respect, the human musicality also stresses the biological relevance of music.

References

BAUMGAERTNER, A., WEILLER, C., and BÜCHEL, C.: Even-related fMRI reveals cortical sites involved in contextual sentence integration. NeuroImage *16*, 736–345 (2002)

DÉMONET, J., CHOLLET, F., RAMSAY, S., CARDEBAT, D., NESPOULOUS, J. L., WISE, R., RASCOL, A., and FRACKOWIAK, R.: The anatomy of phonological and semantic processing in normal subjects. Brain *115*, 1753–1768 (1992)

FERNALD, A.: Intonation and communicative intent in mother’s speech to infants: Is the melody the message? Child Develop. *60*, 1497–1510 (1989)

FRIEDERICI, A. D.: Towards a neural basis of auditory sentence processing. Trends Cogn. Sci. *6*(2) (2002)

FRIEDERICI, A. D., OPITZ, B., and CRAMON, D. Y. VON: Segregating semantic and syntactic aspects of processing in the human brain: An fMRI investigation of different word types. Cereb. Cortex *10*, 698–705 (2000)

HALGREN, E., DHOND, R. P., CHRISTENSEN, N., VAN PETTEN, C., MARINKOVIC, K., LEWINE, J. D., and DALE, A. M.: N400-like magnetoencephalography responses modulated by semantic context, word frequency, and lexical class in sentences. NeuroImage *17*, 1101–1116 (2002)

HELENIUS, P., SALMELIN, R., SERVICE, E., and CONNOLLY, J. F.: Distinct time courses of word and context comprehension in the left temporal cortex. Brain *121*, 1133–1142 (1998)

HEVNER, K.: The affective value of pitch and tempo in music. Amer. J. Psych. *49*, 621–630 (1937)

JONES, M. R., and HOLLERAN, S. (Eds.): Cognitive Bases of Musical Communication. Washington D. C.: Amer. Psychol. Assoc. 1992

JUSCZYK, P. W., and KRUMHANSL, C. L.: Pitch and rhythmic patterns affecting infants’ sensitivity to musical phrase structure. J. Exp. Psych.: Human Perc. Perform. *19*(3), 627–640 (1993)

KELLENBACH, M., WIJERS, A., and MULDER, G.: Visual semantic features are activated during the processing of concrete words: event-related potential evidence for perceptual semantic priming. Cogn. Brain Res. *10*, 67–75 (2000)

Koelsch, S., and Friederici, A. D.: Towards the neural basis of processing structure in music: Comparative results of different neurophysiological investigation methods. Ann. New York Acad. Sci. *999*, 15–27 (2003)

Koelsch, S., Gunter, T. C., Cramon, D. Y. von, Zysset, S., Lohmann, G., and Friederici, A. D.: Bach speaks: A cortical ‚language'-network serves the processing of music. NeuroImage *17*, 956–966 (2002)

Koelsch, S., Kasper, E., Sammler, D., Schulze, K., Gunter, T. C., and Friederici, A. D.: Music, language and meaning: Brain signatures of semantic processing. Nature Neurosci. *7*(3), 302–307 (2004)

Kuperberg, G., McGuire, P. K., Bullmore, E. T., Brammer, M. J., Rabe-Hesketh, S., Wright, I. C., Lythgoe, D. J., Williams, S. C. R., and David, A. S.: Common and distinct neural substrates for pragmatic, semantic and syntactic processing of spoken sentences: An fMRI study. J. Cogn. Neurosci. *12*(2), 321–341 (2000)

Kutas, M., and Hillyard, S.: Reading senseless sentences: Brain potentials reflect semantic incongruity. Science *207*, 203–205 (1980)

Maess, B., Koelsch, S., Gunter, T. C., and Friederici, A. D.: ‚Musical Syntax' is processed in Broca's area: An MEG-study. Nature Neurosci. *4*(5), 540–545 (2001)

Meyer, L. B.: Emotion and Meaning in Music. Chicago: University of Chicago Press 1956

Ni, W., Constable, R. T., Mencl, W. E., Pugh, K. R., Fulbright, R. K., Shaywitz, B. A., Gore, J. C., and Shankweiler, D.: An even-related neuroimaging study distinguishing form and content in sentence processing. J. Cogn. Neurosci. *12*(1), 120–133 (2000)

Osterhout, L., and Holcomb, P.: ERPs and language comprehension. In: Rugg, M., and Coles, M. (Eds.): Electrophysiology of Mind. Event-Related Potentials and Cognition; pp. 192–208. Oxford: Oxford University Press 1995

Papoušek, H.: Musicality in infancy research. In: Sloboda, J. A., and Deliege, I. (Eds.): Musical Beginnings. Oxford: Oxford University Press 1996

Patel, A. D.: Language, music, syntax and the brain. Nature Neurosci. *6*(7), 674–681 (2003)

Peirce, C.: The Collected Papers of C. S. Peirce. Cambridge: Harvard 1958

Price, C., Moore, C., Humphreys, G., and Wise, R.: Segregating semantic from phonological processes during reading. J. Cogn. Neurosci. *9*(6), 727–733 (1997)

Raffmann, D.: Language, Music, and Mind. Cambridge: MIT Press 1993

Swain, J.: Musical Languages. New York: Norton 1997

Trehub, S., Schellenberg, G., and Hill, D.: The origins of music. Perception and cognition: A developmental perspective. In: Wallin, N. L., Merker, B., and Brown, S. (Eds.): The Origins of Music. Cambridge, M. A.: MIT Press 2000

Zatorre, R., and Peretz, I.: The biological foundations of music. Ann. New York Acad. Sci. *930* (2001)

Zbikowski, L.: Conceptualizing Music: Cognitive Structure, Theory, and Analysis. New York: Oxford University Press 2002

Dr. Stefan Koelsch
Max-Planck-Institut für Kognitions-
und Neurowissenschaften
Nachwuchsgruppe „Neurokognition der Musik"
Stephanstraße 1a
04103 Leipzig
Germany
Phone: +49 341 9940121
Fax: +49 341 9940113
E-Mail: koelsch@cbs.mpg.de

Energie

Vorträge anläßlich der Jahresversammlung vom 17. bis 20. Oktober 2003 zu Halle (Saale)

Nova Acta Leopoldina N. F., Bd. *91*, Nr. 339
Herausgegeben von Harald zur Hausen (Heidelberg)
(2004, 378 Seiten, 175 Abbildungen, 25 Tabellen, 39,95 Euro,
ISBN 3-8047-2171-0)

Während früher naturwissenschaftliche und technische Argumente in Diskussionen über Energiebedarf, -erzeugung und -nutzung bestimmend waren, werden diese heutzutage auf vielfältige Weise durch ökologische, soziale und kulturelle Aspekte verdrängt. Bürgerinitiativen, Umweltgruppen, Medien, Gewerkschaften, Parteien und auch Kirchen sind am Energiediskurs beteiligt. Daß Energie eine naturwissenschaftliche Basis hat, wird in der Öffentlichkeit häufig kaum noch wahrgenommen. Aus einem naturwissenschaftlich-technischen ist ein gesellschaftswissenschaftlich-kultureller Diskurs geworden. Angesichts der Vielzahl unterschiedlicher Prognosen zum Weltenergiebedarf und der Energienutzung, die Experten und Politik der Öffentlichkeit vorlegen, kann das nicht verwundern. Die Leopoldina nahm das zum Anlaß, um auf ihrer Jahresversammlung verschiedene Energieszenarien zu erörtern. Ausgehend von den naturwissenschaftlichen Grundlagen werden sowohl die Auswirkungen der verschiedenen Formen von Energieträgernutzung auf die Umwelt, aber auch Leitbilder, Zielvorstellungen und ethische Prinzipien der Energieversorgung hinterfragt. Im Hinblick auf Komplexität, Globalität und Langfristigkeit des Energiebereiches liefern die Beiträge des Bandes eine auf dem heutigen Erkenntnisstand gegründete wissenschaftliche Standortbestimmung zu Fragen der Energieerzeugung und Energienutzung. Dabei werden Windkraft und Biomasse ebenso ausführlich betrachtet wie Kernenergie und Kernfusion. Die Tendenzen in der Nutzung fossiler Energieträger unterliegen einer kritischen Analyse. Außerdem werden technische Fragen (Solarzellen, Brennstoffzellen, Aufwindkraftwerke, energieeffizientes Gebäudemanagement) und ökonomische Probleme (z. B. der Strommarktliberalisierung) umfassend dargestellt. Ein Positionspapier faßt die Sicht der Leopoldina auf die für zukünftige politische, ökonomische und wissenschaftliche Weichenstellungen aktuell bedeutsame Energieproblematik zusammen.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Nova Acta Leopoldina NF *92*, Nr. 341, 113 –126 (2005)

„Wissenschaftlich exakte Musik“ durch elektronische Technik – Eine Idee und ihre Folgen

André Ruschkowski (Salzburg)

Mit 5 Abbildungen

Zusammenfassung

Eine Idee zieht sich wie ein roter Faden durch die Musikgeschichte, die Idee, eine „perfekte“ Musik zu schaffen. Bei der Verwirklichung dieser Vision sollte von Anfang an die Wissenschaft helfen. Im 20. Jahrhundert sah man vor allem in den Werkzeugen, welche die elektronische Musik entwickelt hatte, eine aktuelle Möglichkeit dazu. Es werden ausgewählte Resultate dieser Entwicklung in U- und E-Musik diskutiert und die prinzipielle Frage aufgeworfen, ob wissenschaftliche Methoden empirische Befunde erklären oder theoretische Modelle in sinnlich erfahrbare Praxis transformieren sollen.

Im zweiten Teil des Vortrages stellt der Autor mit *Trakl-Zyklus* und *Vom Blau umschauert ...* zwei eigene Kompositionen vor, welche wissenschaftliche Methoden in ein kompositorisches Konzept integrieren. Diese Integration versucht ein Gleichgewicht herzustellen zwischen dem grenzenlosen Reservoir wissenschaftlicher Methoden zur Generierung und Organisation von Klangmaterial auf der einen Seite und der unverzichtbaren Notwendigkeit subjektiver Entscheidungen des Komponisten auf der anderen Seite.

Abstract

There is a basic idea in the history of music, the idea of “perfect” music. From the very beginning science should help to reach this aim. In the 20th century the special means of electronic music should contribute to that process. In this paper selected results of that development in the area of popular and contemporary music are discussed. The principle question if scientific methods in music should explain practical experiences or transform theoretical models into a practice to become receptable by human senses is also discussed here.

During the 2nd part of the paper the author is presenting two compositions by himself (*Trakl-Zyklus*, *Vom Blau umschauert ...*). Both of them are using scientific methods during the composition process. This kind of integration tries to find a balance between the borderless number of scientific methods for the generation and organization of sound material and the subjective decision by the composer.

Die Beziehung von Musik zur Wissenschaft, d. h. hier genauer zur Naturwissenschaft, könnte man in den letzten Jahrzehnten wohl treffend als eine Art „Haßliebe“ charakterisieren. Gern und in den letzten Jahrzehnten zunehmend häufig versichert man sich im musikalischen Bereich der Unterstützung der Wissenschaft, um aber – oft im gleichen Augenblick – die Eigenständigkeit und Unabhängigkeit von Kunst gegenüber wissenschaftlichen Denkweisen und Praktiken zu betonen.

Von Seiten der exakten Wissenschaften nimmt man das künstlerische Interesse an den eigenen Modellen und praktizierten Methoden überrascht, aber mit Wohlwollen zur Kenntnis, scheint dies doch den eigenen universalistischen Anspruch zu bestätigen. Lebt man ansonsten doch in einer Welt, in der nach landläufiger Vorstellung Kunst, insbesondere Musik, für das Gefühl zuständig ist, und Wissenschaft gewissermaßen für den ernsthaften Rest des Alltages die Verantwortung zu übernehmen hat.

Eine fein säuberliche Aufgabentrennung, die aber, wie eingangs festgestellt wurde, so nicht mehr existiert. Da drängt sich natürlich sofort die Frage nach dem *Warum?* auf. Oder anders gefragt: Was soll mit der Hilfe von Wissenschaft bzw. wissenschaftlichen Methoden im musikalischen Kontext erreicht werden, was mit anderen, wie den tradierten künstlerischen Methoden des jeweiligen Bereiches, nicht realisierbar ist?

Zur Beantwortung dieser Frage ist ein kleiner historischer Seitenblick hilfreich. Sucht man nach den frühesten Anwendungen für wissenschaftliche Methoden in der Musik, dann stößt man sicherlich schnell auf Pythagoras und seine Berechnungen von Saiten- bzw. Schwingungsverhältnissen. Der empirische Befund, daß Saiten mit verschiedenen Tonhöhen schwingen können und daß diese Tonhöhen relativ zueinander Beziehungen eingehen, die wir als harmonisch oder disharmonisch empfinden, war hier der Ausgangspunkt. Um diesen empirischen Befund zu erklären und ihn nach Möglichkeit auch wiederholbar und damit auch künstlerisch gezielt gestaltbar zu machen, suchte – und fand – Pythagoras die heute nach ihm benannten Zusammenhänge.

Das wissenschaftliche Experiment diente also dem Finden einer Erklärung, einer möglicherweise unbewußt, aber immer gleich wirkenden Gesetzmäßigkeit, welche den empirischen Tatsachen zugrunde liegt. Das Ziel dieser Forschungstätigkeit ist also das Verstehen der künstlerischen, d. h. in diesem Fall musikalischen Phänomene, um durch diese Kenntnisse den Umgang mit diesen Phänomenen im musikalischen Schaffensprozeß zu optimieren.

Diese wissenschaftliche Forschungstätigkeit erstreckte sich in den letzten 2000 Jahren im wesentlichen auf die Untersuchung der Tonsysteme, um wiederum ursprünglich empirisch diagnostizierte Beziehungen von Intervallen und Akkorden zu untersuchen.

Die Situation änderte sich allerdings schlagartig, als die ersten Anwendungen elektrischer bzw. elektronischer Technik die musikalische Sphäre erreichten.

Zunächst wurde diese Technik ausschließlich für die Erzeugung neuer, bis dahin unvorstellbarer Klangfarben verwendet. Dabei erwiesen sich die wissenschaftlichen Erkenntnisse, welche man über schwingende Saiten gewonnen hatte, als ausgesprochen nützlich. Auf ihrer Grundlage konnte man auch elektronische Schwingkreise in harmonischen Frequenzverhältnissen in Funktion setzen, und damit war die additive Klangsynthese geboren.

Die erste und bis heute wohl spektakulärste Anwendung dieser Technik fand sich im Dynamophone von Thaddeus Cahill, welches er um 1900 in Form einer 200 t schweren Maschine konstruierte. Dieses Instrument ist heute nicht nur durch seine Monstrosität von Interesse, sondern auch durch zwei weitere Eigenschaften, welche mit diesem Instrument die Neuzeit des elektronischen Musikinstrumentenbaus einleiteten. Der Konstrukteur Thaddeus Cahill, ein professioneller Erfinder, der u. a. durch die Erfindung der elektrischen Schreibmaschine von sich reden machte, wollte mit seiner Entwicklung nicht die wissenschaftliche Forschung im musikalischen Bereich fördern, sondern vor allem eines: Geld verdienen. Dazu hatte er sich für die Konzerte mit dem Dynamophone ein System von Subscriber-Zirkeln ausgedacht, welche für die Möglichkeit, Musik mit dem Dynamophone am Telefon zu hören, einen monatlichen Betrag zu entrichten hatten. Das von ihm offerierte Musikprogramm orientierte sich dabei an dem, was einen maximalen Zuspruch des Publikums erwarten ließ, und beinhaltete das, was man heute als „populäre Klassik" bezeichnen würde. Sein Werbespruch war „Sensation, Education, Orchestration and Revelations by Electrical Music" (Weidenaar 1995, S. 180). Nach anfänglichen hohen Zuwachsraten bei den Teilnehmern geriet das Projekt jedoch rasch an seine technischen Grenzen, d. h., die Zahl der Teilnehmer ließ sich aus technischen Gründen nicht beliebig steigern. Beeinträchtigungen des normalen Telefonverkehrs waren die Folge, und das führte schnell zum Ende dieses vielverspechenden Instruments und Geschäftsmodells.

Es gibt aber noch einen zweiten Punkt, der an diesem Instrument und der Wahrnehmung dieses Instruments in der zeitgenössischen Öffentlichkeit bemerkenswert ist. Ein zeitgenössisches Magazin (Baker 1906) bescheinigte dem Dynamophone nichts weniger, als die Fähigkeit, »wissenschaftlich perfekte Musik« erzeugen zu können. Eine bemerkenswerte Formulierung, welche ich auch gleich in den Titel meiner Ausführungen hier übernommen habe. Scheint sie doch prägnant zusammenzufassen, was die Erwartungen an die Anwendung elektronischer Technik im musikalischen Kontext von Anfang an waren: Man wollte nichts geringeres als das universell handhabbare Werkzeug zur Herstellung perfekter Musik schaffen. Und was »perfekte« bzw. »wissenschaftlich perfekte« Musik denn überhaupt sei, das wurde zumindest indirekt definiert, nämlich Musik, die sich perfekt verkaufen läßt, d. h. möglichst perfekt die Erwartungen des Käufers bedient.

Diese Orientierung der Forschung und Entwicklungsarbeit war bei Cahill und dem Dynamophone nicht etwa ein Einzelfall, auch der nur einige Jahre später gebaute RCA-Synthesizer von Harry F. Olson und Herbert Belar hatte ursprünglich die Aufgabe, die Realisation von perfekter Popmusik zu ermöglichen. Der Ankauf dieses Gerätes durch das *Columbia-Princeton Tape Music Center* im Jahr 1959 führte dann allerdings zu einer anderen Orientierung der Arbeit mit diesem Gerät.

Wenn man es genau untersucht, dann läßt sich die gesamte Geschichte elektronischer Musikinstrumente im populären Bereich unter diesem Aspekt zusammenfassen. Vom Moog-Synthesizer bis hin zu MIDI- und Audiobearbeitung im Computer, stets erwartete man von der neuen Technik auch eine neue Stufe der Perfektionierung des damit erstellten musikalischen Produktes, immer stärkere Klangreize, welche vor allem die abgenutzten melodischen Skalen und Rhythmen wieder mit neuem Leben erfüllen sollten. Damit läßt sich die Rolle elektronischer Technik zumindest im populären Musikbereich hinreichend charakterisieren.

An dieser Stelle könnte ich meine Ausführungen eigentlich abbrechen, denn für die Mehrheit der Hörer endet die musikalische Wahrnehmung auch hier, d. h. an den Grenzen der Popmusik. Alle weiteren Aktivitäten werden im öffentlichen Bewußtsein kaum registriert, was aber (bis jetzt zumindest) nicht dazu führt, daß es keine weiteren Aktivitäten über Pop- und Volksmusik hinaus gibt.

Gerade in der zeitgenössischen Musik der 2. Hälfte des 20. Jahrhunderts haben wissenschaftliche Methoden in einem Ausmaß Einzug gehalten, so daß man – wie eingangs erwähnt – schon fast von inflationären Tendenzen in diesem Bereich sprechen kann.

Nachdem der Hauptmotor im populären Bereich, nämlich die Perfektionierung des Produktes in Bezug auf eine bessere Vermarktbarkeit, im E-Musikbereich weitgehend vernachlässigt werden kann, drängt sich an dieser Stelle die schlichte Frage auf: Warum ist das dann so? Bei der Beantwortung dieser Frage scheint es auch wiederum hilfreich, danach zu suchen, wie alles begann. Oder genauer: Was das ursprüngliche Interesse an wissenschaftlichen Methoden im E-Musikbereich begründet hat.

Da steckte man Anfang der 50er Jahre des 20. Jahrhunderts in einem Dilemma. Die serielle Kontrolle der Dimension Klangfarbe wollte einfach nicht überzeugend gelingen. Abhilfe versprach die Umkehrung des Fourier-Theorems, nachdem man alle Klangfarben nicht nur in Sinustöne zerlegen kann, sondern sie eben auch aus solchen wieder zusammensetzen können müßte.

Wissenschaftliche Methoden waren hier also nicht dazu da, empirische Tatsachen zu erklären, sondern ein kompositorisches System, wie es die serielle Musik verkörperte, zu perfektionieren. Die elektronische Musik, zumindest jene Spielart, die in Köln und Umgebung praktiziert wurde, war geboren.

Die wissenschaftlichen Methoden der elektronischen Technik sollten hier also etwas erreichen, was mit Hilfe der bis dahin bekannten Methoden musikalischer Technik praktisch unmöglich war: die serielle Kontrolle des Parameters Klangfarbe durch additive Synthese von Sinustönen.

Die Praxis im (N)WDR-Studio für elektronische Musik zeigte alsbald die Begrenztheit dieser Methode, und die zahlreichen technischen Schwierigkeiten bei der Umsetzung traten deutlich hervor. Schlimmer noch, die musikalischen Resultate blieben hinter den hohen Erwartungen zurück, und so blieb nur die bittere Einsicht, daß das ursprüngliche Konzept gescheitert war.

Was war hier geschehen? Im künstlerischen Kontext wurde ein naturwissenschaftliches Experiment durchgeführt (mit: Hypothese – Versuch – Verifikation/Falsifikation des Ergebnisses), wobei das Ergebnis nicht den in der Hypothese formulierten Erwartungen entsprach. Experimentelle Naturwissenschaft pur sozusagen.

Sogar die Reaktion auf diesen Mißerfolg kann man als wissenschaftlich experimentell bezeichnen, indem man nämlich begann, die Ausgangs- bzw. Rahmenbedingungen für nachfolgende Experimente zu verändern. Die wesentliche Modifikation bestand nun in der Integration von auch nicht aus Sinustönen zusammengesetzten Schallereignissen, was u. a. zu Kompositionen wie Stockhausens *Gesang der Jünglinge* geführt hat.

Hätte man also den Traum von „wissenschaftlich perfekter" Musik mit Hilfe elektronischer Technik bereits zu diesem Zeitpunkt begraben müssen? Ja und nein.

Man sah in den Mitteln der elektronischen Musik das Werkzeug, nicht nur um musikalische Ideen realisierbar zu machen, die mit traditionellen musikalischen Methoden nicht zu verwirklichen waren, sondern mehr noch: man wollte so wissenschaftliche, und damit gewissermaßen objektive Ordnungsprinzipien in die Kunstproduktion einführen. Der Einfluß des Komponisten tritt zurück zugunsten einer eben „perfekten wissenschaftlichen" Musik, die in ihrer abstrakten Idee sicherlich nicht zufällig an eine *musica mundana* erinnert, die das perfekte Abbild Gottes verkörpert.

Eine Ursache für diese universalistische Vision dürfte die Verwechslung von Komposition und Organisation sein, ein Umstand, den seinerzeit schon Pierre Boulez beklagte.

Methoden zur Generierung und Organisation von Klangmaterial gibt es heute in mannigfachen Ausführungen. Dabei können wissenschaftliche Methoden eine wichtige, ja oftmals unverzichtbare Hilfe sein. Dennoch, und das ist das Entscheidende, können diese so gewonnenen musikalischen Elemente stets nur als Ausgangspunkte für den eigentlichen, subjektiv geprägten Kompositionsprozeß fungieren. Diese kompositorischen Entscheidungen sind nicht ungestraft einem Computerprogramm zu überantworten, weil dies, so Boulez an gleicher Stelle, „mit geradezu verheerender Inhaltslosigkeit bestraft wird" (Boulez 1972).

Musik bleibt also eine durch und durch irdische Veranstaltung, welche sich zwar wissenschaftlicher Methoden bedienen kann, letztlich aber auch die subjektmächtige Brechung von Ordnungs- und Regelsystemen durch einen Komponisten erfordert, der dies dann allerdings auch selbst zu verantworten hat.

Nova Acta Leopoldina NF *92*, Nr. 341, 113–126 (2005)

Im nun folgenden zweiten Teil meines Beitrages möchte ich Ihnen zwei Beispiele aus meiner kompositorischen Praxis vorstellen, welche die soeben gemachten Ausführungen (hoffentlich) anschaulich nachvollziehbar machen sollen.

Durch die nahezu grenzenlose Vielfalt des elektronischen Klangmaterials sind überlieferte musikalische Regelsysteme, welche diskrete Tonhöhen mit unterscheidbaren Klangfarben in das Zentrum ihrer Gestaltung stellen, in elektronischer Musik nur bedingt anwendbar, da diese das eigentlich neue Potential dieses Klangmaterials – vor allem die unerhörte Geschmeidigkeit bei der Schaffung und Modifikation von Klangfarben – weitgehend ungenutzt lassen.

Daraus ergibt sich jedoch zwangsläufig die Frage nach geeigneten Alternativen für eine angemessenere kompositorische Gestaltung. Woran sollte diese sich aber halten, wenn nicht an diskrete Tonhöhen, welche sich in 2000 Jahren Musikgeschichte als relativ verläßlicher Faktor erwiesen haben? Eine Möglichkeit, diesem Dilemma zu entkommen, war und ist die Verwendung von Sprache bzw. Sprachmaterial als Gegenstand musikalischer Gestaltung. Warum nun gerade Sprachmaterial, da doch das sprachliche Kommunikationssystem des Menschen nahezu unabhängig ist von der ererbten musikalischen Ebene?

Zunächst einmal, weil es überhaupt eine weitgehend verläßliche Basis für akustische Kommunikation bildet und daher einen allgemein geläufigen Ausgangspunkt für weitere Erkundungen abgeben kann. In jedem Fall ergibt sich bei der musikalischen Gestaltung durch den nahezu vollständigen Verzicht auf traditionelle melodische und harmonische Elemente die Notwendigkeit zu verstärkter Reflexion und auch theoretischer Systematisierung der eigenen künstlerischen Handlungsweise. Eine stärkere Orientierung auf unmittelbar wirksame klangsinnliche Komponenten war und ist oft die Folge.

Ansonsten haben sich Komponisten schon immer von Bildern und Texten inspirieren lassen. Diese Beziehungen kann man heute zusätzlich auch auf kompositionstechnische Ebenen ausweiten, indem die Transformationen visueller und akustischer Strukturen zu direkten Quellen für musikalische Strukturen werden.

Sprachkomposition ist innerhalb elektronischer Musik inzwischen zu einem eigenen Genre geworden. Den Anfang machte 1956 der schon erwähnte *Gesang der Jünglinge* von Karlheinz Stockhausen, der Sprache bzw. Gesang zur erlösenden Erweiterung des streng seriell strukturierten Konzeptes der Kölner elektronischen Musik verwendete. Weitere, mittlerweile berühmte Stücke, wie *Thema – Omaggio à Joyce* von Luciano Berio und *Epitaph für Aikichi Kuboyama* von Herbert Eimert, folgten 1958 bzw. 1962 und waren ebenfalls Erkundungen auf dem Weg, die serielle Ordnung mit ihr nicht unterordenbaren Elementen anzureichern, um sie schließlich vollständig zu durchbrechen, durchaus mit Erfolg, wie man heute weiß. Andere Komponisten setzten von Anfang an vor allem auf die suggestive Kraft elektronischer Klänge, befürchteten jedoch, wie Edgard Varèse, daß es nicht lange dauern wird, bis „einige musikalische Nekromanten elektronische Musik in Regeln einbalsamieren wollen" (Varèse 1983, S. 23).

Gerade weil die assoziativen Komponenten elektronischer Klänge so dominierend sein können, war von Anfang an der Wunsch nach einem Wegweiser, einer allgemein kommunizierbaren Referenz für künstlerische Gestaltung besonders groß. Bei der Suche danach gewann die Erforschung genereller menschlicher Wahrnehmungsprinzipien in der künstlerischen Produktion an Bedeutung. Dabei wurde der Vergleich künstlerischer Gestaltungsweisen in unterschiedlichen Medien für die Ableitung möglichst allgemeingültiger Gesetze künstlerischer Wahrnehmung und damit auch künstlerischer Produktion bedeutsam.

Von den verschiedenen künstlerischen Medien ist die Beziehung von Poesie und Musik von besonderem Interesse, da es sich in beiden Fällen um zeitlich strukturierte auditive Ereignisse handelt, die jeweils spezifischen Regeln ästhetischer Produktion unterworfen sind.

Seit dem Anfang des 20. Jahrhunderts übte vor allem die bildende Kunst einen starken Einfluß auf das musikalische Denken von Moderne und sich ab 1910 entwickelnder Neuer Musik aus. Daher ist nicht erst seit Pierre BOULEZ' Aufsatz „An der Grenze des Fruchtlandes" der Maler und Kunsttheoretiker Paul KLEE auch in der Musik des 20. Jahrhunderts ein wichtiger Bezugspunkt. Neben dem musikalisch inspirierten Charakter eines großen Teils seines bildnerischen Schaffens – KLEE war bekanntlich auch ein guter Geiger – und seinen Aktivitäten beim „Blauen Reiter" gibt es noch eine weitere bemerkenswerte, bisher aber kaum beachtete Seite in KLEES Schaffen. Sie betrifft Grundzüge seiner bildnerischen Schaffensästhetik um 1920 und ihr bisher ungenutztes Potential im musikalischen Kontext.

Ab 1916 begann Paul KLEE den Vorrat seiner Darstellungsmittel um abstrakte Zeichen, Zahlen und Buchstaben zu erweitern. In dem 1918 entstandenen Aquarell *Einst dem Grau der Nacht enttaucht ...* nahm KLEE, einen geschriebenen poetischen Text als unmittelbaren Ausgangspunkt für die malerische Gestaltung.

Dieser Text ist im Bild so deutlich gegenwärtig, daß die Buchstabenketten nicht nur die Struktur des Bildes fast vollständig determinieren, sondern die Konturen der Buchstaben begrenzen auch die einzelnen Feldflächen, mit deren Farbwahl er den semantischen Inhalt der Textzeilen direkt kommentiert. KLEE verwendet hier also die Darstellung eines poetischen Textes als bildkompositorischen Ausgangspunkt, und zwar sowohl auf der formalen als auch auf der inhaltlichen Ebene.

Aus dem Jahr 1920 stammt das Ölbild *Kamel in rhythmischer Landschaft*, 1924 entstand das Aquarell *Wasserpflanzenschriftbild*, in denen deutliche gestalterische Parallelen zum Textaquarell von 1918 erkennbar sind.

Die strenge horizontale Gliederung, ursprünglich durch die Textketten determiniert, wird hier von KLEE als zentrales Strukturierungsprinzip beibehalten, obwohl er nun keinen erkennbaren Text mehr benutzt. Die Verwendung des Wortes „rhythmisch" im Bildtitel ist ein deutlicher Hinweis auf die zeitliche Dynamisierung, die KLEE mit Hilfe von Texten in seinen Bildern zu erreichen gedachte, wie er in seinem im gleichen Jahr erschienenen Manifest „Schöpferische Konfession" anmerkt. Diese horizontalen Gliederungen bilden nun das Gerüst für eine freizügigere malerische Gestaltung dessen, was sich zwischen diesen Linien abspielt. Beim *Kamel in rhythmischer Landschaft* ist die Verwandtschaft mit den wenige Jahre zuvor entstandenen Textbildern in den Konturen des Kamels besonders deutlich sichtbar.

Im Gesamtschaffen von Paul KLEE markieren diese Bilder eine Etappe auf dem Weg zu seinen nur wenig später entstandenen Farbform-Rhythmus-Gemälden, die sich u. a. durch weiterreichende formale Abstraktionen auszeichnen. KLEE griff also in einer für ihn bedeutsamen Phase künstlerischer Neuorientierung auf sprachliche Strukturen zurück, um diese als Ausgangspunkt sowohl für formale als auch inhaltliche Gestaltung zu verwenden. Dabei nutzte er die Qualität der Sprache, d. h. in seinem Fall poetischer Strukturen, als unmittelbar wirksames, allgemein verständliches Medium menschlicher Kommunikation und daher auch künstlerischer Artikulation.

Abb. 1 Paul KLEE: *Einst dem Grau der Nacht enttaucht* (1918)

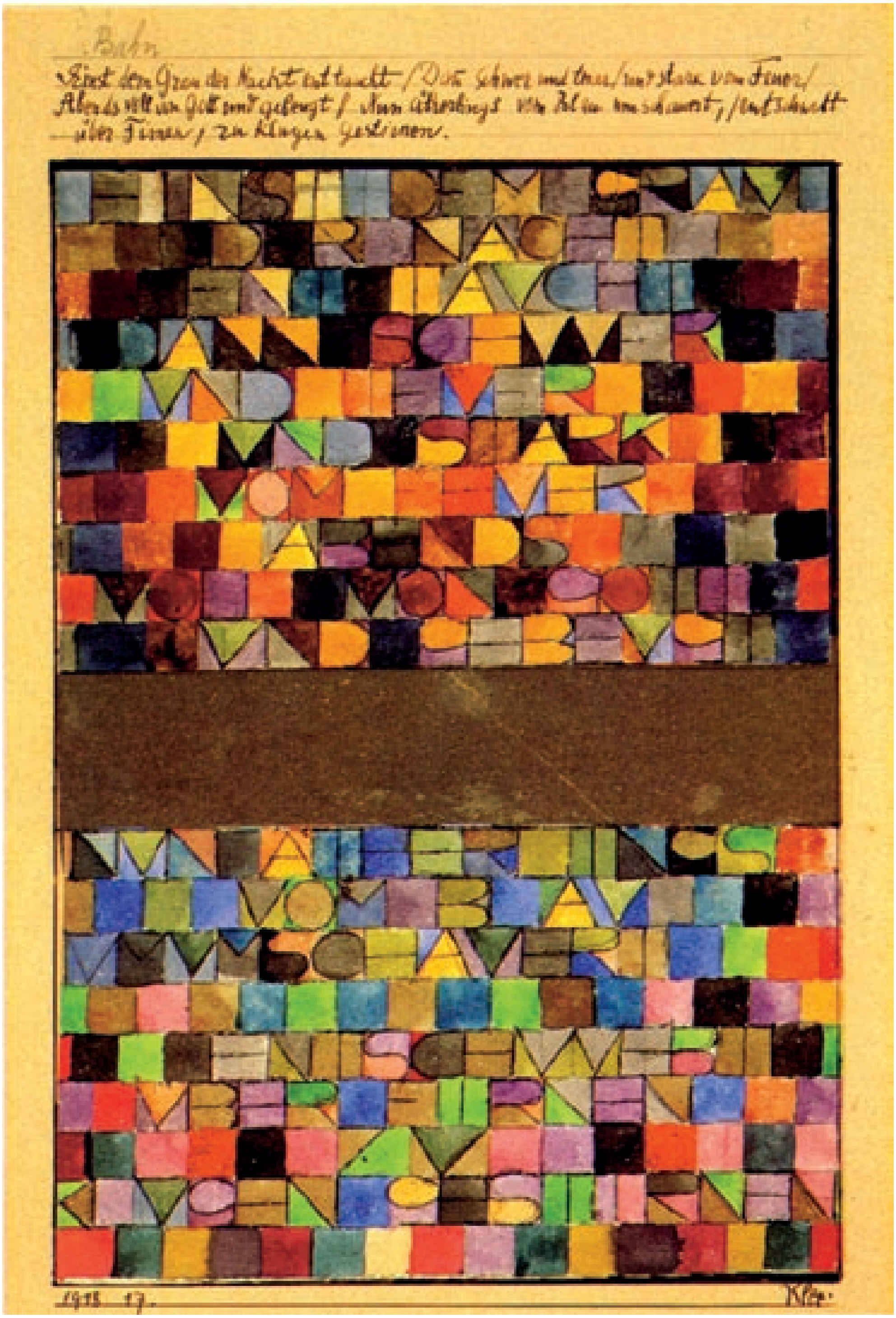

Abb. 2 Paul Klee: *Kamel in rhythmischer Landschaft* (1920)

Aus der Wirksamkeit dieses Konzeptes in der bildnerischen Sphäre folgt, daß sich auch im musikalischen Bereich Sprache auf diese Weise einsetzen lassen müßte. Sprache bzw. poetischer Text würde dann nicht auf konventionelle Weise vertont, sondern sowohl auf formaler als auch auf klanglicher und inhaltlicher musikalischer Ebene als Ausgangspunkt für die finale Gestaltung eines musikalischen Objektes verantwortlich sein.

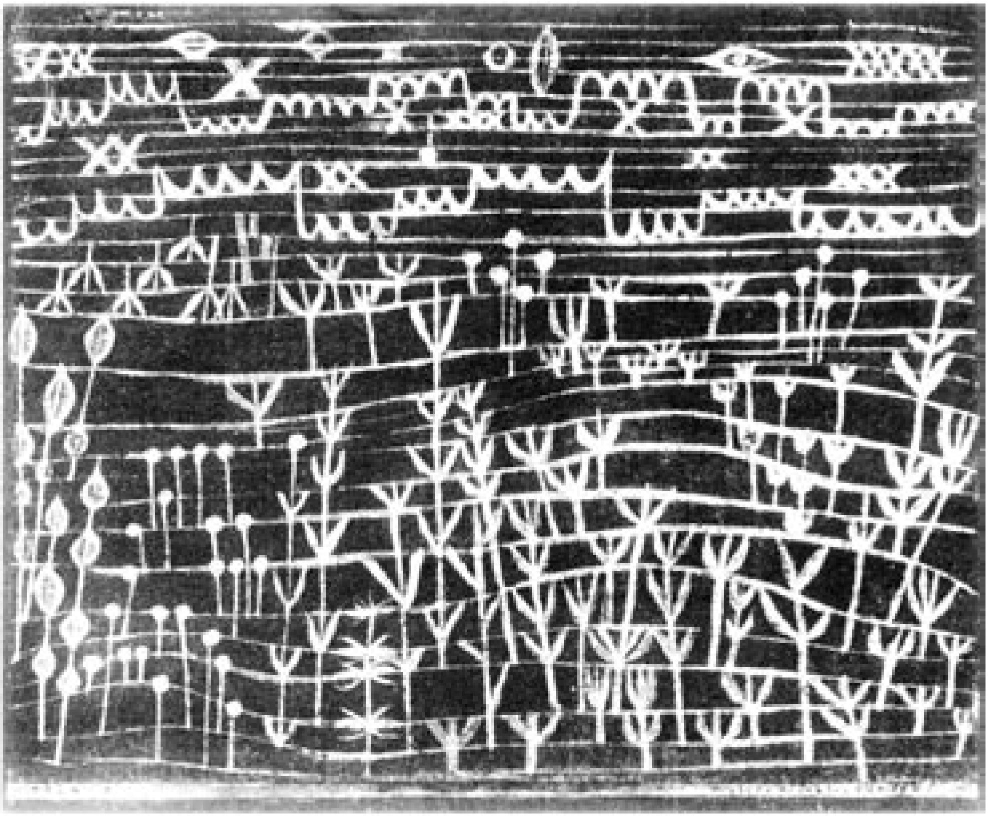

Abb. 3 Paul Klee: *Wasserpflanzenschriftbild* (1924)

Eine Verwendung von Sprache bzw. poetischem Text in dieser Weise liegt mehreren meiner elektronischen Kompositionen zugrunde, die in der Zeit seit 1989 entstanden sind. Dabei wurde für jedes der Stücke eine eigene kompositorische Technik entwickelt, um dem jeweiligen Ausgangstext in musikalischer Hinsicht möglichst nahe zu kommen.

Im Mai 1997 wurde in Salzburg mein *Trakl-Zyklus* für Sopran, Ensemble und Tonband uraufgeführt, welcher sämtliche Elemente der musikalischen Gestaltung unmittelbar aus Texten von Georg Trakl ableitet. Er besteht aus insgesamt vier separaten Kompositionen für unterschiedliche Besetzungen, die auch separat aufgeführt werden können. Alle verwenden poetische Texte von Georg Trakl als strukturelle und klangliche Grundlage.

Dabei bestimmen diese Texte sowohl die Klangfarben als auch die Struktur des musikalischen Resultats auf direkte Weise. Diese klanglichen Transformationen des Textes geschehen durch verschiedene Arten von Text- bzw. Klang-Analyse mit elektronischen Mitteln. Der Prozeß der Transformation unterteilt sich in 5 Phasen:

1. Der poetische Text wird rezitiert und das Ergebnis (mit einem DAT-Recorder) aufgenommen.
2. Das aufgenommene Textmaterial wird in einen Computer transferiert und einer Zeitdehnung bei gleich bleibender Tonhöhe unterworfen.

3. Das gedehnte Material wird mit Hilfe eines Bandpaß-Filters (BPF) in 4 verschiedene Frequenzbänder im Oktavabstand zerlegt.
4. Diese Frequenzbänder werden mit Hilfe der Fast-Fourier-Transformation analysiert und so die jeweils dominierenden Tonhöhen in diesen Bändern ermittelt.
5. Die letzte Phase beinhaltet das eigentliche Zusammensetzen dieser Elemente (vom griechischen Wort „componere") durch den Komponisten.

In der Praxis heißt das vor allem „wegwerfen" bzw. auswählen, da mit Hilfe dieser Technik sehr viele Tonhöhen selektiert werden. Am Ende steht dann – wenn alles gut gegangen ist – die auf dieser Grundlage entstandene Partitur für traditionelle Instrumente.

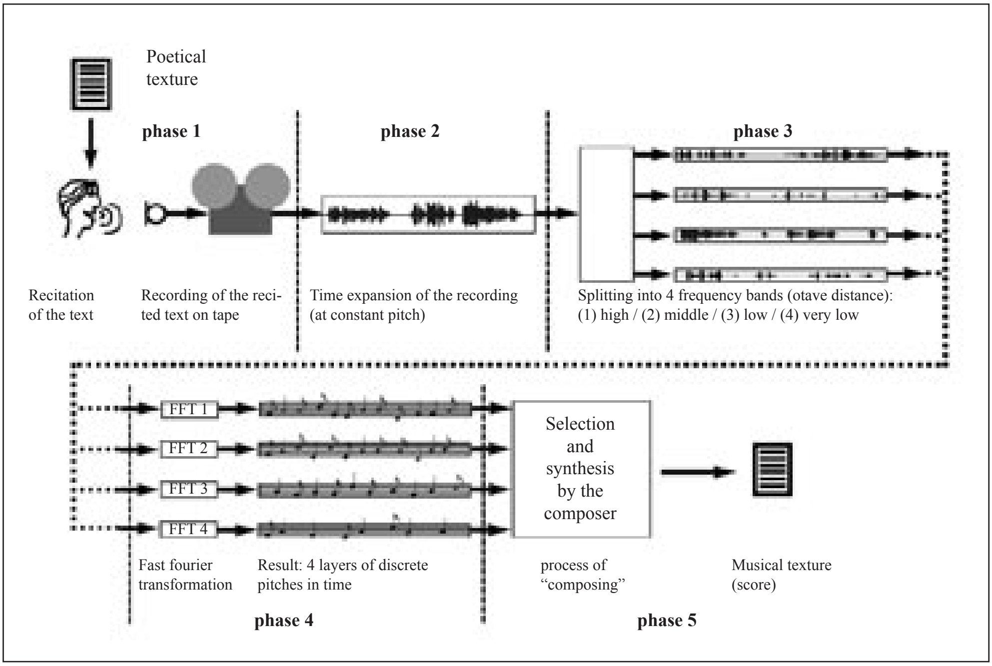

Abb. 4 Poetischer Text als eine Quelle für musikalische Struktur und Timbre (Ruschkowski 1997)

Wie wird nun diese Technik im *Trakl-Zyklus* angewandt? Sehen sie dazu die Abbildung 5.

Das Schema für die Entstehung von *In blauem Kristall* entspricht exakt dem der letzten Folie. Die Aufführung ist rein instrumental, d. h. ohne Elektronik ausschließlich für Flöte, Klarinette, Violine, Cello und Klavier. Lassen sie mich ein kurzes Klangbeispiel geben aus der Mitte des Stückes, wo der Sprachduktus bei den Instrumenten besonders deutlich wird.[1]

1 Musikbeispiel 1 CD Composers Edition Vol. III – [1] *In blauem Kristall*. Österreichisches Ensemble für Neue Musik, Leitung: Oswald Sallaberger. Bei den CDs der Reihe „Composers Edition" mit Kompositionen von André Ruschkowski sowie auch der DVD mit *Vom Blau umschauert* handelt es sich um eine signierte Autorenedition, und diese ist exklusiv im Internet unter www.ruschkowski.de erhältlich.

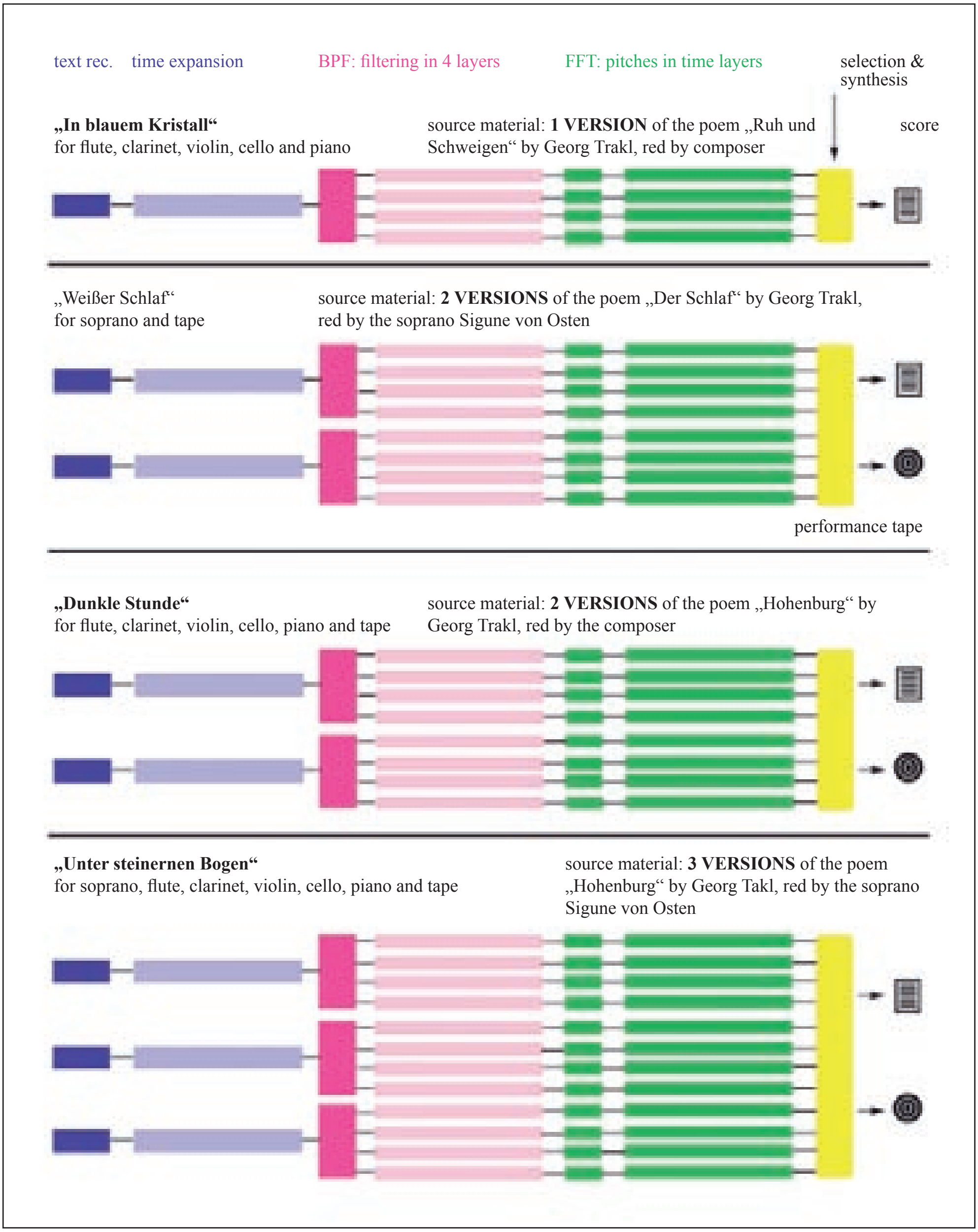

Abb. 5 Trakl-Zyklus (Ruschkowski 1997)

Sie sehen in der Abbildung, daß bei den weiteren Stücken wesentlich mehr Elemente an ihrer Entstehung beteiligt sind. Die Ursache dafür ist, daß Georg Trakl oft mehrere Fassungen seiner Gedichte – oft im Abstand von mehreren Jahren geschrieben – veröffentlicht hat. Der Vergleich der Fassungen zeigt, daß oftmals gleiche oder sehr ähnliche poetische Bilder mit anderen Strukturen von Wörtern erzeugt werden. Die Existenz dieser verschiedenen Varianten eines Textes von Georg Trakl findet ihre musikalische Entsprechung in der simultanen Verwendung von zwei – bzw. im letzten Stück sogar drei – verschiedenen Strukturebenen.

Ich möchte sie hier nicht mit zu vielen technischen Details ermüden. Neu ist hier – im Gegensatz zum ersten Stück –, daß stets ein 4-Kanal-Tonband bei der Aufführung dabei ist. Es erklingt gemeinsam mit den Instrumenten und der Singstimme. Diese Tonbänder beinhalten jeweils Kombinationen der einzelnen Frequenzbänder, die aus der Textrezitation und deren Zeitdehnung abgeleitet wurden.

Die Zuordnung der Frequenzbänder und der daraus abgeleiteten Tonhöhen – in Phase 5 des grafischen Schemas – zu den Tonbandspuren und den Instrumenten bzw. der Stimme erfolgt durch Entscheidung des Komponisten nach musikalischen und technischen Gesichtspunkten.

Dazu wurden die jeweiligen Texte zunächst durch die Sopranistin Sigune von Osten bzw. den Komponisten rezitiert und das klangliche Ergebnis mit einem Tonbandgerät aufgezeichnet. Diese Aufzeichnungen der gesprochenen Texte wurden anschließend im Computer verschiedenen Klanganalysen unterzogen. Die so gewonnenen Parameter über Zeit- und Frequenzstruktur der Grund- und Obertöne bildeten den Ausgangspunkt für den Tonsatz von Sopran, Instrumenten und auch für die Gestaltung des Klangmaterials der entsprechenden Tonbänder.

Die formale Struktur der jeweiligen Kompositionen wurde direkt aus den rezitierten Trakl-Texten abgeleitet, indem die Zeitachse der Originalaufnahmen um das 8- bis 12-fache linear gedehnt wurde, so daß deren ursprüngliche Proportionen erhalten blieben.

Die Frequenzspektren der gedehnten Textaufnahmen wurden jeweils in vier Oktavbänder unterteilt, um die zeitliche Zu- und Abnahme von Grund- und Obertönen der Sprechstimme in den jeweiligen Frequenzbereichen zu isolieren. Im Klangmaterial dieser Oktavbänder wurden nun mit Hilfe der Fast-Fourier-Transformation (FFT) die dominierenden Frequenzanteile ermittelt und diese in musikalische Tonhöhen übertragen. Die so abgeleiteten Tonhöhenstrukturen bildeten den Ausgangspunkt für die Komposition des Sopranparts und der Instrumentalstimmen.

Das 4-Kanal-Tonband beinhaltet Klangmaterial, welches sich ausschließlich aus den rezitierten Texten ableitet. Es wurde im Computer auf bis zu 15 Audiospuren ausgearbeitet und zur räumlichen Separierung komplementärer Klangereignisse sowie deren Bewegung im Raum auf eine Hörebene rund um das Publikum projiziert. Das 2-Kanal-Tonband transformiert die ursprünglich vierkanaligen Raumbewegungen so weit wie möglich in die räumliche Tiefe des Stereo-Panoramas.[2]

Ein relativ aktuelles Produkt in diesem Kontext ist die Sprachkompositionen *Vom Blau umschauert ...* nach einem Textgemälde von Paul Klee. Ausgangspunkt war Paul Klees Aquarell *Einst dem Grau der Nacht enttaucht ...* aus dem Jahr 1918, was zu Beginn des Vortrages bereits als Beispiel für Klees Technik herhalten mußte, aus Text- bzw. Buchstabenketten optische bzw. grafische Elemente abzuleiten.

Das im Vergleich zu den zuvor geschilderten Arbeiten Neue besteht in der Tatsache, daß Klees Textbild als direkter Ausgangspunkt für die musikalische Umsetzung verwendet wird.

2 Musikbeispiele 2 – CD Composers Edition Vol. III – [4] *Unter steinernen Bogen*. Österreichisches Ensemble für Neue Musik, Sopran: Sigune von Osten.

Das heißt, sowohl der Text selbst als auch seine grafische Gestaltung sind hier Quellen für die kompositorische Anordnung musikalischer Elemente.

Diese Elemente bestehen ausschließlich aus dem Text *Einst dem Grau der Nacht enttaucht* ..., den ja auch Klee als Ausgangspunkt verwendet. Dieser Text wurde gesprochen, d. h. rezitiert, das Resultat mit einem Mikrofon aufgenommen und in den Computer transferiert.

Was mit diesem Sprachtext im weiteren Verlauf des Kompositionsprozesses geschah, hing wiederum vor allem von Klees Textbild selbst ab: Die dort befindlichen 17 Textzeilen wurden im Computer abgetastet und ihre Farb- und Helligkeitswerte als Steuerungsparameter für die Modifikation des mit dem Mikrofon aufgenommenen Sprachtextes verwendet. Diese Modifikationen umfaßten vor allem zahlreiche Filterungen des Sprachsignals, aber auch eine Reihe von Resynthese-Parametern, die sich auf komplexere Veränderungen der Zeit- und Frequenzstruktur der Sprachklänge sowie deren Räumlichkeit bezogen.

Seit 2003 existiert diese Komposition auch in einer Fassung für Videoprojektion und Tonband. Die neu entstandene Video-Ebene dieser Komposition verwendet das Bild von Paul Klee als Ausgangspunkt für die Variation der dort vorhandenen Form- und Farbelemente. Das Textgerüst ist hier wirklich auch ein visuell wahrnehmbares Gerüst, welches – wie auch auf der akustischen Ebene – den Raum für die periodischen Variationen von Elementen des Original-Bildes strukturiert.[3]

Wo liegen nun die Vorteile einer solchen sprachorientierten Arbeitsweise? Zunächst ermöglicht dieses Vorgehen eine innige Verbindung von historisch gewachsenen Arbeitstechniken der elektronischen Musik mit denen der *Musique concrète* sowie den weitreichenden Möglichkeiten zur Klangsynthese und -bearbeitung heutiger Computertechnik. Im Mittelpunkt der musikalischen Gestaltung steht die sinnliche Erfahrbarkeit des Klanges. Die Strukturierung über Sprache bzw. ihre Elemente schafft eine wichtige Voraussetzung dafür, daß diese Dispositionen ebenfalls direkt wahrgenommen und verstanden werden können, d. h., ihr semantischer Gehalt wirkt ebenso wie die sinnliche Qualität des Klanges unmittelbar und ohne bewußte Decodierungsleistung des Rezipienten. Vom kompositorischen Standpunkt besonders reizvoll ist der Aufenthalt in der Übergangszone zwischen verständlichen und nicht mehr verständlichen Sprachelementen. Dieser Grenzbereich ist nicht konstant, er verschiebt sich beim Hören – je nach Kontext – ständig, und zeigt deutlich die Prozeßhaftigkeit der musikalischen Wahrnehmung. Der nachvollziehbaren Gestaltung dieses Prozesses waren in den hier genannten Musikbeispielen alle kompositionstechnischen Mittel untergeordnet. Damit bietet diese Methode der Sprachkomposition nicht nur eine praktikable, sondern auch eine flexibel und individuell erweiterungsfähige Alternative zu reinen material- oder strukturdominierten Vorgehensweisen beim Komponieren im elektronischen Medium.

3 Musikbeispiele 3 DVD Visuals I – *Vom Blau umschauert* ... Siehe Fußnote 1.

Literatur

Baker, R. S.: New Music for an Old World. McClure's Magazine July 1906
Boulez, P.: Einsichten, Aussichten. In: Boulez, P.: Werkstatt-Texte. Frankfurt (Main), Berlin 1972
Varèse, E.: Die Befreiung des Klanges. In: Varèse, E.: Rückblick auf die Zukunft. München 1983
Weidenaar, R.: Magic Music from the Telharmonium. N. J., London: The Scarecrow Press Inc. 1995

Dr. André Ruschkowski
Straußstraße 3
83457 Bayerisch Gmain
Bundesrepublik Deutschland
Tel.: +49 8651 68236
E-Mail: ruschkowski@web.de

Nova Acta Leopoldina NF *92*, Nr. 341, 127–134 (2005)

Wahrnehmung und Präsenz von Kunst

Helga de la Motte-Haber (Berlin)

Mit 2 Abbildungen

Zusammenfassung

In dem vorliegenden Aufsatz werden verschiedene Theorien der Wahrnehmung diskutiert, vor allem die Gestalttheorie und die Theorie des Mustererkennens. Jenseits der Differenzen zwischen diesen Theorien gibt es eine Übereinstimmung dahingehend, daß die Wahrnehmung keine bloße Widerspiegelung der physikalischen Bedingungen sei. Daraus kann geschlossen werden, daß ein ästhetischer Eindruck das Ergebnis einer Interaktion von äußeren Reizen und subjektiver Bedeutungsverleihung ist. Die traditionelle Ästhetik berücksichtigt weitgehend nicht den subjektiven Einfluß. Neue Ansätze sind daher notwendig.

Abstract

In this paper different theories of perception are discussed, mainly the Gestalt-theory and the theory of pattern recognition. Beyond the differences all theories assume that perception is not a pure reflection of the physical stimuli. Therefore it can be concluded that any aesthetic impression is the result of an interaction of the relation of the external stimulation and a subjective imagination. The traditional aesthetic does not respect the subjective impact. New forms are necessary.

1. Notwendigkeit von Rezeptionsästhetik

Ausgangspunkt für die Entstehung der Ästhetik als wissenschaftlicher Disziplin der Philosophie war einmal die Wahrnehmung gewesen. Eine *Cognitio sensitiva*, Erkenntnis durch Empfindung, hatte Alexander Gottlieb Baumgarten im Sinn, und bei Immanuel Kant spielte das Vermögen des Urteilens eine zentrale Rolle. Zunehmend aber geriet in den ästhetischen Schriften das rezipierende Subjekt aus dem Blick, oder es wurde in einen Anhang verdrängt. Formalästhetische Betrachtungen, im Fall der Musik die sogenannte werkimmanente Analyse, gewannen die Oberhand.

Die seit dem Ende der 1960er Jahre von der Literaturwissenschaft entwickelte sogenannte Rezeptionsästhetik hat zwar gegen diese Idee opponiert, dennoch meist eine Form der traditionellen Hermeneutik geübt. In der Musikwissenschaft scheint bis zum heutigen Tag der Hörer ein überflüssiges Beiwerk zu sein.

In der Kunstgeschichte allerdings finden sich in jüngerer Zeit mit dem unschönen Wort der Immergenz Überlegungen beschrieben über den „Betrachter im Bild". Denn allzu offensichtlich spielen bei Künstlern Gedanken an den Rezipienten eine Rolle. Ein Hinweis auf Caspar David Friedrich und die Rückenfiguren seiner Bilder möge dies belegen. Es handelt sich um Techniken, den Rezipienten in das Bild zu versetzen und in jene unbestimmte Ferne blicken zu lassen, die Friedrich auch als Projektion des tiefsten Inneren des Betrachters verstanden hatte.

Ist es also gerechtfertigt, nur die Frage zu stellen: „Was ist Kunst?“ Belehren uns nicht die Künstler darüber, daß doch über das „Wie“ der Wahrnehmung nachgedacht wurde. Die Konzentration auf die formalen Aspekte von Kunst, die wir gewohnt sind, verdankt sich einer einseitigen Rezeption der idealistischen Philosophie, die nur manchmal in den letzten beiden Jahrzehnten durch Erörterungen über ästhetische Erfahrungen durchbrochen wurde.

Andere Beispiele, die es geboten erscheinen lassen, die Wahrnehmungsakte zu bedenken, seien angeführt. Richard WAGNER hat den Hörer sehr bewußt in seine Musik einkomponiert, und zwar so, daß dieser regelrecht in die Klänge eintauchen soll. Er hatte keinen aktiven Nachvollzug im Sinn. Er zielte auf die völlige Identifizierung. Eine Technik, die er dazu benutzte, ist das Spiel mit dem Aufmerksamkeitsmechanismus des Hörers. Er überrollt ihn durch die satztechnische Faktur seiner Werke, so durch eine Form der Polyphonie, die keine Stimmen zu unterscheiden erlaubt. Ständige Überforderung riefe eine Form der gelernten Hilflosigkeit hervor, d. h., es würde abgeschaltet. Solcher Gleichgültigkeit beugt WAGNER vor, indem er mit den deutlich hervortretenden und wiedererkennbaren Leitmotiven suggeriert, daß der Hörer eventuell doch einen Überblick haben könnte. Die Leitmotive sind Weckrufe, die zu erneuter angestrengter Konzentration führen.

Den Aufmerksamkeitsmechanismus überzustrapazieren, fachlicher ausgedrückt, die Selektion von Information extrem zu erschweren, gehört – unabhängig von Material und historischem Standort – zu den wichtigsten Techniken, mit denen Komponisten eine maximale Nähe zwischen Hörer und Werk erreichen können. Alles was auf winzigen Unterschieden beruht, Gestaltauflösung andeutet, an der relativen oder absoluten Schwelle der menschlichen Wahrnehmung angesiedelt ist, erweist sich hierfür als taugliches Mittel. Die Intention, mit dem Aufmerksamkeitsmechanismus zu spielen, läßt sich an vielen Kompositionen der 2. Hälfte des 20. Jahrhunderts beobachten. Überlange Pausen wären als ein einfaches und probates Mittel zu nennen. Schon Iannis XENAKIS hatte mit 12 Sekunden in *Herma* die unmittelbare Gedächtnisspanne des Zuhörers weit überschritten, d. h., er bürdet dem Hörer eine extreme Anstrengung auf, wenn dieser seine Aufmerksamkeit aufrechterhalten möchte. In vielen Stücken der 1990er Jahre finden sich bei verschiedenen Komponisten solche auf eine psychologische Wirkung zielenden überlangen Pausen. Sie sollen nicht als transzendente Stille thematisiert werden. Bei Tonträgern sind übrigens solche Pausen meist erheblich gekürzt. Es zeigt sich daran, wie sehr ein Konzert ein audiovisuelles Ereignis ist.

Ein anderes leicht zu schilderndes Mittel aus jüngerer Zeit, mit dem die Aufmerksamkeit „auf die Folter gespannt“, d. h. überanstrengt wird, ist das vielfache Piano. Was extrem leise ist, ruft Orientierungsreaktionen des gespannten Lauschens hervor. Denn wer möchte nicht den *Reigen seliger Geister* von Helmut LACHENMANN wahrnehmen? Stücke, die an der Hörschwelle angesiedelt sind, diese zuweilen unterschreiten, um gespanntes Lauschen zu bewirken, waren in den 1990er Jahren eine Zeitlang so sehr in Mode, daß man glauben konnte, es ginge gar nicht mehr um ein individuelles ästhetisches Gebilde, sondern nur um eine akustische Reizsituation.

Resümee: Halten wir ein erstes Ergebnis fest: Künstlerische Sachverhalte sind ausgespannt zwischen objektiven Gegebenheiten und subjektiver Wahrnehmung. Sie lassen sich auf mehreren Ebenen theoretisch betrachten, nämlich im Hinblick auf Materialien oder Formen. Wichtig ist aber auch die intendierte und tatsächliche ästhetische Erfahrung. Eine nur material-formal ausgerichtete Annäherung an Kunst kann leicht zu kurz greifen.

Mit einem für die Kunst der 1960er Jahre wichtigen Werk ist dies besonders gut zu veranschaulichen. Robert MORRIS realisierte 1961 seine Auffassung: Einfachheit der Form ist

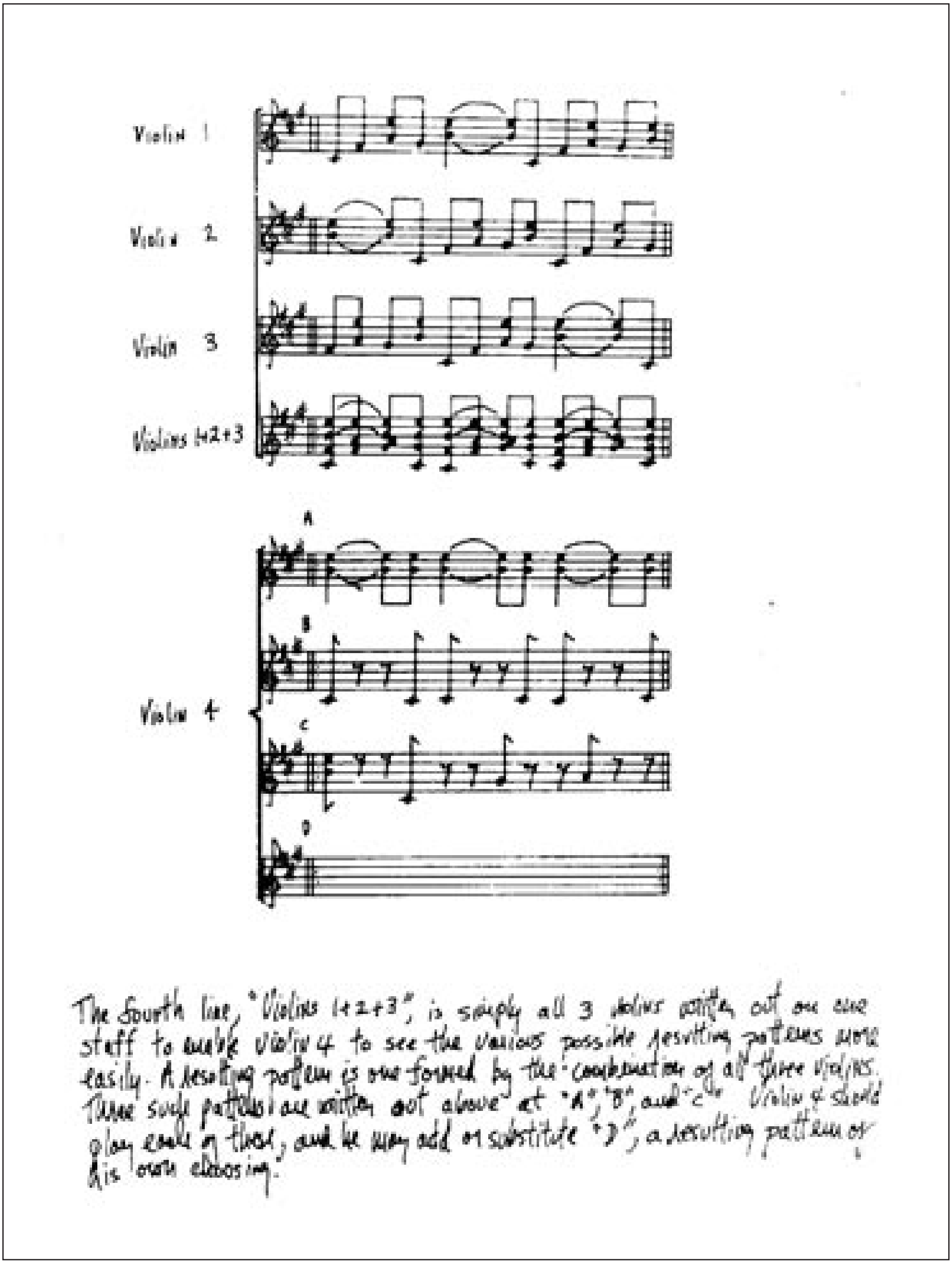

Abb. 1 Notenbeispiel 1. Steve Reich, *Violin Phase* (1967). In der auf repetitiven Strukturen basierenden Komposition von Steve Reich spielt ein Geiger zu drei Tonbandspuren, die er vorher eingespielt hat. Aus diesem Zusammenwirken von Stimmen können weitere Muster herausgehört werden, die der Komponist in der zweiten Akkolade andeutet. Da er jedoch die aktive Mitgestaltung eines Hörers intendiert, der noch weitere Pattern heraushören könnte, hat der Komponist ganz unten im System eine Notenzeile freigelassen.

nicht einfache Erfahrung mit einem mehr als schlicht zu nennenden Holzwürfel, aus dem von einer Kassette die Arbeitsgeräusche des Herstellungsprozesses tönen. Diese *Box With The Sound Of Its Own Making* rief die Kritik des prominenten amerikanischen Theoretikers Clement Greenberg hervor. Er warf dem Künstler einen Mangel an Richtigkeit der Form vor. Richtigkeit der Form: Theodor W. Adorno – vom musikalischen Treiben seiner Zeit irritiert – könnte mit seinem zur gleichen Zeit entstandenen Aufsatz *Vers une musique informelle* Greenberg an die Seite gestellt werden. Unter dem veränderten Blickwinkel einer Subjekt-Objekt-Relation könnte man allerdings eher Momente der Beunruhigung, des Irritiertseins bei diesen prominenten Kritikern diagnostizieren. Aversionen wären die Folge, weil das kategoriale System der Urteilenden sich nicht anpassen konnte. Ist also Wahrnehmung bereits ein kategorial geformter Vorgang?

2. Was ist Wahrnehmung?

Einige unerläßliche akademische Erörterungen sind notwendig. Sie sollen vor allem dazu dienen, Wahrnehmung und Vorstellungsvermögen als untrennbar miteinander verflochten darzustellen. Das einfache Modell der Psychophysik von „Empfindung – Wahrnehmung – Vorstellung“ hat mehr als 100 Jahre die Bewußtseinsforscher beschäftigt und gleichzeitig die Hoffnung geweckt, man könne eine Unmittelbarkeit der sinnlichen Erkenntnis beweisen und somit auch auf eine ästhetische Widerspiegelung pochen. Die Psychophysik ist zwar nicht gänzlich gescheitert, aber doch nicht mehr die wichtigste Disziplin, um die Wahrnehmung zu erklären. Ich gehe davon aus, daß Wahrnehmung bereits ein kognitiver Akt ist, der eine Form der Informationsverarbeitung darstellt, die eng verbunden ist mit den Vorstellungen. Wahrnehmung und Vorstellung sind nicht qualitativ zu unterscheiden. Weitere Merkmale der Wahrnehmung seien genannt.

Die mentalen Akte der Wahrnehmung scheinen ganzheitlich zu funktionieren, d. h., wir nehmen immer Informationen mit allen Sinnesorganen auf. Ob es sich dabei nur um einen ganzheitlichen Eindruck oder um einen wirklich ganzheitlichen Prozeß handelt, ist eine Frage, die gegenwärtig heftig diskutiert wird.

1. Die sogenannten Gestalttheoretiker gingen von der letztgenannten Auffassung aus. Sie haben damit sehr anregend auf die jüngere Kognitionsforschung gewirkt, wenngleich sie weniger wissensbasierte Kategorien als Voraussetzung der Wahrnehmung betonten, statt dessen vielmehr automatisch erfolgende Gestaltbildungen, aus denen nachträglich erst Teile ausgegliedert werden. Bei Camille Pisarros Bild *Die Große Brücke von Rouen* würden wir kaum annehmen, daß die Brücke einstürzt, obwohl ihre Kontur zweimal unterbrochen ist. Auf den ersten Blick sehen wir als Ganzes das geschwungene Halbrund; die Unterbrechungen zeigen sich erst bei einer Ausgliederung von Teilen. Auditive Reize können gleichermaßen als Gestalten erlebt werden. So werden Töne ähnlicher Frequenz, wenn sie rasch aufeinander folgen, in der Wahrnehmung zu einer Melodie zusammengezogen. Sie werden nicht als isolierte Elemente erlebt, wie dies für ihre physikalische Erscheinung gilt. Luigi Nono hat in seiner Musik von diesem Wahrnehmungsmechanismus Gebrauch gemacht.

Die zeitliche Abfolge von Tönen muß nicht von spielenden Musikern erzeugt werden. Sind die Töne oder Klänge im Raum fest installiert oder positioniert, so kann der Besucher durch seine Bewegung im Raum melodische Abfolgen erzeugen und darin umhergehen. In

Abb. 2 Notenbeispiel 2. Luigi NONO, *Canto Sospeso* (1956). An vielen Stellen NONOS *Canto Sospeso* gibt das Partiturbild nicht den Höreindruck wieder. So bilden die geteilten Streicher ab Takt 41 melodische Linien aus, die sich der Zusammenfassung von Tönen im Höreindruck verdanken. Obwohl die erste und zweite Geige nur Partikel spielen, fügen sie sich ihre Töne zu zwei in der Oktavlage getrennten Linien zusammen. Die unterschiedliche Herkunftsquelle der Töne wird vernachlässigt zugunsten einer melodischen Gestalt.

den Installationen von Andreas Oldörp, in denen Töne durch im Raum verteilte singende Flammen oder durch Orgelpfeifen erzeugt werden, kann man ebenfalls solche Melodien hören. Solche Gestaltbildungen folgen immanenten Regeln des menschlichen Geistes. Dazu gehört die Tendenz zur Bildung prägnanter Gestalten, die als Figur von einem Grund abgehoben sind. Dieser Vorgang kann jedoch wie im Fall der erwähnten Scheinpolyphonie erschwert werden, so daß allenfalls unklare Vorgestalten erlebt werden.

2. Aber ob der primäre Prozeß ganzheitliche Gestaltbildungen sind, oder wir die Töne im Raum einzeln zusammensetzen, ist selbst bei solchen melodischen Konturen schwer zu entscheiden. Die sogenannten Merkmalstheoretiker bieten eine andere Erklärung als die Gestalttheorie. Sie gehen davon aus, daß auf der untersten Stufe des Wahrnehmungsprozesses Elementarmerkmale oder elementare Teilkörper eines Gegenstandes nebeneinander bestehen, ehe der Eindruck entsteht, man habe etwas wahrgenommen. Vorausgesetzt ist ein sogenannter *Bottom-up*-Prozeß, d. h. der Aufbau aus kleinsten Elementen. Allerdings können dabei auch ganzheitliche Vorstellungen eine Rolle spielen. Wissensbasierte Kategorien können durch sogenannte *Top-down*-Prozesse in die Struktur der einfachen Wahrnehmungsakte eingreifen und sie modifizieren. Solche Kategorien werden durch Lernen und Erfahrung erworben. Es handelt sich um sogenannte Schemata, die der schnellen Orientierung dienen. Aufmerksamkeit wird als eine Selektion von Informationen beschrieben, die entweder die frühe Stufe der Elementarmerkmale betrifft (Filtertheorie) oder aber Entscheidungen auf einer späteren Verarbeitungsebene über die Zusammengehörigkeit von Merkmalen. Auch diese Vorgänge können erschwert werden, indem sie entweder keine klaren „Muster" ergeben oder aber die Umstrukturierung der vorhandenen Schemata erforderlich machen. Die ästhetische Erfahrung wird in der Regel als Abweichung von der Alltagserfahrung beschrieben, d. h., sie ist mit einer Störung der vorhandenen Kategorien verbunden. Vor allem die moderne Kunst will eine Wahrnehmung des bisher Nicht-Wahrgenommenen bewirken, Hör- und Sehgewohnheiten sollen außer Kraft gesetzt werden. Dabei kann es durchaus auch zu den künstlerischen Intentionen gehören, die Konstruktionen bewußt zu machen, die wir an die Wahrnehmung von Wirklichkeit herantragen.

3. Es wäre eine eigene Darstellung notwendig, um genau darzulegen, daß das Auge beim Wahrnehmungsakt nicht so ausschließlich als dominantes Organ wirkt, wie wir gewöhnlich glauben. An der aus mehreren Sinneskanälen gespeisten multisensorischen Wahrnehmung gilt es jedoch, den Unterschied zwischen multisensorisch und intersensorisch zu betonen.

Die alltägliche Wahrnehmung ist in der Regel multisensorisch. Wir hören und sehen zugleich, andere sinnliche Eindrücke spielen dabei eine Rolle. Von besonderer Bedeutung können kinästhetische Informationen über die Position unseres Körpers sein.

Als intersensorisch ist eine Wahrnehmungsform zu bezeichnen, bei der etwas Allgemeines an einem nur durch ein einziges Sinnesorgan aufgenommenen Ereignis wahrgenommen werden kann, z. B. Klänge als schwarz oder gelb erscheinen. Diese Allgemeinqualitäten, die uns ein sogenanntes *Cross Modality Matching* erlauben würden, sind noch kaum untersucht. Auch ihr Verhältnis zu den früher einmal faszinierenden Sonderfällen der Synästhesie ist noch unklar.

Für die multisensorische Wahrnehmung hingegen hat sich überraschender Weise gezeigt, daß es im Gehirn Zentren gibt, die nur aktiv werden, wenn zugleich gesehen und gehört wird. Aus hirnphysiologischen Messungen sind jedoch meistens nur schwer psychologische Sachverhalte zu erschließen. Die Spezialisierung bestimmter Hirnareale auf audiovisuelle Stimuli erlaubt daher keine Entscheidung über eine ganzheitliche oder eine merkmalsintegrierende Funktionsweise der Wahrnehmung.

4. Durch Musik werden in der Regel Gefühle ausgelöst, oder aber sie werden als Ausdruck an der Musik erlebt. Melodische Vorgänge, die nicht ganz leise sind und mit unregelmäßigen Intervallen vorgetragen werden, können sowohl bei der sprachlichen Kommunikation wie auch beim Musikhören als Freude erlebt werden. Fallende, leise melodische „Intonation“ wird eher mit Trauer assoziiert und tremolierend schnelle, zackige Bewegungen als zornig empfunden. Der umfangreichste Teil der musikpsychologischen Forschung dient der differenzierten Darstellung dieses Ausdrucksverstehens. Wichtig zu unterscheiden ist, ob die emotionalen Qualitäten am Objekt haftend erfahren werden oder als im eigenen Gefühl verwurzelt. Es gibt zwei Arten des Ausdrucksverstehens: objektiviertes Symbolverstehen und subjektives, Gefühle evozierendes Berührtsein. Letzteres ist ein Verstehen durch Resonanz, das neben dem Vergnügen am Artifiziellen bis in das empfindsame Zeitalter hinein eine ästhetische Gültigkeit hatte, heute zwar dem Konzertpublikum immer noch zugestanden wird; jedoch billigt man dem kognitiven Ausdrucksverstehen einen höheren Wert zu. Solchem Ausdrucksverstehen fehlt jedoch die emotionale Wärme. Denn Emotionen sind doppelt bestimmt als Identifikation von Qualitäten und als körperliche Erregung. Wird letztere unterdrückt, so kommt es zu einem reinen Symbolverstehen, das weitgehend den identifizierenden Leistungen der kognitiven Schemata zu verdanken ist. Ob ein solches reines Symbolverstehen jenseits von bekannter Musik möglich ist, darf bezweifelt werden. Verfremdungen von kognitiven Schemata, typisch für ästhetische Sachverhalte, rufen nämlich Orientierungsreaktionen hervor, die immer mit einer körperlichen Aktivierung einhergehen. Die sogenannte experimentelle Ästhetik würde ästhetische Lust und Unlust mit dem Ausmaß dieser Aktivierung begründen, d. h.: für das Wohlgefallen ist ein bestimmtes Ausmaß an Aktivierung notwendig. Wird die Erregung zu groß, so geht sie mit dem Gefühl der Unlust und mit Ablehnung einher. Vieles spricht dafür, daß die ästhetische Erfahrung eine Teilhabe des Rezipienten an der Kunst zu verlangen scheint. Sie ist allerdings sehr stark davon abhängig, welches Vorwissen ein Individuum hat, was es als neu empfindet, wie offen sein kategoriales System ist.

3. Wahrnehmung eine Voraussetzung für die Präsenz der Kunst

Im Zusammenhang mit der europäischen Cage-Rezeption, später verstärkt durch die Auseinandersetzung mit der erwähnten Rezeptionsästhetik, wurden von Seiten formalästhetisch orientierter Wissenschaftler die schlimmsten Befürchtungen geäußert: Die Beschäftigung mit Fragen ästhetischer Wahrnehmung, so meinte man, hätte die fatale Konsequenz des extremen Relativismus, nämlich die Auflösung der Identität des Werks dahingehend, daß BEETHOVENS *Eroica* so oft existiere, wie es Köpfe im Auditorium gäbe. In der Tat würden Gestalttheoretiker wie experimentelle Ästhetik davon ausgehen, daß der Rezeptionsprozeß in irgendeiner Weise individuell bestimmt, wenn nicht gar kreativ und produktiv ist. Nützlich erscheint eine Unterscheidung, die die materialiter bestimmte physikalische Existenz eines Werks von dem erlebten ästhetischen Objekt unterscheidet. Ersteres wäre ein Dokument, das eine unübersehbare Fülle von Erfahrungen provozieren kann, ohne die es aber nicht mehr als nur ein historisches Faktum ist. Es muß im Rezeptionsvorgang vergegenwärtigt werden, ein Umstand, der den Künstlern wohl zu allen Zeiten bewußt gewesen ist, die daher implizit oder bewußt auf eine Wirkung zielten, einen kognitiven und emotionalen Bezug hervorzurufen versuchten. Präsenz gewinnt Kunst erst im Rezeptionsvorgang. Die Ausarbeitung einer solchen phänomenologischen Wahrnehmungsästhetik ist eine der Zukunft vorbehaltene Aufgabe, die jedoch Anregungen von den eingangs erwähnten Konzeptionen aus den Anfängen der wissenschaftlichen Ästhetik erhalten könnte. Eine wichtige Hilfestellung würde dabei auch die Psychologie leisten.

Dem befürchteten Relativismus beugt der Gedanke vor, daß es zur Besonderheit der ästhetischen Wahrnehmung gehört, daß sie eine unabschließbare Fülle von Gedanken hervorruft. Kunst erscheint damit als ein „Nicht-Faßbares", das sich der völligen In-Besitznahme entzieht. Sie erscheint als etwas, das eine ständige Annäherung erfordert, um es in die uns vertraute Nähe zu rücken. Musik macht dies besonders deutlich. Niemand wird behaupten können, daß ihm durch ein einmaliges Hören eines Stücks ein Werk hinreichend vermittelt sei. Vielleicht sind es Momente der dialektischen Verschränkung von erlebter Nähe und nicht-faßbarer Ferne, die die ästhetische Wahrnehmung von der des Alltags unterscheidet und zugleich wichtige Charakteristika des künstlerischen Werks sind.

Prof. Dr. Helga de la Motte-Haber
Technische Universität Berlin
Musikwissenschaften
Straße des 17. Juni 135
10623 Berlin
Germany
Tel.: +49 30 3419978
Fax: +49 30 31422235
E-Mail: de-la-motte@t-online.de

Nova Acta Leopoldina NF *92*, Nr. 341, 135–145 (2005)

Acoustical Correlates of Musical Expressiveness

Wolfgang Auhagen (Halle/Saale)

With 4 Figures

Abstract

The paper has three sections. First, the term "expression" will be briefly discussed. Then, those parameters which can be influenced by a performer to give his presentation expressive qualities will be analyzed: pitch (or intonation respectively), duration of tones (or tempo respectively), dynamics, and timbre. It will be shown that especially tempo and dynamics can be used to communicate musical structure to the listener. The expressive quality of intonation is context dependent to a high degree. Timbre, in combination with other parameters, may be used to convey emotional feelings of the performer stimulated by the composition or the improvisation. This gives support to the idea that music performance has some parallels with speaking by using the same acoustic code of expression. Finally, some open questions concerning visual parameters influencing expression in music performances will be touched.

Zusammenfassung

Der Beitrag gliedert sich in drei Abschnitte. Zunächst wird der Begriff „Ausdruck" in seinen unterschiedlichen Bedeutungen diskutiert. Hieran schließt sich eine Analyse derjenigen Parameter an, die von einem Instrumentalisten oder Sänger beeinflußt werden können, um seiner Interpretation Expressivität zu verleihen. Es handelt sich um die Parameter Tonhöhe (bzw. Intonation), Tondauer (und damit zusammenhängend Tempo), Dynamik und Klangfarbe. Anhand einiger Beispiele soll gezeigt werden, daß insbesondere Tempo und Dynamik zur Verdeutlichung musikalischer Strukturen dienen können. Die expressive Wirkung von Intonation ist in hohem Maße kontextabhängig. Klangfarbe kann in Verbindung mit anderen Parametern zum Ausdruck von emotionalen Zuständen wie beispielsweise Zorn verwendet werden. Es zeigen sich Parallelen zum Sprechen, die die Vermutung stützen, daß Sprechen und Musizieren den gleichen akustischen „Code" im Hinblick auf Ausdruck verwenden. Der Schluß des Beitrags widmet sich Fragen, die den Einfluß visueller Parameter auf den musikalischen Ausdruck betreffen.

1. The Term "Expression"

The idea that music is somehow expressive has a long tradition. However, the precise meaning of this presumed expressive quality varied. For example, in the 17^{th} and 18^{th} centuries, composers wanted to present different passions (in German "Affekte") to the audience, like anger, sadness, or happiness. Accordingly, music theory searched for correspondences of passions and musical structures (Cf. Mattheson 1739). The early 19^{th} century was sceptical about this idea. Now, ambiguity was considered to be the special category of musical expression. While the meaning of words was rather clearly determinable, music was said to be able to express something miraculous that could not be expressed by words. Thus, the writer and composer E. T. A. Hoffmann called music the *romantischste aller Künste* (Hoffmann 1814/1972, p. 44). The idea that a composer might communicate his feelings to a listener through music is also part of romantic music aesthetics. However, the well-known critic Eduard Hanslick argued against the idea that music expresses something beyond specifically musical ideas. His famous statement *Tönend bewegte Formen sind einzig und allein Inhalt und Gegenstand der Musik* (Hanslick 1854, p. 32) has been influential in the aesthetics of music up to the present. It means that sounding forms of motion alone are relevant to music which thus should be understood in its own terms.

The idea that expressiveness is confined to specifically musical ideas influenced the theory of interpretation. In the early 20th century, the musicologist Hugo Riemann argued for an analytical interpretation so that the meaning of musical structures, in Riemann's terminology the *Sinngliederung* (Riemann 1900, p. 14), becomes obvious to the audience. Theodor W. Adorno published so-called *Interpretationsanalysen* in order to impart the performance practice of the Second Viennese School to modern interpreters (Adorno 1963). In what follows this last mentioned view stressing the intrinsically musical qualities like tension and relaxation is the point of reference. However, the question whether emotions can be encoded in musical ideas will be touched briefly.

2. Parameters that Can Be Influenced by a Performer

There are four dimensions of tones and tone sequences that are subject to the performer's individual idea of a composition:

- Pitch or intonation respectively;
- duration or tempo respectively (generic term: timing);
- dynamics;
- timbre (or sound color).

However, these dimensions cannot be varied completely independently from each other. With most musical instruments variations of the force of excitation lead to variations of both, dynamics and timbre. And variation of pitch may lead to variation of perceived dynamics because of the frequency-dependent sensitivity of the human ear. Despite this fact it is possible to decouple parameters to a certain degree and the question is raised in which way interpreters use such variations in an expressive sense. In the early 20th century, the psychologist Carl Seashore defined expression of a performance as follows: "As a fundamental proposition we may say that the artistic expression of feeling in music consists in esthetic deviations from the regular – from pure tone, true pitch, even dynamics, metronomic time, rigid rhythms, etc." (Seashore 1938, p. 9.) We will see that this idea still is relevant to the study of expression, even though not all deviations that can be observed have an expressive meaning. Accordingly, Roger A. Kendall and Edward C. Carterette (1990) argued that when talking about expressiveness in musical performance the relationship between the performer and the listener has to be taken into consideration. Some results of their empirical study will be demonstrated.

2.1 Pitch and Intonation

The realization of the tone symbols of a score with regard to pitch is called "tuning" for instruments with fixed pitches such as a piano. It is called "intonation" if a performer's adjustment of pitches is required. The question whether tuning and intonation are a means for lending expressive qualities to a performance has been discussed in western music theory from the 17th century on. Some authors excluded tuning and intonation from expressive techniques: a performer should simply play or tune his instrument correctly. All deviations of such a correct intonation should be considered mistakes. For example, the German music theorist Wilhelm Marpurg states: „Ist es nicht sonderbar, daß die bloß zum Behuf der reinern Ausfuehrung erfundne Temperatur zum Behuf des Ausdrucks misgebrauchet werden soll ...“ (Marpurg 1776, p. 194.) Other theorists, however, argued that a variation of the degree of correctness of different chords and keys should be seen as an expressive means (Kirnberger 1776, p. 70). But what is “correct” and which deviations from ideal values are tolerable?

In polyphonic music, intervals whose frequency-relations cannot be expressed by small integer ratios like 2:1 or 3:2 cause beatings or even roughness. Obviously, in the western tradition of artificial music, such rough polyphonic sounds were avoided. Intervals were judged to be correctly tuned if the ratio deviated from small integer proportions not at all or only to a very small extent. Above all, organs and harpsichords whose tones have a harmonic overtone series are sensitive to deviations from such interval proportions. Thus, one of the standard tunings of the 17th century, the so-called “Meantone Temperament”, tried to minimize the deviations from small integer ratios with respect to fifths (3 : 2) and major thirds (5 : 4).

c	g	d	a	e	h	f#	c#	g#	e*b*	b	f	c	
696.6	696.6	696.6	696.6	696.6	696.6	696.6	696.6	737.4	696.6	696.6	696.6	(Cent)	

A*b* Major	427.3 / 737.4	D Major	386.3 / 696.6
E*b* Major	386.3 / 696.6	A Major	386.3 / 696.6
B*b* Major	386.3 / 696.6	E Major	386.3 / 696.6
F Major	386.3 / 696.6	B Major	427.3 / 696.6
C Major	386.3 / 696.6	F# Major	427.3 / 696.6
G Major	386.3 / 696.6	C# Major	427.3 / 696.6

Pure major third (5:4):	386.3 Cent
Pure fifth (3:2):	701.9 Cent

Fig. 1 *Upper part*: Cent values of the circle of fifths in Meantone temperament. *Lower part*: Cent values of major thirds and fifths in Meantone temperament

Figure 1 shows Cent values of major thirds and fifths in Meantone Temperament and of their pure size. 1 Cent is 1/100 of a semitone in equal temperament. While the chords of E*b* Major, B*b* Major, F Major, C Major, G Major, D Major, A Major and E Major deviate from ideal values to only a small extent the other chords, especially A*b* Major, show large deviations. When the Prelude in A*b* Major (BWV 862) from the first part of the “Well Tempered Clavier” by Johann Sebastian Bach is played on an instrument tuned according to Meantone Temperament the performance does not seem to be very expressive but rather badly tuned. Bach would hardly have composed this prelude if Meantone Temperament had been the only available tuning in his time, which of course was not the case. On the one hand the above mentioned deviations cause roughness, on the other they produce distortions in the melodic line which sound strange because they are not related to the melodic movement in any systematic way.

The situation is different when an instrument is played with vibrato and if the deviations from small integer ratios are justified by the melodic context of these intervals. Vibrato diminishes the perception of roughness and context-dependent variation of interval size even supports the perception of musical structure.

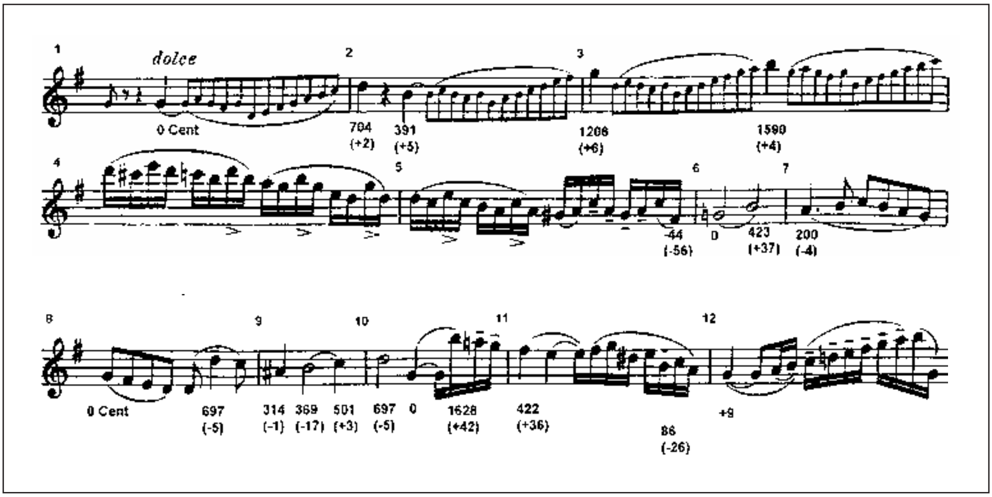

Fig. 2 Excerpt of the second movement of L. VAN BEETHOVEN's concerto for violin and orchestra op. 61 as performed by Fritz KREISLER. Bar 1 of the excerpt is bar 40 of the movement. Unit of the interval size is Cent. Record: Fritz KREISLER (violin), orchestra of the Staatsoper Berlin, Leo BLECH (conductor), date: 15./16. December 1926. Dacapo C 047-01 243

Figure 2 shows the intonation in an excerpt of the second movement of L. VAN BEETHOVEN's concerto for violin and orchestra in D Major as it was performed by Fritz KREISLER in 1926. Measurements of the intervals of this passage show that KREISLER by no means plays in just intonation all the time. The first three bars of the excerpt expose the tonic chord of G Major. Here, KREISLER is very accurate with regard to the intonation of the tones of this chord. Deviations from pure intervals are smaller than 10 cent. Bar 4 and 5 show a descending melodic line ending with a sequence of semitones leading to the tonic followed by its major third in bar 6. The semitone between F# and G is very small. In fact, it is realized as a quarter tone of only 44 cent. The major third B on the contrary is very large (423 cent). It deviates from the ideal value to nearly the same degree as the third of the A*b* Major chord in Meantone Temperament. This tendency of small ascending semitones in order to stress the smooth melodic line and of stretched major thirds in order to make them sound brilliant can be observed in the following bars as well. For example the semitone A# – B in bar 9 is 55 cent. That means it has the size of a quartertone. In bar 10, the interval G–B which is an octave plus a major third (1586 cent) exceeds this size by 42 cent (size: 1628 cent). As to the fifth of the G Major chord, it is often a little too small having cent values of about the standard fifth in Meantone Temperament.

Despite the fact that in KREISLER'S performance there are many deviations from pure intervals we accept his interpretation and may call it expressive since the variation of interval size is in accordance with the melodic movement. To sum it up: intonation and tuning may serve as a means of expression. However, the effect of changing interval sizes is context dependent and even seems to be subject to changes in the course of the history of performance practice.

2.2 Timing

Performing a composition in metronomic tempo gives the impression of a mechanically played instrument. In fact, there is a lot of evidence that human performers always produce small variations in local tempo (GABRIELSSON 1999). As to the global tempo, comparison of different interpretations of the same composition shows that there is not only one single correct tempo for a performance but a range of tempi that are acceptable (AUHAGEN 1993). This is a difference to the parameter intonation which has non-beating intervals as points of reference. Several questions arise:

(*i*) Are there systematic variations of tempo on the micro-level related to the rhythmic structure of the composition?
(*ii*) Are there systematic variations of the global tempo related to the structure of the composition?
(*iii*) Are there aesthetic limits of different basic tempi?

(*i*) Empirical research on micro-variations of tempo related to musical structure started at the beginning of the 20th century. In 1928, Guy Montrose WHIPPLE used roles for the reproducing piano to study dynamics and timing of different famous pianists (WHIPPLE 1928). In the 1930's, Carl SEASHORE used a camera for monitoring the hammer action of a piano (SEASHORE 1938). From the 1960's on, extensive research on rhythmical performance was done by the Swedish musicologist Ingmar BENGTSSON and the psychologist Alf GABRIELSSON using special recording techniques (GABRIELSSON 1999). Results showed systematic patterns of performed rhythms. Some examples are given below:

- The three beats of the accompaniment in Viennese waltzes show a "short-long-intermediate" pattern which means that the second beat comes "too early".
- Melodies in triple meter, showing rhythmic patterns like half note – crotchet, which is a 2 : 1 ratio, were performed with a shortening of the first note with a tendency to the proportion 1 : 1.
- Dotted rhythms representing the ratio 3 : 1 were sometimes played "sharp" with a ratio higher than 3 : 1, but more often "soft" with a tendency to the 2 : 1 ratio.
- In sequences of four equal notes, the last note usually was lengthened. This may be interpreted as the consequence of a segmentation process.

These results were replicated in later studies and thus showed that human performers nearly always play rhythmical structures with proportions that deviate from integer ratios. That is, they shape notated rhythms in a special way.

(*ii*) Many studies revealed systematic variations of the overall tempo in performances by professional pianists and students of piano playing. E. g. Gabrielsson (1988) observed in Ingrid Haebler's performance of the theme of Wolfgang Amadeus Mozart's piano sonata in A Major (K. 331) the following characteristic variations of tempo:

– Sharpened dotted rhythms.
– Accelerating the tempo at the beginning of phrases.
– Slowing down the tempo at melodic phrase boundaries.
– Slowing down the tempo at peak notes of the melodic line.

These results were confirmed by other studies (cf. Penel and Drake 1997).

(*iii*) The question whether there are aesthetic limits for choosing different basic tempi still has to be examined in detail. Up to now, it has become clear that faster tempi are associated with various expressions of activity, excitement, or joy while slow tempi are associated with calmness, serenity, dignity, or sorrow (cf. Juslin 2001). This confirms Eduard Hanslick's notion that if music resembles an emotion it does so by sharing its dynamic qualities (cf. Davies 2001). So, choosing a high tempo or a low tempo for the performance of a composition conveys different moods. In addition, it has become clear that the range of acceptable tempi as expressed by the quotient of the maximum and the minimum acceptable number of beats per minute is different for different compositions (Auhagen and Busch 1998). The complexity of the rhythmic-melodic structure seems to play a crucial role in limiting the range of acceptable tempi. However, the role of harmonic features still has to be explored.

2.3 Dynamics

While expressive timing was analyzed in a lot of experiments, only few empirical studies focused on dynamics. A study by Reinhard Kopiez (1997) contributed a lot to the understanding of the role of this parameter in an expressive performance. In his study, a pianist was asked to play 9 short compositions on a MIDI piano in two versions each: with expression and without expressive timing. From these versions two versions with reduced dynamic range to only 25 % of the original range were generated with the help of a computer program. Listeners' task was to rate the similarity between two performances. In total subjects had to rate 54 pairs. Analysis of the data showed that both, timing and dynamics, contributed to perceived similarity of performances. There was no simple hierarchical relationship between these two parameters. Performances of compositions with high metrical stability were mainly rated on the basis of expressive timing whereas compositions with low metrical stability were mainly rated on the basis of expressive dynamics. In addition, analyses of the performances showed that the idea "the faster the louder, the slower the lower", proposed by Sundberg, Frydén and Askenfelt (1983) as a rule for generating expressive performances by a computer program is too simple even though composers sometimes link tempo and dynamics this way in their compositions. Timing and dynamics may be decoupled to a large extent and this seems to be aesthetically relevant (Kopiez 1997, pp. 180–182).

Kendall and Carterette (1990) asked players of different instruments like violin or trumpet to play melodies in three versions: without any expression, with expression, and with "too much" expression. These performances were recorded and presented to listeners who had to categorize the stimuli according to the three levels of expression. Categorization in general was quite good indicating that the intended expressiveness was conveyed to the listener. Signal analysis of the performances of Henry PURCELL's "Thy hand, Belinda" from the opera *Dido and Aeneas* (1689) revealed that the interactions of timing and amplitude of the tones were only moderate. Correlations of the time deviations and the root mean square values were moderate for all of the three expressive levels and mostly negative. This shows that in this experiment, performers varied expressive timing and dynamics quite independently. If there was a relationship between timing and dynamics lengthened tones tended to be played softer and *vice versa*.

The question how musicians express various emotional characters in their performances was studied by Alf GABRIELSSON and Patrik N. JUSLIN (1996). They asked a singer, a violin player, a flute player and several guitar players to play four melodies so as to render the performance with different emotional expressions like happy, sad, or angry. As was to be expected the "angry" version was the loudest of all versions, followed by the "happy", the "tender" and finally the "fearful" versions. Obviously dynamic encoding of emotions in musical performance has some parallels with speaking.

2.4 Timbre

At first glance, timbre of musical instruments seems to be a parameter that is almost completely determined by the instrument itself. While this holds true for some instruments like harpsichords or vibes, other instrument groups like strings or brass allow a modification of sound color. The question arises whether there are some similarities between musicians' realizations of different sound colors dependent on their imaginations e.g. of dark, bright, or aggressive tones. In an own experiment, we asked instrumentalists to realize certain sound qualities like "dark" (dunkel), "bright" (hell), "carrying" (tragend) or "screaming" (schreiend). Instrumentalists' performance was captured by a video camera monitoring the playing-technique, and by a Digital Audio Tape recorder. The video tapes were analyzed by means of a digital video system. The audio tapes were analyzed by means of a computer using the program *Soundscope/16* which includes various forms of Fourier analysis. Fourier analysis decomposes a complex sound into its components that is into a series of sine waves. The result is a spectrum showing the energy of these components and their frequencies. Up to now, performances by violin-, violoncello-, oboe-, and bassoon players were analyzed (for details cf. AUHAGEN and SCHONER 2001). The results show that the musicians were able to produce changes of sound quality to correspond with verbal attributes and they showed a consistency in the variation of playing parameters and parameters of the sound spectrum. Some examples of dark, bright, and screaming bassoon tones are given below.

The figure shows sound spectra of the tones E_2 and D_3 realized in mezzoforte or forte by two bassoon players. Dark bassoon sounds are characterized by high amplitudes of the partials in the region between 400 and 600 Hz and a rapid decrease of the amplitudes of higher partials. The region of high energy is independent of the fundamental frequency within a wide range of tones and thus may be called a "formant" comparable to the formants of the vowels A, E, I, O, U etc. Bright sounds show higher amplitudes of partials in the region of 1200 and 1400 Hz in comparison with dark sounds. With sound A, the relative maximum in this region is raised from –30 dB to –20 dB in relation to the peak of the first formant. With sound B it is raised from –28 dB to –10 dB.

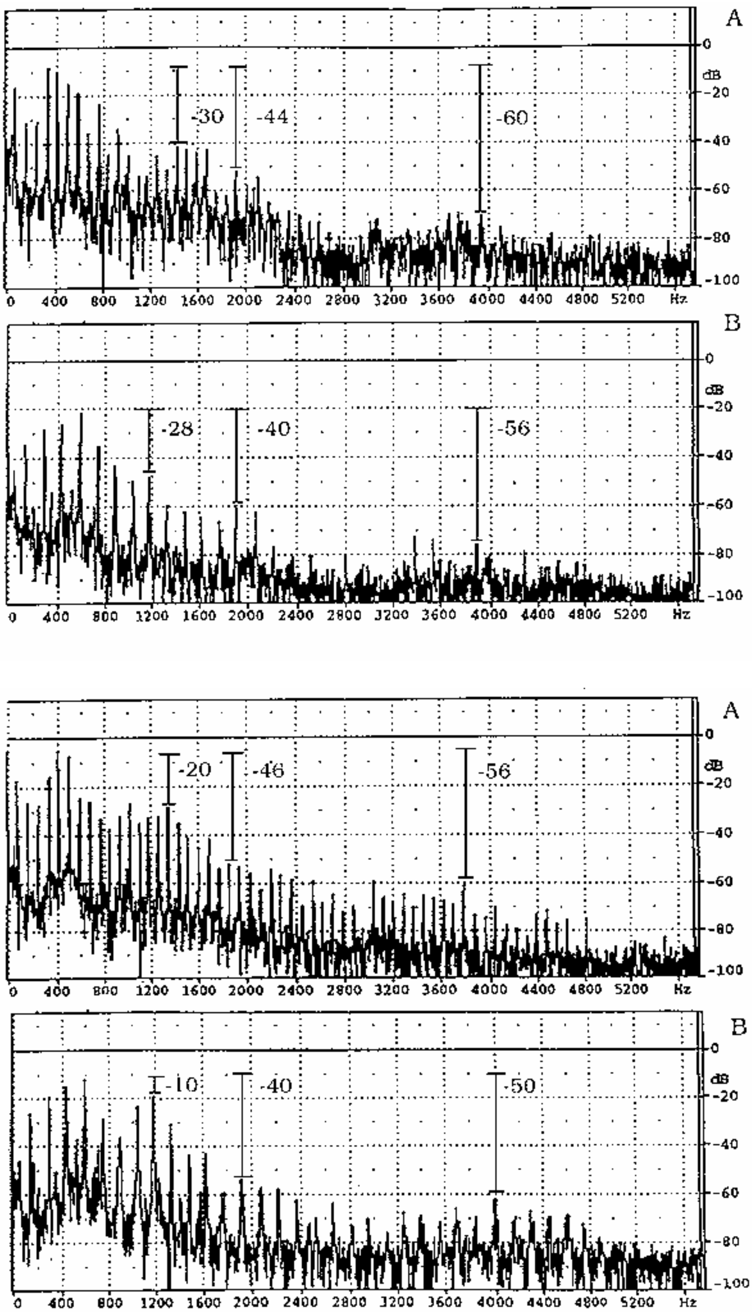

Fig. 3 Sound spectra of two *dark* (upper half) and *bright* (lower half) bassoon sounds (A: E_2, B: D_3); parameters of the FFT: Hamming time-window, 2^{14} samples (= 0.37 s).

Obviously, for the quality “bright” not all of the higher partials have higher amplitudes but only those within a relatively small frequency-region. This region was called the second formant in some studies but was not constantly observed in former research (REUTER 1995, p. 100). Thus, this formant clearly depends on musicians’ ideas of timbre. Like bassoon tones, dark violoncello sounds and violin sounds show spectra whose envelopes are characterized by a steep slope, while the higher partials of bright sounds again have comparatively higher amplitudes only within a limited frequency range (for details cf. AUHAGEN and SCHONER 2001). Obviously, players of different instruments share similar imaginations of sound qualities and they realize such sound qualities in similar ways.

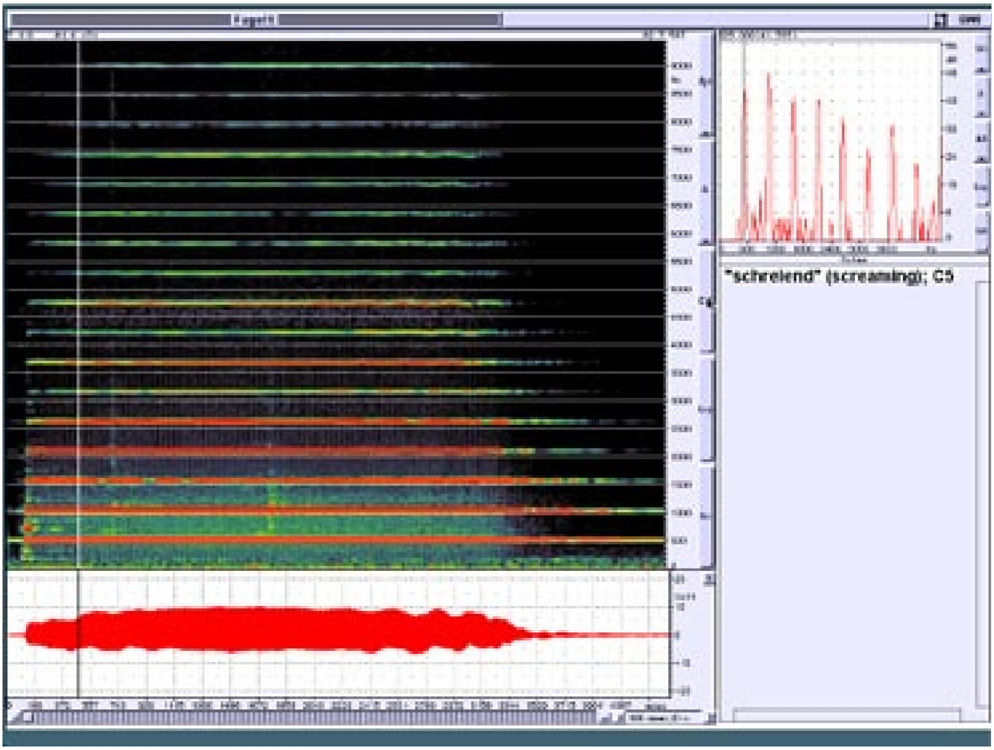

Fig. 4 Spectrogram of a *screaming* basson tone (C_5); parameters of the FFT: Hamming time-window, 2^{11} samples (= 0.046 s)

The figure shows a “screaming” tone played by a bassoon player. The lower part of the figure shows the complex vibration of the radiated sound as a function of time, the upper part shows the spectral content of the signal as a function of time. Grades of color show differences in the intensity of partials. Red represents high energy and blue represents low energy. The way how this “screaming” tone starts differs from that of other sound qualities. There is a very short attack time with many partials starting at nearly the same time. In addition, the sound is characterized by a lot of noisy components between the harmonic partials. And finally, the screaming tone is played at a high pitch of 527 Hz. Short attack times and noisy components can also be found in “angry” tones (Gabrielsson and Juslin 1996). So, the way of forming individual tones, called “articulation”, is an important factor in an expressive performance.

3. Conclusion

Musical expression in a broad sense of the word comprises emotions like anger or happiness and musical ideas that cannot be described completely by verbal attributes. Among the parameters pitch (or intonation respectively), tempo, dynamics, and timbre, especially tempo and dynamics can be used to communicate musical structure to the listener. The expressive quality of intonation is context dependent to a high degree. So, not every deviation of just intonation has the same effect. Timbre, in combination with other parameters, may be used to convey emotional feelings of the performer stimulated by the composition or the improvisation. It has become evident that music performance has some parallels with speaking. According to Patrik N. Juslin, “music performers are able to communicate emotions to listeners by using the same acoustic code as is used in vocal expression of emotion” (Juslin 2001, p. 321). In future research, this idea will have to be tested in cross-cultural experiments. Up to now, there is some evidence that the affective response “is determined more by cultural tradition than by the inherent qualities of music” (Gregory and Varney 1996, p. 47).

One aspect of expressive performance was not touched in this presentation: visual factors like bodily movement or facial expression. Klaus-Ernst Behne (1990) examined the effect of these parameters in an experiment. He presented video tapes that shared the same audio track and differed only with regard to the performing actors who were male and female piano players representing different types of bodily movement and facial expression. Despite the fact that the audio track always was the same the evaluation of the interpretation varied dependent on gender-specific associations of the audience. So, besides acoustical factors conveying expressiveness there are strong visual factors contributing to expression as felt by the listener. These visual factors still have to be explored in detail.

References

Adorno, T. W.: Der getreue Korrepetitor. Frankfurt (Main): Fischer 1963

Auhagen, W.: Eine wenig beachtete Quelle zur musikalischen Tempoauffassung im frühen 19. Jahrhundert. Archiv für Musikwissenschaft *50*, 291–308 (1993)

Auhagen, W., and Busch, V.: The influence of articulation on listeners’ regulation of performed tempo. In: Kopiez, R., and Auhagen, W. (Eds.): Controlling Creative Processes in Music; pp. 69–92. Frankfurt (Main): Peter Lang 1998

Auhagen, W., and Schoner, V.: Control of timbre by musicians. A preliminary report. In: Godøy, R. I., and Jørgensen, H. (Eds.): Musical Imagery; pp. 201–218. Lisse: Swets & Zeitlinger 2001

Behne, K.-E.: „Blicken Sie auf den Pianisten?!“ Zur bildbeeinflußten Beurteilung von Klaviermusik im Fernsehen. Medienpsychologie *2*, 115–131 (1990)

Davies, S.: Philosophical perspectives on music’s expressiveness. In: Juslin, P. N., and Sloboda, J. A. (Eds.): Music and Emotion; pp. 23–44. Oxford and New York: OUP 2001

Gabrielsson, A.: Timing in music performance and its relations to music experience. In: Sloboda, J. A. (Ed.): Generative Processes in Music. The Psychology of Performance, Improvisation, and Composition; pp. 27–51. Oxford: Clarendon Press 1988

Gabrielsson, A.: The performance of music. In: Deutsch, D. (Ed.): The Psychology of Music; pp. 501–602. Second Edition. San Diego: Academic Press 1999

Gabrielsson, A., and Juslin, P. N.: Emotional expression in music performance: Between the performer’s intention and the listener’s experience. Psychology of Music *24*, 68–91 (1996)

Gregory, A. H., and Varney, N.: Cross-cultural comparisons in the affective response to music. Psychology of Music *24*, 47–52 (1996)
Juslin, P. N.: Communicating emotion in music performance: a review and a theoretical framework. In: Juslin, P. N., and Sloboda, J. A. (Eds.): Music and Emotion; pp. 309–337. Oxford and New York: OUP 2001
Hanslick, E.: Vom Musikalisch-Schönen. Leipzig: Weigel 1854
Hoffmann, E. T. A.: Kreisleriana, Nr. 4: Beethovens Instrumentalmusik (1814). In: Geiger, H. (Ed.): Sämtliche poetischen Werke *1*. Wiesbaden: Vollmer 1972
Kendall, R. A., and Carterette, E. C.: The communication of musical expression. Music Perception *8*, 129–164 (1990)
Kirnberger, J. P.: Die Kunst des reinen Satzes in der Musik *2*. Berlin, Königsberg: Decker & Hartung 1776
Kopiez, R.: Experimentelle Untersuchungen zur Wahrnehmung musikalischer Interpretationsunterschiede. Habilitationsschrift TU Berlin. Berlin: Typescript 1997
Marpurg, F. W.: Versuch über die musikalische Temperatur. Breslau: Korn 1776
Mattheson, J.: Der Vollkommene Capellmeister. Hamburg: Herold 1739
Penel, A., and Drake, C.: Timing variations in music performance: hierarchical segmentation organisation and rhythmic grouping. In: Gabrielsson, A. (Ed.): Proceedings of the Third Triennial ESCOM Conference; pp. 465–470. Uppsala: Uppsala University 1997
Riemann, H.: Vademecum der Phrasierung. Leipzig: Hesse 1900
Reuter, C.: Der Einschwingvorgang nichtperkussiver Musikinstrumente. Frankfurt (Main): Lang 1995
Seashore, C.: Psychology of Music. New York: McGraw-Hill 1938
Sundberg, J., Friberg, A., and Frydén, L.: Musical performance: A synthesis-by-rule approach. Computer Music Journal *7*, 37–43 (1983)
Whipple, G. M.: A new method of analyzing music style by means of the reproducing piano. Journal of Applied Psychology *12*, 200–213 (1928)

Prof. Dr. Wolfgang Auhagen
Martin-Luther-Universität Halle-Wittenberg
Institut für Musikwissenschaft
Kleine Marktstraße 7
06108 Halle (Saale)
Germany
Tel.: +49 345 5524560
Fax: +49 345 5527206
E-Mail: auhagen@musikwiss.uni-halle.de

Bohley, Johanna:
Christian Gottfried Nees von Esenbeck. Ein Lebensbild

Acta Historica Leopoldina, Nr. *42*
(2003, 244 Seiten, 11 Abbildungen, 19,95 Euro, ISBN 3-8047-2075-7)

Die historische Bedeutung Christian Gottfried Daniel Nees von Esenbecks (1776–1858) liegt neben seiner vierzigjährigen Amtszeit als XI. Präsident der Leopoldina in seinem Lebenswerk als Botaniker, Naturphilosoph und Wissenschaftsorganisator. Als Hochschullehrer war er an den Universitäten Erlangen, Bonn und Breslau tätig. Weit darüber hinaus engagierte er sich im Vormärz zunehmend in verschiedenen sozialpolitischen Bewegungen, was ihn zum Freidenker, Ehereformer, Revolutionär, Arbeiterfreund und schließlich zum Restaurationsopfer werden ließ.
Leben und Werk Nees von Esenbecks sind in vielfacher Weise ein Spiegel der Wissenschafts- wie besonders auch der allgemeinen Geschichte in der ersten Hälfte des 19. Jahrhunderts. Im Lebensbild werden die zentralen Entwicklungslinien aus den Quellen Brief, Werk und Wirken zusammengestellt. Daraus entsteht ein eindrückliches Bild eines ungewöhnlichen Gelehrtenlebens der späten Goethezeit.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart

Nova Acta Leopoldina NF *92*, Nr. 341, 147–159 (2005)

The Impact of Musicality on Human Development

Heiner Gembris (Paderborn)

Abstract

This contribution discusses the impact of music on the phylogenetic and ontogenetic aspects of human development. Studies on singing birds demonstrate the important function of singing for mate selection, as described in the "courtship-theory" and the "aesthetic display theory". This paper also considers the question as to whether these theories can be applied to humans as well. Further speculative theories about the evolutionary impact of music deal with aspects such as social cohesion, expressing and coping with emotions, aspects of perceptual development, language acquisition and other communicative functions. In the preverbal stages of human development, the use and perception of musical parameters such as melody, pitch, timbre, temporal structuring etc. are important nonverbal means used by child and parents to communicate feelings, emotions and needs. From puberty on and for the rest of life, music plays an important role in the shaping of identity and socio-cultural positioning; it may influence mood, helps coping with everyday life and fosters recreation and relaxation. Studies with patients suffering from Alzheimer's disease demonstrate that music can maintain its communicative functions even in advanced stages of disease, being able to affect the emotional, cognitive and social aspects of personality. Altogether it can be said that music can fulfil unique communicative functions from the earliest stages of preverbal development until the very last stages of human life.

Zusammenfassung

Der Beitrag geht der Frage nach, welchen Nutzen Musik für die phylogenetische und ontogenetische Entwicklung des Menschen hat. Anhand von Studien mit Singvögeln werden die „courtship-theory" sowie die „aesthetic display theory" dargestellt und die Frage gestellt, inwieweit diese Theorien auf die menschliche Spezies übertragbar sind. Weitere spekulative Theorien über den evolutionären Nutzen der Musik beziehen sich auf Aspekte wie Gruppenzusammenhang, Gefühlsausdruck und -bewältigung, auf Aspekte der Wahrnehmungsförderung, Sprachentwicklung und andere kommunikative Funktionen. In der präverbalen Entwicklungsphase des Individuums erfüllen der Gebrauch und die Wahrnehmung musikalischer Parameter wie Melodik, Tonhöhe, Klangfarbe, zeitliche Strukturierung etc. in den nonverbalen Vokalisationen des Kindes und seiner Bezugspersonen wichtige Funktionen in der Kommunikation von Befindlichkeit, Emotionen und Bedürfnissen. Ab der Zeit der Pubertät und für das weitere Erwachsenenleben besitzt Musik wichtige Funktionen für die Identitätsbildung und soziokulturelle Positionierung, aber auch in Hinblick auf Stimmungsbeeinflussung, Alltagsbewältigung, Rekreation und Entspannung. Studien mit Alzheimerpatienten zeigen, daß Musik auch noch in fortgeschrittenen Krankheitsphasen kommunikative Funktionen erfüllen kann und Einfluß auf emotionale, kognitive und soziale Persönlichkeitsbereiche ausüben kann. Ingesamt gesehen kann Musik von den frühesten Stadien der präverbalen Entwicklung bis hin in die letzten Phasen menschlichen Lebens einzigartige kommunikative Funktionen erfüllen.

1. Introduction

Nobody will question the significance of intelligence for human development or ask why we want to be as intelligent as possible. The answer is clear: We need intelligence in order to survive; the more intelligence we possess, the better is our chance of survival. With musicality it is a different thing. Why are we musical? The evolutionary and everyday value of musicality is not that obvious – leaving aside professional musicians who earn their living with it. Musicality appears not to be directly necessary for survival. Why, then, does musicality exist? What does musicality mean for human development? Before dealing with these questions, I would like to present some terminological and conceptual framework.

2. Terminology

The terms musicality, musical giftedness or musical talent are entwined with much folklore and myth. They can be discussed at length without reaching any common, generally accepted definition. If you ask two musicians about it, you will get three opinions, and with laypersons the results are even more confused. To cut a long matter short, I would like to pragmatically propose to define musicality simply as the predisposition to experience music and to produce or reproduce music by means of voice, instrument or notes.

Just as nobody is completely unintelligent, nobody is downright unmusical. To a greater or lesser extent, every person possesses a certain level of musicality or musical talent. Musicality, in the sense of a predisposition to music, is innate in every human being, just as the predisposition to language. How it develops throughout life depends on the respective environment, motivation and practice. Most people probably possess a medium level of musicality, comparable to the degree of intelligence. If there were a musicality quotient to measure musicality just as the IQ measures intelligence, most people would score around 100. Extremely gifted persons are just as rare as persons with an extremely low level of musicality.

There are always persons who partly excusatory, partly coyly claim that they are unmusical. This is just as absurd as to say "I am not intelligent". Nobody would make a point of the latter. But to say "I am unmusical" is not compromising and does not bring about any social disadvantages, as the value of musicality tends to be perceived as a rather noncommittal and decorative one and not in the hard currency of practical use for everyday life. At this point, we have once more reached the initial question as to how human beings and human development benefit from musicality.

Before discussing this issue, I will make a few short remarks regarding the term "development". In my opinion, musical development starts with prenatal development and lasts until old age, until death. It comprises the whole span of human life. At every stage of human life, music may, to a greater or lesser extent, have an impact on the individual. In the following, I would like to examine the impact of music on human development from different points of view.

3. Economical Factors

A quite simple method to measure the importance of something consists in finding out the amount of time, money and other resources people spend on it. This method can be used for music, too.

In 2003, the turnover of the German Phonoindustry amounted to 1.648 billion Euro in spite of economic depression. 183.2 million sound storage media were sold. In the same year, 7.3 million people downloaded 602 million songs illegally from the internet, tendency rising (source: Pressemitteilung der deutschen Phonowirtschaft[1] as of March 30, 2004).

The global music market was worth US-$ 32 billion or 28.7 billion euro in 2003 (Heise Online: www.heise.de/newsticker/meldung/print/46365). In Europe only, 600,000 people make their living directly or indirectly from the music business (Söndermann 2002). But those, that do not live on music, are musically active, too: In 2002, Germany had 61,000 choirs with 3.2 million members; adding those people that play an instrument in their leisure time, the total grows to the impressive number of almost 7 million (6,984,000) people who are making music in various ensembles, from church choirs to pop groups (Allen 2002, Rohlfs 2002). Almost impossible to figure out is the number of those, young or old, that listen to music for hours every day: in concerts, driving a car or in the supermarket. Omnipresent music media have made it a rule to listen to music almost always and everywhere; not to listen to music seems to be rather an exception. In the Unites States, the music industry is larger than the pharmaceutical industry (Huron 2001, p. 51). As Huron (2001, p. 51) puts it a bit cheekily, music may not be more important than sex; probably it is more expensive, but it is definitely more time-consuming.

The base and business foundation of such an abundance of music – music making, listening, buying and selling music – is the human musicality that becomes obvious in the desire to listen to music and to make music. But what stands behind musicality, how do people and human development profit from it?

I intend to deal with this question from two different points of view: Firstly, regarding the question of the evolutionary impact of music, i.e. the question why musicality and music actually developed and how music was or is of advantage for human development. The second question deals with the impact of music on individual development.

4. The Evolutionary Value of Music – Speculative Discourses

If one wonders about the significance, the value of music within the development of the human species, pop music offers a succinct reply: “Man müßte Klavierspielen können! Wer Klavier spielt, hat Glück bei den Frau’n!“ [*One should be able to play piano! Who plays piano is lucky with women.*] Such is the refrain of a catchy piece of popular music (from the movie *Immer nur du* 1941), written by Hans Fritz Beckmann and composed by Friedrich Schröder. Its lyrics sum up what, in a scientific context, Darwin’s theory of evolution suggests about the origin and function of music.

Carl Stumpf, one of the fathers of musicology and music psychology, discusses in his book about the beginnings of music (1911) different theories about the origins of music. He describes Darwin’s theory as follows: “According to Darwin’s theory, whereupon all perfectioning must be understood basically as resulting from natural selection or the survival of the fittest, musical art constituted at first a strange anomaly. St. Cecily, the patroness of music and singing, is looking up to the sky – what help can she give in the struggle for existence? Of course, some of her successors do earn a lot of money and move forwards by means of the well developed piano muscle; but for the majority of people, the indefinable, bodiless

1 Press release of the German Phonoindustry.

something [Luftgebilde] called music does not relate to the real utilities and requirements of everyday life." Carl Stumpf continues: "Still, Darwin knew good advice. His solution can be summed up as follows: 'In the beginning, there was love'. Of course not celestial, but earthly love, the love of the sexes. According to this, music evolved in our animal ancestors in order to attract mates. The males tried to attract females, and the females chose those males that appeared most advantageous. Just as, from ancient times, those were chosen that were most beautiful in stature and color, the best singers or shouters were chosen, too. That is why, in animals, preferably the males are gaudy and fond of singing. Initially, primitive artists used to be males, but the females added critical taste. Nowadays, both sexes sing and perform music, females almost more than males; but undisputedly, men are still more productive in music, and 'Süße Liebe denkt in Tönen' [*Sweet love thinks in tunes*] – this is valid today just as in ancient times." (Stumpf 1911, p. 8f.)[2]

The ironical tone indicates that Stumpf does not think much of this theory; after all, he himself deduces the development of music, just like the development of language, from a need for signaling, for communication through signals.

According to present knowledge, Darwin's theory that music is of evolutionary value for mating is not as ridiculous as Stumpf suggested. Nowadays, the interest in the question as to the origins of music experiences a general renaissance (Brown et al. 2001) and can revert to a completely different pool of data and knowledge than Darwin could. In 1991, Nils Wallin coined the term "biomusicology", an area of research that comprises the three branches "evolutionary musicology", "neuromusicology" and "comparative musicology" and that aims to study the origins of music and its function for humankind. In this context, Darwin's theory of mating plays an important role regarding the evolutionary value of music.

It is deemed to be a fact that in many species the males distinguish themselves by abundant singing (Slater 2001). This circumstance can also serve as a key for identifying the function of birdsong: On the one hand it attracts females, on the other it serves to drive away male rivals from a bird's territory. With the beginning of the breeding season there are often keen territorial wars and territorial neighbors are having downright duels with their songs. As Slater (2001) reports, a male red-winged blackbird that cannot sing, usually suffers from more invaders into its territory than those that are able to sing. Surveys dating back to the 1970s prove that when a male blackbird is removed from its territory and the birdsong of this species is produced by loudspeakers instead, its territory will be less rapidly seized by other members of its species (Krebs 1977, cit. after Slater 2001, p. 51).

What might be the function of birdsong attracting mates? Slater (2001) explains it as follows: Male birds abruptly stop singing after pairing. On the other hand, they recommence enormous singing activities if they lost their mate for whatever reasons. The singing does not only attract females but it stimulates nest building activities and the growth of eggs in the ovaries.

Other studies document that the more varied the trills, whistles and songs of male starlings, the greater are their chances of attracting a female. Male birds with a rich repertoire manage to attract females faster than those that master less songs and calls. This is explained by the fact that a male with a broader repertoire is usually stronger, better fed and more experienced in the breeding business than birds that sing less frequently. It is assumed that the process of sexual selection is the main reason for the huge repertoire of different calls and

2 Translation: Martina Schrade.

songs of birds. (Slater 2001, p. 51). Interesting in this context is a feature that singing birds and humans have in common, viz, the extremely rapid development of their vocal skills. In both species these are decisive for communication. In singing birds, they develop twice as fast as in other birds and thrice as fast as in mammals (see Slater 2001, p. 51).

Of course such findings about animal behavior cannot be directly applied to humans. Still, the hypothesis that musicality and musical skills may contribute to the attractiveness of potential partners, appears to be regarded as a promising one by some scientists. The biologist Geoffrey Miller (2001) parallels animal and human behavior as follows: In the animal kingdom, attributes such as a loud voice, manifoldness and diversity of the singing repertoire as well as the duration of singing serve as indicators for strength, health, endurance, height, age, nutritional situation etc. Ultimately, quality and quantity of vocal utterances serve as indicators of genetic quality.

According to Miller (2001) a number of indicators of healthy and comprehensive cerebral function might play a role in mate selection, as cerebral development was and is of decisive significance for human development. Music, i.e. musical behavior, might be an indicator for the efficiency of both cerebral and bodily functions. Dancing, for example, could advertise fitness, coordination skills, strength and health. As nervousness disturbs both the fine tuning of motor skills and the control over the voice, singing might be an expression of self-confidence, status and extroversion. A virtuosic instrumental performance demonstrates motoric control and skills in learning automated, complex behavior. Furthermore it points out that there was time to practice, signifying sexual availability as no time-consuming parental duties have to be carried out. Melodic creativity gives evidence of the intellectual capacity to master different musical styles and of the intelligence required to produce something musically new. Miller (2001, p. 340) admits that all these parallels and hypotheses are speculative. But they could be tested empirically, e. g. by collecting demographic data and identifying correlations between certain characteristics (such as motor coordination) and their indicators (dancing). Experiments examining, for example, to what extent a high or low value of certain indicator variables affects sexual attractiveness, are another possibility.

The complementary counterpart of this indicator theory is the “aesthetic display theory” (cp. Miller 2001, p. 341 ff.). According to this theory, the display of aesthetic preferences can be relevant to the choice of partner because it provides the possibility to choose the partner that best meets one’s own preferences. Interesting in this connection is an own study examining if and in which contexts musical activities are mentioned in marriage advertisements (Gembris 1995, see also Reu 1995). As it turned out, music is mentioned in almost one fourth of the advertisements of a large German weekly journal (*DIE ZEIT*). Musical skills, in these ads often associated with sensibility, culture and other social values, appear to enhance the attractiveness of potential spouses, at least regarding the educated readership of this journal.

Miller (2001, p. 354) tries to demonstrate the functional impact of music on the choice of partner using an unconventional experiment: From respective encyclopaedias he chose at random 1,800 jazz albums, 1,500 rock albums and more than 3,800 pieces of classical music and analyzed them according to the age and gender of their originators. The findings documented that in all genres, men had produced ten times more music than had women. Their productivity is highest at around 30 years of age.[3] He concludes that the general musical productivity

3 Most other studies suggest that the peak of creative productivity depends on musical genre and occurs about ten years later (e.g. Lehman 1953, Dennis 1966, Simonton 1991; for an overview see Gembris 2002, p. 375ff).

rockets upwards after puberty, peaks at early adult age when mate selection is at its most intense, then declines gradually with increasing age and the taking over of parental duties.

This naive experiment and the "courtship-theory" behind it of course provoked contradiction.

Sandra Trehub (2001) suggests that within the normal population of non-musicians, women sing probably more melodically and expressively. Huron comments rightly that there are no indications whether or not one gender is more musical than the other. Somewhat ironically he comments: "Women may be impressed by men who serenade them outside their balcony windows, but unlike female songbirds, female humans are perfectly capable of serenading men." (Huron 2001, p. 48.)

Besides this "courtship theory" or "mate selection theory" there are seven other theories trying to explain the evolutionary significance and thus the origins of music, focusing on the following aspects (see Huron 2001, p. 47):

– *Social cohesion*: Music is an effective means of social organization. It can serve as a uniting force, establishing and sustaining social groups. It can synchronize individual emotions in a larger group, foster group solidarity or altruism. Prehistorical humans or tribes could survive only as a group. Music is a medium to convey feelings of unity, mutual goals, ideas, sentiments and a mutual set of beliefs. Thus, music plays an important role e. g. in religious rites as a means of unification and expression of mutual convictions. In wars music was used to encourage, to make marching easier or to stir up hatred towards the enemy.
– *Group effort / Coordination of group work*: Another important function of music is the accompaniment of work, thereby serving as a tool for coordinating and synchronizing mutual efforts.
– *Expressing and coping with emotions*: Music is a means to deal with emotions. Emotions are an important but difficult part of human life and human experience. Music can be very helpful with this: It can, for instance, express emotions; it can convey them to others, thus arousing their sympathies or care. To musically express emotions such as mourning, anger, joy, frustration is a possibility to cope with feelings by means of musical activities and experience. Accordingly, music, as a means of expressing, controlling and refining emotions, may have had an evolutionary advantage.
– *Perceptual development*: Listening to music can be a kind of practice for acoustic perception.
– *Promotion of language acquisition*: Musicality can be conducive to the acquisition and the use of language (Hodges 1989). As language is an important element of human survival, skills that support the acquisition or the use of language may be advantageous for survival. Prelingual acoustic differentiation skills, i.e. the degree to which an individual succeeds to differentiate pitch, rhythms, timbre etc., before speech and language have been learned, also affect the ability of linguistic differentiation. Language offers a wide range of nonverbal differentiation possibilities: Any utterance can be pronounced in many different ways so that a wide variety of meanings is possible. If a child disposes of the respective acoustic-musical ability of differentiation, he or she is in a better position to send and decode non-verbal linguistic messages. According to Daniel Stern, the experience of being able to communicate one's emotional state and of "affect attunement" by nonverbal means represents an important step towards the applicability of symbols and the development of language. (Stern 1985, p. 230.)

- *Motor skill development*: Singing and other musical activities offer an opportunity to practice motor skills. Singing, for instance, could have been a necessary precursor for language development.
- *Conflict reduction*: In comparison to language, music can reduce interpersonal conflicts. It is thinkable that verbal quarrels at the bonfire lead to fights while singing at the bonfire was a safe social activity.
- *Safe time-passing*: The more effective humans became, e.g. with hunting, the more spare time they had that could be filled in a harmless way with music.
- *Transgenerational communication*: As proven by the ubiquity of folk ballades and epics, music is a useful medium to store knowledge and to convey it across generations. Music can serve as social memory. In preliterate cultures, tribal history was conveyed by songs and music. This makes music an instrument to preserve the identity of a people or a social group. Not only history and other facts can be effectively conserved by musical storage, but also the feelings that are connected with these facts or incidents. Thus, poems, songs or dances are bearers of cultural identity and cultural heritage.

All of these hypotheses about the evolutionary significance of music are more or less speculative. Still, there is distinct evidence and empirical proof especially of an evolutionary significant connection between music and social attachment behavior. David Huron (2001) points out that a high degree of sociality may come along with a high degree of musicality, whereas a low degree of musicality correlates with poor social skills. As an example he cites the Williams syndrome, a mental retardation usually combined with an explicit musicality and positive social behavior. The disturbed social behavior of the Asperger syndrome, an autistic disorder, is correspondingly often associated with a low degree of musicality. As another evidence of the impact of social functions on music he cites the fact that according to Fuld's studies (1995, cit. after Huron 2001, p. 56), the most successful piece of music of newer history is one which is performed exclusively in social situations where several persons are present, which has been translated into countless languages und which is doubtlessly being performed every single day millions of times by people of all ages and classes, viz the song *Happy Birthday* (composed 1893 by Mildred and Patti Hill, revised in the 1930s). Finally, and these are definitely remarkable findings, empirical data show that music is able to affect the hormone level and, furthermore, social behavior. Experiments by Fukui (2001) revealed that listening to music can influence the testosterone level in such a way that it is reduced in male listeners and elevated in female ones. Fukui's assumption is that the influence of music on the testosterone level could have had a social function in the course of evolution, namely the control over aggressive and sexual behavior. Due to the lowered hormone level, the aggressiveness in male listeners is reduced, while, on the other hand, sexual desire in females is suppressed.

The neurophysiologist Walter Freeman (1995; cit. after Huron 2001) discovered that music may cause a release of the hormone oxytocine. This hormone is connected with social attachment behavior and occurs both in animals and in humans in situations of emotional closeness and attachment. Even the hormonal system of babies has been found to be influencable by music. By means of saliva samples from babies aged 5–7 months, Shenfield, Trehub, and Nakata (2003) found out that the level of the hormone cortisol which acts as an indicator for the degree of activation can be influenced by maternal singing. The children's cortisol level was determined right before the mothers started singing. After 20 minutes it was measured a second time. Infants who had a relatively high cortisol level before their mother sang to them had a lower one afterwards, whereas in children whose saliva showed a rather low level of cortisol it was elevated after singing. This means that maternal singing can modulate and alter the babies' degree of excitation, which can be verified even at a biochemical level (see also Trehub 2001).

These facts demonstrate that already at a very early age, music plays an important role for individual human development. I would like to discuss this ontogenetic aspect in the following two parts.

5. The Ontogenetic Impact of Music

An individual gains acoustic experiences already prior to birth. Around the sixth or seventh month of pregnancy, children start to perceive extrauterine acoustic stimuli. From a developmental point of view, acoustic experiences are among the infant's first sensory experiences of life. Maybe that is why they are of special importance.

The important function of fundamental musical skills for human development becomes especially obvious when observing the nonverbal communication in the mother-child-interaction of the first two years of life prior to language acquisition. The child's oral communication with his or her parents or caregivers takes place by using musical parameters such as pitch, dynamic, tempo respectively rhythm, and timbre. The more differentiated the way in which children can handle these parameters and perceive them with their caregivers, the better they can express their needs and feelings, the better are their possibilities of expression, perception and communication, the better they understand their environment. These fundamental musical elements serve as a means for communicating love, commitment and others feelings as well as the communication of needs between child and mother. The basic skill to communicate by means of such musical, preverbal elements works similarly across cultures and is innate to every human being (see e. g. Papoušek 1994, 1996, Papoušek and Papoušek 1995).

Thus, in the beginning, there was *not* the word and there was *not* language. In the beginning, there was the ability of musical communication. This ability allowed us to establish contact and a relationship with our closest relations, without any possession of word and language. None of us was born as the speaking creature we became later. But still, we were born as communicating creatures, i.e. as creature that were able to express needs, feelings, emotions in such as way that they could be perceived and understood by mother, father or other caregivers. In the same way did we as infants perceive and understand the commitment, confirmation or rejection of these caregivers, actually without the lexical meanings, grammar and syntax of language. The basis of this communication is of a musical-emotional nature. Such a "communicative musicality" (Malloch 1999/2000) or "protosymbolic communication" (Trevarthen 1992/2000) as some scientists call it, is innate and resides in every human being. For that reason alone, nobody is unmusical.

After all, every human being communicated in his or her early infancy by means of this preverbal language. To large extent, the perception of such musical elements has to be connected with pleasant experiences: warmth, love, commitment, security, perhaps happiness. Maybe that is why music is often associated with pleasant feelings and even with happiness – because it somehow ties in with these experiences? Authors in the fields of psychoanalysis, music education and music psychology widely agree on the conclusion that music may provoke regression experiences going back far into early stages of infancy, reaching even those early childhood stages where the Ego and the outside world were not yet distinctly separated. This might explain why intense music experiences can cause the feeling of becoming one with the outside world or the universe. The psychoanalyst Pinchas Noy points out the importance of the predisposition to musical ability and refers to the emotional exchange with the outside world by means of musical elements in early childhood. He continues: "And later, when the adult is stirred up by longings for the lost paradise of oral infancy, for that symbiotic mother love, such longings may take on the shape of craving for those 'fondling tones'. Music, with its sound patterns set according to primary period when through the sensory modality of hearing he had felt reassured by his mother's love." (Noy 1968, p. 344.)

During the first decade of life, children learn the musical language of their culture. They acquire a comprehension of meter, rhythm, tonality and become acquainted with different styles of music. Already with eight or nine years of age, children start to develop definite musical likes or dislikes. Such a formation of musical preferences, the development of musical tastes takes a central position in musical development between the ages of 10 and twenty. While the acquisition of sound vocabulary and the mastery of musical grammar are the central development tasks of the first decade of life, another important task accrues in the second decade, namely to find one's own position and identity within music culture. This happens by developing individual aesthetic likes and dislikes. However, these preferences are by no means an aesthetic end in itself, but they fulfill important functions in the shaping of identity and in social development. After all, musical preferences signal an affiliation to particular social groups and at the same time the social distance towards others. Musical preferences are the result of the functions they fulfill. This applies to social functions as well as to individual psychological functions. They develop mainly during puberty, stabilize in the course of years and often remain the same for several decades. Among these functions are the conscious applications of music to influence moods or for relaxation, to express emotions and find comfort, to cope with feelings of depression, loneliness and other everyday life problems or to get away from it. Thus, music helps not only to cope with everyday problems (and be it only that it provides temporary but recreative distraction), but also to experience meaning, happiness and last not least transcendence in a secularized world.

Of course, such functions are not reserved to adolescence but they are part of the use and function of music in adulthood. Recently, the German news magazine *Focus* (*16*/2004, p. 146f.) published the results of the so-called "Große Deutsche Genussstudie", a survey which representatively scrutinized the small und big pleasures of everyday life in Germany. According to this survey, listening to music ranks second in the small, but important everyday pleasures among 41 % of men and 35 % of women. It is, by the way, remarkable that more men than women consider listening to music as one of the most important small pleasures and that it is mentioned more often than the daily meals (39 % of men and 26 % of women). If this points at the importance of music or at the quality of the daily means remains open to question. In the category "belongs to my top three pleasures", 23 % of men and 14 % of women named "media i.e. music consumption". Although this makes music not the first among the top pleasures, which can be found rather in the field of nature or sport, it ranks clearly before the category sex and tenderness. If Darwin had known!

In the course of adulthood, the significance of music and its function may change, as the context of life – factors such as working life or family – plays a very important role. Unfortunately, there is hardly any research on this subject (apart from very few studies: Lehmann

1994, Mende 1991), so that hardly any assured facts can be given. However, Darwin made some interesting observations about himself, which he describes in his autobiography.

He relates that up to the age of 30, poetry and music delighted him very much. Later in life, this fondness and delight had been displaced by scientific work and was now, in old age, almost completely lost. He regrets this as a deplorable loss of higher tastes and relates it to a degeneration, an atrophy of the respective cerebral parts, commenting it as follows: "… if I had to live my life again, I would have made a rule to read some poetry and listen to some music at least once every week; for, perhaps, the parts of my brain now atrophied could thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature." (Darwin 1974, p. 84.)

I am convinced that Darwin made several important points here. This can be supported by a number of arguments: From everyday life experiences and developmental psychology we know that abilities which are not needed generally degenerate throughout life. Findings from brain research suggest that without the ability of emotional sensations, even the most brilliant intellect lacks moral and social orientation (Damasio 1997). I do not mean to go further into this topic; instead, I would like to change Darwin's experiences into the following positive statement: By means of regular music experiences, musical receptivity is kept intact. These experiences bring about an increase in happiness; what's more, even fields other than music are affected: Our intellectual skills, especially the emotional and moral parts of our nature, benefit as well.

6. Music as a Means of Communication in Old Age

Finally, I would like to point out some important aspects about music in the last stages of life. Music can play an important role as a means of communication for memories and retrospection, both with healthy persons and in the therapeutical field. In the following, I am going to focus on the latter one, namely on the role of music in the treatment of patients suffering from Alzheimer's disease. I would like to outline some interesting findings.

Quite a few surveys (Brotons et al. 1999) show that Alzheimer's patients are able to keep singing old songs and dancing to old melodies notwithstanding memory loss and aphasia. This suggests that music is a channel for communication and retrospection. Another interesting result is that in spite of aphasia and language degeneration, musical skills can be maintained in patients who were musicians. This phenomenon can be explained by a dissociation between declarative and procedural memory. For this reason it is possible that the ability to remember musical coordination is still widely intact although the patients are suffering from Alzheimer's disease. Single case studies show that there are persons who are still able to play recently learned pieces of music, although they know neither the name of the piece nor its composer. Relevant literature reports about Alzheimer's patients who are still able to play the trombone in a Dixieland band.

All in all, music-related mechanisms appear to be the last to degenerate in the course of the disease, at least in a part of the patients. As artistic therapies, especially music therapy, depend to a lesser extent on language mechanisms, they offer a unique approach to communication at a stage when other means of communication such as language are no longer possible, or only in a constricted way. Here, music can meet communicative functions in various ways: It can convey a feeling of appreciation, give energy and reassurance. It can stimulate emotions, bring backs memories that seemed to be already lost. It also contributes to reduce depression, isolation, tension, fear etc.

In single case studies, reactions on music could be found even in the last stages of Alzheimer's disease (movements of the mouth, opening of the eyes, change in pulse and breath rate, movements of hand and feet).

Briefly outlined, some further points to be mentioned (see Brotons et al. 1999):

– As single case studies demonstrate, reactions on music are possible even in the last stages of Alzheimer's disease (movements of the mouth, opening the eyes, changes in pulse and breath rate, movements of hand and feet). Experiences from music therapy show that music brings about more reactions than any other stimuli. But there is a tendency towards increasing reactions in the course of time.
– Singing in the group promotes social behavior (talking, gesticulation, smiling, touching each other). Compared to other groups (e.g. doing jigsaw puzzles), better spirits. Social interactions and memory were improved after musical activities.
– Patients listening to music fall asleep significantly easier than control groups without music. Listening to music soothes agitation, especially when the patient's preferences are taken into consideration. There are only very few surveys on the improvement of cognitive/memory skills. They document that after a music therapeutical session the recollection of words is better, if the words had been chanted. Even new linguistic material could be learned if repeated sufficiently often and presented in the context of a song.

Altogether, relevant surveys have come to the conclusion that Alzheimer's patients can maintain musical communication skills into late stages of disease. Thus, it can be said that the impact of musicality may last from the earliest stages of life to the very last one. Prior to speaking, we communicate by means of musical parameters. If, at the end of our life, we have lost the ability to speak, musical communication is the last to remain.

7. Conclusion

Although the origin and the role of music in human evolution is still a controversial issue, there are quite a few important arguments and empirical evidences supporting the theory that musicality, as a predisposition to music, may have played an adaptive role. I doubt that Steven Pinker (1996), who popularized the idea of the "language instinct", is right when he says that music is of no use because it does not contribute anything to prolong our lives, to have a lot of grandchildren or to perceive the world better. If music disappeared from our species and from our world, this would, according to Pinker, hardly affect our lifestyle, contrary to the disappearance of language or technical know-how. My intention was to point out that music definitely does have a central function and significance in human life, regarding both the phylogenetic and the ontogenetic development, albeit often unconsciously and not always obvious at first glance.

According to Donald Hodges (1989) we are musical because music – just as language and other forms of intelligence – has played an important role in the formation of our human nature and will always do so. He concludes (Hodges 1989, p. 20): "If music is a 'built-in' system, put there because of its importance, it must be important for us still to engage in musical behaviours."

References

Allen, H.: Vokales Laienmusizieren. Musik-Almanach 2003/2004. Daten und Fakten zum Musikleben in Deutschland. S. 21–35. Edited for the Deutsche Musikrat by Eckhardt, A., Jacoby, R., und Rohlfs, E. Kassel: Bosse/Bärenreiter 2002

Brotons, M., Koger, S. M., and Pickett-Cooper, P.: Music and dementias: A review of literature. Journal of Music Therapy *XXXIV*(4), 204-245 (1999)

Brown, S., Merker, B., and Wallin, N. L.: An introduction to evolutionary musicology. In: Wallin, N. L., Merker, B., and Brown, S. (Eds.): The Origins of Music. Second ed. Cambridge, Mass.: MIT Press 2001

Damasio, A. R.: Decartes' Irrtum. München: dtv 1997

Darwin, C. (and Huxley, T. H.): Autobiographies. Edited with an Introduction by Gavin de Beer. London: Oxford University Press 1974

Dennis, W.: Creative productivity between the ages of 20 and 80 years. Journal of Gerontology *21*, 1–8 (1966)

Fukui, H.: Music and testosterone: A new hypothesis for the origin and function of music. In: Zatorre, R. J., and Peretz, I. (Eds.): The Biological Foundations of Music; pp. 448–451. New York, NY: New York Academy of Sciences 2001

Gembris, H.: Musikalische Interessen und Aktivitäten im Erwachsenenalter. Psycho-soziale Funktionen in zwischenmenschlichen Beziehungen. In: Gembris, H., Kraemer, R.-D., und Maas, G. (Eds.): Musikpädagogische Forschungsberichte 1994. S. 123–133. Augsburg: Wißner 1995

Gembris, H.: Grundlagen musikalischer Begabung und Entwicklung. 2. Aufl. Augsburg: Wißner 2002

Heise Online: Der weltweite Musikmarkt ließ auch 2003 nach. Retrieved September 16, 2004 from www.heise.de/newsticker/meldung/print/46365 (2004, July 4)

Hodges, D. A.: Why are we musical? Speculations on the evolutionary plausibility of musical behavior. Council for Research in Music Education, Bull. No. *99*, 7–23 (1989)

Huron, D.: Is music an evolutionary adaption? In: Zatorre, R. J., and Peretz, I. (Eds.): The Biological Foundations of Music; pp. 43–61. New York, NY: New York Academy of Sciences 2001

Lehman, H. C.: Age and Achievement. Princeton: Princeton University Press 1953

Lehmann, A. C.: Habituelle und situative Rezeptionsweisen beim Musikhören: Eine einstellungstheoretische Untersuchung. Frankfurt: Lang 1994

Malloch, S. N.: Mothers and infants communicative musicality. Musicae Scientiae, Special Issue: Rhythm, Musical Narrative, and Origins of Human Communication, 29–57 (1999/2000)

Mende, A.: Musik und Alter. Ergebnisse zum Stellenwert von Musik im biographischen Lebensverlauf. Rundfunk und Fernsehen 39. Jg., Nr. *3*, 381–392 (1991)

Miller, G.: Evolution of human music through sexual selection. In: Wallin, N. L., Merker, B., and Brown, S. (Eds.): The Origins of Music. Second ed., pp. 329–360. Cambrigde, Mass.: MIT Press 2001

Noy, P.: The development of musical ability. The Psychoanalytic Study of the Child *23*, 332–347 (1968)

Papoušek, H., and Papoušek, M.: Beginning of human musicality. In: Steinberg, R. (Ed.): Music and the Mind Machine. The Psychophysiology and Psychopathology of the Sense of Music; pp. 27–34. Berlin: Springer 1995

Papoušek, M.: Vom ersten Schrei zum ersten Wort. Anfänge der Sprachentwicklung in der vorsprachlichen Kommunikation. Bern: Huber 1994

Papoušek, M.: Intuitive parenting: a hidden source of musical stimulation in infancy. In: Deliège, I., and Sloboda, J. A. (Eds.): Musical Beginnings. Origins and Development of Musical Competence; pp. 88–112. Oxford: Oxford University Press 1996

Pinker, S.: Der Sprachinstinkt. München: Kindler 1996

Reu, S.: Musik und Beziehung – Musikpräferenzen in Heiratsannoncen. In: Gembris, H., Kraemer, R.-D., und Maas, G. (Eds.): Musikpädagogische Forschungsberichte 1994; pp. 327–334. Augsburg: Wißner 1995

Rohlfs, E.: Instrumentales Laienmusizieren. Musik-Almanach 2003/2004. Daten und Fakten zum Musikleben in Deutschland. S. 36–44. Edited for the Deutsche Musikrat by Eckhardt, A., Jacoby, R., und Rohlfs, E. Kassel: Bosse/Bärenreiter 2002

Shenfield, T., Trehub, S., and Nakata, T.: Maternal singing modulates infant arousel. Psychology of Music *31/*4, 365–375 (2003)

Simonton, D. K.: Emergence and realization of genius: The lives and works of 120 classical composers. Journal of Personality and Social Psychology *61/*5, 829–840 (1991)

SLATER, P. J. B.: Birdsong repertoires: Their origins and use. In: WALLIN, N. L., MERKER, B., and BROWN, S. (Eds.): The Origins of Music; pp. 49–64. Cambridge, Mass.: MIT Press 2001

SÖNDERMANN, M.: Musikwirtschaft. Musik-Almanach 2003/2004. Daten und Fakten zum Musikleben in Deutschland. S. 101–115. Edited for the Deutsche Musikrat by ECKHARDT, A., JACOBY, R., und ROHLFS, E. Kassel: Bosse/Bärenreiter 2002

STERN, D. N.: Die Lebenserfahrung des Säuglings. Stuttgart: Klett-Cotta 1985

STUMPF, C.: Die Anfänge der Musik. Leipzig: J. A. Barth 1911

TREHUB, S. E.: Musical predispositions in infancy. In: ZATORRE, R. J., and PERETZ, I. (Eds.): The Biological Foundations of Music; pp. 1–16. New York, NY: New York Academy of Sciences 2001

TREVARTHEN, C.: Musicality and the intrinsic motive pulse: evidence from human psychobiology and infant communication. Musicae Scientiae, Special Issue: Rhythm, Musical Narrative, and Origins of Human Communication, 155–199 (1999–2000)

Prof. Dr. Heiner GEMBRIS
Universität Paderborn
Institut für Begabungsforschung in der Musik
Pohlweg 85
33100 Paderborn
Germany
Phone: +49 5251 605210
Fax: +49 5251 605209
E-Mail: Heiner.Gembris@upb.de

Christian Gottfried Nees von Esenbeck – Politik und Naturwissenschaften in der ersten Hälfte des 19. Jahrhunderts

Leopoldina-Meeting
am 20. und 21. Juni 2003 in Halle (Saale)

Acta Historica Leopoldina Nr. *43*
Herausgegeben von Dietrich von Engelhardt (Lübeck), Andreas Kleinert (Halle/Saale) und Johanna Bohley (Halle/Saale)
(2004, 245 Seiten, 5 Abbildungen, 1 Tabelle, 19,95 Euro, ISBN 3-8047-2153-2

Ausgehend von der Leopoldina-Edition der Korrespondenz des XI. Präsidenten der Kaiserlich Leopoldinisch-Carolinischen Akademie, des Botanikers und Naturphilosophen Nees von Esenbeck, mit dem preußischen Kultusminister Altenstein, der ein eigener Beitrag gewidmet ist, wird die Thematik des Meetings in den drei Komplexen Akademie, Universität und Romantische Naturphilosophie behandelt.
Im vorliegenden Tagungsband werden zunächst die zwei unterschiedlichen Modelle der Institutionalisierung von Wissenschaft – Akademie und Universität – thematisiert (Beiträge zur Reformierung der Leopoldina im 19. Jahrhundert, zur Gründungsgeschichte der Universität Berlin, zur Bedeutung der Naturwissenschaften an der 1818 neugegründeten Universität Bonn und dem dortigen *Seminar für die gesammten Naturwissenschaften* sowie zur Rolle von Bildung und Politik im Denken der romantischen Naturforscher). Im Mittelpunkt des anschließenden Abschnitts zur Romantischen Naturphilosophie stehen die Institutionalisierung der Naturphilosophie nach Schelling, die Bedeutung von Wissenschaft und Politik in Lorenz Okens Naturphilosophie sowie – in einer biographischen Fallstudie – die Bedeutung von gesellschaftspolitischen Veränderungen im Leben des Naturforschers K. W. G. Kastner.
Christoph Meinels Abschlußkommentar verweist auf lohnenswerte, weil weiterführende Fragestellungen wie die Definition des Terminus Wissenschaftspolitik für diese Zeit, das Verhältnis von Wissen und Macht bzw. Wissenschaft und Gesellschaft. Der übergreifende Abendvortrag von Hans Joachim Meyer über das Verhältnis von wissenschaftlicher Freiheit und politischer Verantwortung führt schließlich zurück in die Gegenwart.

In Kommission bei Wissenschaftliche Verlagsgesellschaft mbH Stuttgart