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Human Proto-Development: Very Early Auditory Stimulation

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Abstract: Early sound stimulation beginning before birth can perfect sensomotoric development, prevent deprivation and perhaps heighten human perception epigenetically. On the basis of this assumption, an experimental group of 45 expectant mothers and children between the 16th prenatal and the 24th postnatal week were presented with the sound stimulation programme *Leonardo 180*. Postnatal assessment using the Denver and ELM scales showed a considerable improvement of the test values in this group, and in our view these test values were the result of sound stimulation. The Leonardo 180 programme is designed such that it begins by activating the somatosensory and vestibular system of the unborn child using low frequencies and fairly slow rhythms; after the second trimester of pregnancy and in the postnatal phase, higher tone frequencies, faster rhythms and more complicated melodies are used to work on the cochlear auditory system. The listening sequence of Leonardo 180 contains several repetitions of short selected pieces of vocal and instrumental music that presumably acts as basic musical elements or mantras to foster later sensomotoric development.

Long-term studies in which psychophysiological methods supplement or replace the relatively arbitrary development psychology tests are needed to confirm these very speculative results.

Zusammenfassung: *Prä- und postnatale Klangstimulation*. Eine frühe, pränatal beginnende Klangstimulation kann die sensomotorische Entwicklung vervollkommnen, Deprivationen vorbeugen und vielleicht die menschliche Wahrnehmung epigenetisch sensibilisieren. Basierend auf dieser Annahme wurde einer experimentellen Gruppe von 45 werdenden Müttern/Kleinkindern zwischen der 16. pränatalen und der 24. postnatalen Woche das Klangstimulationsprogramm *Leonardo 180* dargeboten. Die postnatale Auswertung im Rahmen der Denver- und ELM-Skala zeigte in dieser Gruppe eine deutliche Verbesserung der Testwerte, in der sich nach unserer Interpretation Effekte der Klangstimulation manifestierten. Das Programm *Leonardo 180* war so aufgebaut, daß es zunächst im tieferen Frequenzbereich und mit langsameren Rhythmen das somatosensorische und vestibulare System des ungeborenen Kindes aktivierte und nach dem zweiten Trimester der Schwangerschaft sowie in der postnatalen Phase mit höheren Tonrequenzen, schnelleren Rhythmen und komplexeren Melodien auf das cochlear-auditive System wirkte. Der Hörplan von

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Leonardo 180 enthielt mehrfache Wiederholungen kurzer ausgewählter Stücke vokaler und instrumentaler Musik, die vermutlich in der Funktion musikalischer Keimzellen oder „Mantras“ die spätere sensomotorische Entwicklung bereicherte.

Langzeituntersuchungen, in denen psychophysiologische Methoden die relativ willkürlichen entwicklungspsychologischen Tests ergänzen oder ersetzen, werden diese noch sehr spekulativen Ansätze absichern.

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Introduction

The approach toward early sensomotoric education presented here dates back to an international conference on prenatal psychology held in Atlanta/Georgia in 1991 during the 5th Congress of APPPAH. A small group of scientists, therapists, pediatricians and gynecologists who believed in the possibilities of intervention during very early human development, discussed the few systematic studies on prenatal sensomotoric stimulation which had been published at that time. In addition we outlined a large body of questions and experiments necessary for a better understanding of the transition from prenatal to postnatal perception and memory and the possible roots of individual differences in human sensitivity. The initial results of those discussions and the first data on human proto-development, as we called our new field research, were published two years later (Blum 1993) and formed a basis for proto-developmental programs such as *Leonardo 180* and *Leonardo 240* which are to be introduced with this paper.

The objective of every proto-developmental program is to activate the creativity of the unborn and newborn child and at the same time to stimulate all parental skills available in one of the most wonderful and crucial periods of their parenthood.

In this text on the evolution of childhood, Lloyd de Mause (1982) describes the desirable transition from a “socializing mode” of child rearing characterized by role-learning and functionalism to the “helping mode” in which co-operation and creativity overcome strategies to separate losers and winners at an early age. Today, at the beginning of the 21st century, the vast majority of children are far from having experienced this helping mode, not only in Africa, SE-Asia or India, but also in industrialized countries, where child abuse and abandonment can be identified at a frequency never expected. The helping mode can only be realized on a certain level of sensitivity. This level can be raised we believe, by sensomotoric stimulation to be started prenatally and to be continued postnatally until the child is able to enter more conventional programs of pre-school education. Unfortunately, pre-school education in many countries is considered a luxury which has to be financed privately. Therefore in conjunction with scientific research on human sensomotoric development, campaigns must be started to establish budgets on the level of global organizations which will allow every child in the world to participate in a proto-developmental program over a period of at least 24 months (e.g., 6 prenatal and 18 postnatal months). The worldwide fast-increasing income from inheritance taxes might be regarded as a possible resource to finance early human education.

The committed participation of both parents is the essential part in every proto-developmental program; the early period of child rearing should no longer be delegated to a nanny or an au-pair. Early sensomotoric stimulation should be understood as the injection of a new and attractive stimulus into the genepool of the young family. This stimulus will induce a series of interactions between genetic and epigenetic mechanisms, resulting in a maximum expression of the genotype. Latent sensitivity will be structured and safe and we assume that the degree of the genotypical expression is in proportion to the refinement of the stimulus: stimuli of a low refinement such as the baby rattle or similar noisy things will not show remarkable developmental enrichment effects. Every proto-developmental program therefore should include a certain level of sophistication to which the parents then will be motivated to adapt.

Proto-Development: Brain Plasticity and Stimulus-Dependent Changes in Morphology

The first extended period of human development, characterized by a maximum plasticity of brain structures, is designated here as the proto-developmental period. Interventions in this period in most cases irreversibly affect all later stages of human cognitive and emotional growth. They can accelerate the process of maturation and improve special skills while inadequate interventions and early deprivations may set off a series of deficiencies which remain throughout a person's life. It has been shown in neurobiology that the plasticity of brain structures during early development allows external stimuli to induce morphological changes at the microlevels of synapses, neurons and neuronal maps (Edelman 1992). How an external stimulation like a massage or a piece of music might be related to the morphological change of a synapse, is sketched in Fig. 1. Through external stimulation electromagnetic action potentials are generated within the neural network. When an action potential arrives at the presynaptic terminal, it causes the fusion of vesicles to the presynaptic membrane, the release of neurotransmitters, and a flux of ions across the postsynaptic membrane. In conjunction with the release of transmitters there is the appearance of neural cell adhesion molecules (NCAM)

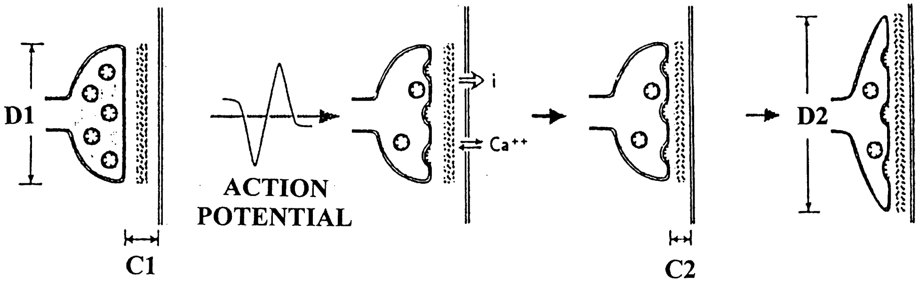


Fig. 1. Stimulus-dependent morphological change of a synapse. Action potentials evoked e.g. by an external stimulation cause an increased adhesive interaction between pre- and postsynaptic cells. The original synapse (*left*) changes into the more efficient synapse (*right*) with a smaller cleft C 2 and a larger diameter D 2 (Schubert 1991).

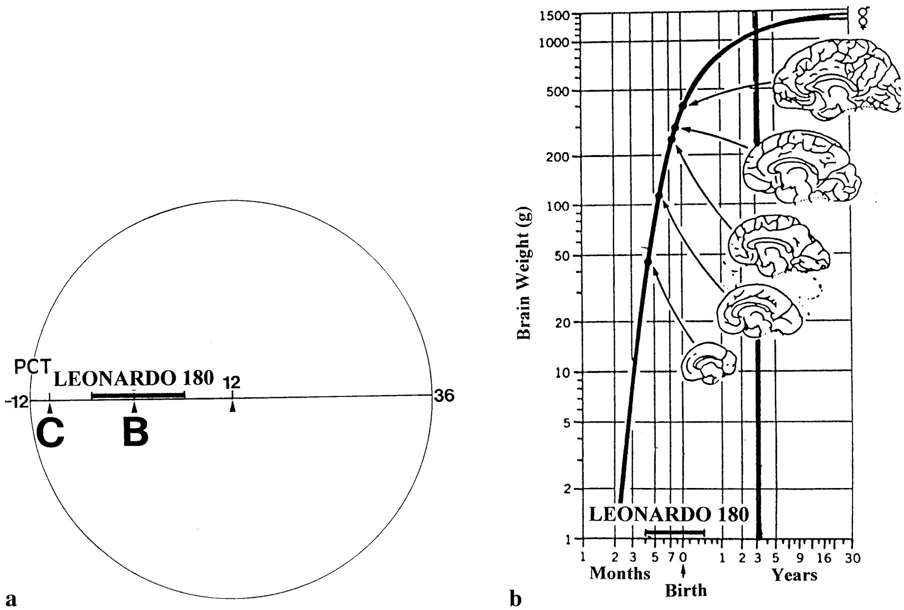


Fig. 2. (**a**) A circle with the 12th postnatal month as the center and a radius of 24 months defines the length of the human proto-developmental period, the period of the maximum brain plasticity. The length of the program *Leonardo 180* here is marked between the 16th prenatal and 24th postnatal week. (**b**) Program *Leonardo 180* and the proto-developmental period as related to the increase in human brain weight, which until the 3rd postnatal year increases exponentially.

at the surface of the presynaptic cell and a transient flux of free extra-cellular CA(++) into the synaptic cleft. These two events increase the adhesion of both cell types, leading finally to (a) a decrease in the synaptic cleft width from C1 to C2; (b) an increase of the diameter of the presynaptic membrane surface from D1 to D2.

Those stimulus-dependent morphological changes of a single synapse – a smaller cleft size and a larger membrane surface are – related to increased efficiency in neuronal network. Using a memory model of this kind (cf. LTP-model) it follows that such a morphological stabilization of a perceived and learned stimulus can be regarded as corresponding to epigenetical changes induced by the environment. Changes in the phenotype are composed from stimulus-dependent changes on the microlevel. Gottlieb (1992) argues for a bi-directional interaction of all genetic and epigenetic mechanisms and he speculates on the transgenerational preservation of phenotypical changes: "transgenerational stability of new phenotypes is preserved by the repetition of the developmental condition that gave rise to them in the first place". First stimulations always will result in very basic developmental effects. Changes in child rearing may have caused the transition from homo erectus to homo sapiens. New proto-developmental programs of first harmonic stimuli to activate human sensomotoric function might contribute to further evolutionary transitions towards mindfulness and a better integration of intuition and ratio.

As shown in Fig. 2a, where the 12th month has been chosen as center point of a circle with a radius of 24 months, the proto-developmental period in our definition incorporates 36 postnatal months as well as 8–10 months of prenatal life including a preconception period of about 2 months. Over the course of the proto-developmental period between conception (C) and the 36th postnatal month there are many overlapping critical periods in which particular sensomotoric and cognitive functions achieve maturity. Some critical postnatal periods can be easily observed without much developmental experience via the so called sensomotoric milestones (cf. Denver-Scale), such as the milestone for "walking" or for "rolling over" or for "sitting without support".

There are prenatal milestones which we are just beginning to be recognized in proto-developmental research. One of these prenatal milestones, important for design of proto-developmental programs, is the function of auditory skin perception, which seems to be mature in the first trimester of pregnancy, long before cochlear audition is possible. Proto-developmental programs like ours consist of predominantly auditory stimulation and therefore can be started in the first trimester of pregnancy, stimulating first the skin of the unborn child, activating the rudimentary somatosensory system and preparing audition in the lower frequency range up to 1000 Hz. As indicated in Figs. 2a and b, our sound stimulation program *Leonardo 180* should be applied between the 16th week of gestational age and the 24th postnatal week. Figure 2b shows the increase in human brain weight over the proto-developmental period.

Early Listening Via Skin and Cochlea: Prenatal Audio-Somatosensory Stimulation

Auditory stimuli, as compared with other sensory stimuli, can be employed most advantageously in proto-developmental programs. At lower frequencies they penetrate the maternal abdominal wall and uterine tissue and reach the unborn without significant losses of intensity. At medium frequencies such as around 4000 Hz the intensity loss of a prenatal auditory stimulation is about 10 dB (Richards et. al. 1992), but it increases to 35 dB in the high frequency domain of 10 kHz (Lecanuet 1996). Therefore a high frequency stimulation as included in our program *Leonardo 240* is better suited to the postnatal than to the prenatal stage. For prenatal stimulation we recommend vocal and instrumental music with lower and medium basic frequencies which first will be perceived via the fetal skin, the most sensitive and meaningful receptor organ of the unborn child. During gastrulation the ectoderm is seen as the origin of the skin as well as of the central nervous system (CNS) and the common origin of both the skin and the CNS has implications for later cognitive development and for the accumulation of the ego in a psychoanalytical sense. For Dowling (1990), fetal skin sensitivity is to be regarded as the primary mode of consciousness during prenatal life. He refers to the British analyst Francis Mott, who speculated in the fifties, that fetal skin activity can be seen as the basis of all later skin-imagery, such as casting off the skin-clothes in rebirth rituals. He also assumes that libido was not first generated postnatally at the baby's sucking mouth, as proposed in classical psychoanalysis, but it was generated prenatally over the entire skin surface of the unborn child.

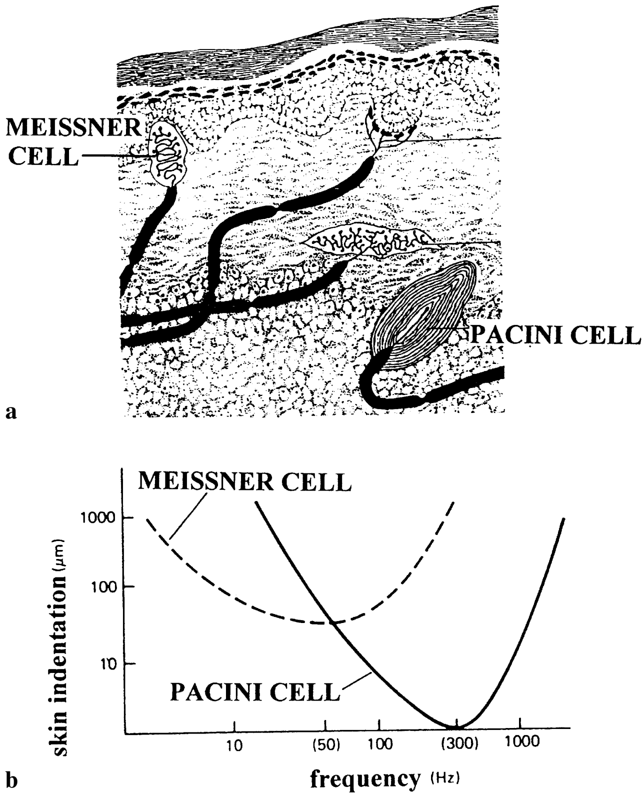


Fig. 3. (**a**) Meissner cells and Pacini cells in the human skin. The Pacini cells are located deeper in the dermis with larger receptive fields in comparison to the Meissner cells (Martin 1985). (**b**) Sensitivity of Pacini and Meissner-cells as expressed by the skin indentation (micrometer). Pacini cells have their maximum sensitivity to sound waves in the frequency range between 100 and 1000 Hz (with a peak sensitivity at 300 Hz). Meissner cells are about ten times less sensitive in the frequency range between 10 and 100 Hz as compared with Pacini cells (Martin 1985).

For Dowling the awareness of the fetus somehow resides in the skin. Within this context we can understand David Chamberlain (1988, 1992) who finds wisdom and intelligence in the unborn child.

More related ideas on prenatal sensitivity, intelligence and musicality can be found in Verny and Kelly (1981), Fridman (1985), Fedor-Freybergh (1987), Janus (1991), Lecanuet et al. (1995) or Deliège and Sloboda (1996).

According to a human prenatal physiology, the so called Pacini and Meissner-cells of the skin can be regarded as the mechanoreceptors of the growing somatosensory system, sensitive to sound waves, which are identical to pressure waves. In Fig. 3a, Pacini and Meissner-cells are shown as embedded in the human dermis. Here Meissner cells are located near the surface. They have small receptive fields which are mostly suited to spatial frequency analysis necessary to identify contours of pressure waves. Pacini cells, located much deeper in the dermis, have larger receptive fields and therefore a poor spatial resolution, but their sensitivity is about ten times higher than that of Meissner cells.

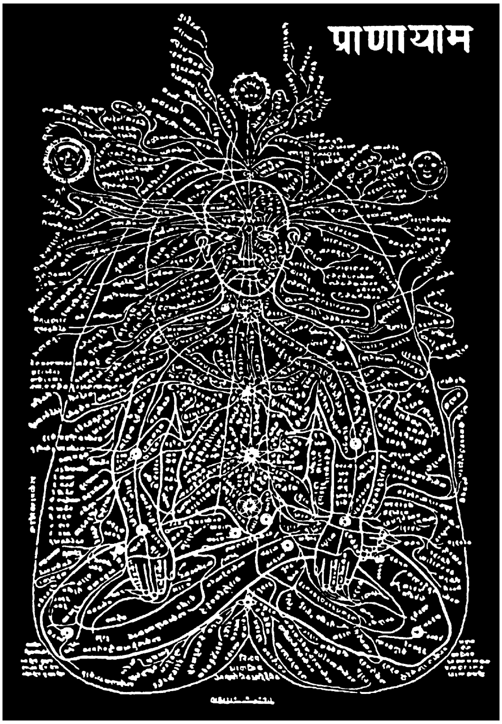
The sensitivity of these skin receptors is measurable by the amount of skin indentation sufficient to activate the receptors. Figure 3b shows the skin indentation for Pacini and Meissner cells as related to the frequency of sinusoidal sound waves. Here one can observe that Pacini cells are very sensitive in a frequency range between 100 and 1000 Hz with a maximum sensitivity at about 300 Hz. The skin indentation here is less than 10 micrometers. Meissner cells are activated most efficiently in the very low frequency range between 10 and 100 Hz, but here the skin indentation is 100 micrometers which means that their sensitivity is ten times smaller than that of Pacini cells. From these data we expect that prenatal auditory stimulation is first processed by Pacini cells and that it can be understood as an acoustic massage: the neonate might have memories of an early bath in a sea of sounds as created by the harmonic vibrations of the amniotic fluid.

Such an early acoustic massage can prepare the perception of rhythms with the somatosensory and vestibular system and later fine resolution of pitches with the cochlear system. Cochlear listening also begins prenatally in the second trimester of pregnancy, but because of the attenuation of higher frequencies in the womb it only will reach its full potential at a postnatal stage. Neonates are able to listen to frequencies as high as 20 kHz and it is one of the objectives of postnatal sound stimulation, using methods of Tomatis (1991), to unfold the human potential of high frequency listening which can vitalize emotion as well as cognition. Early losses in the high frequency domain have severe consequences for sensomotoric development.

Using this physiological knowledge it is quite appropriate, to start an auditory proto-developmental program prenatally with lower frequencies and slow, perhaps monotonous rhythms, and then continue with a gradual inclusion of higher frequencies and faster and more variable rhythms and melodies.

Such a progression from lower to higher temporal and spatial frequencies can also be found on the path to enlightenment as described in Sanskrit philosophy where mantras or seed sounds are used to stimulate the chakra energy centers and to evoke elemental archetypes for healing. Certain stages of enlightenment are attained, when prana – the universal energy of live – is flowing throughout all of the finely branched channels (called nadi) of the four human energy bodies, the ethereal, astral, mental and spiritual body. Such a mantra-stimulation should help to dissolve blockades in the complex nadi network and Fig. 4a depicts a Tibetan idea of such a differentiated and fragile network which is said to be composed of about 350 000 single channels. The bright knots shown in this figure are chakras which are connected to receptor surfaces on the skin with diameters up to 10 cm.

The seven main chakras, all projected onto the corporal axis, are shown in Fig. 4b. Beginning with the basic chakra 1 and ending with the corona chakra 7, they represent the primary structure of the complex nadi network. In traditional Indian sound therapy, the chakras from 1 to 7 are classified according to increasing pitch. The table in Fig. 4b delineates these classifications and one can see that chakra 1 corresponds to the tone C as well as to the mantra LAM, the vowel O (opened) and the 4-leaved lotus. Similarly, chakra 2 is related to the tone D, mantra RAM, vowel O (closed) and the 6-leaved lotus. Mantra-meditation then



a

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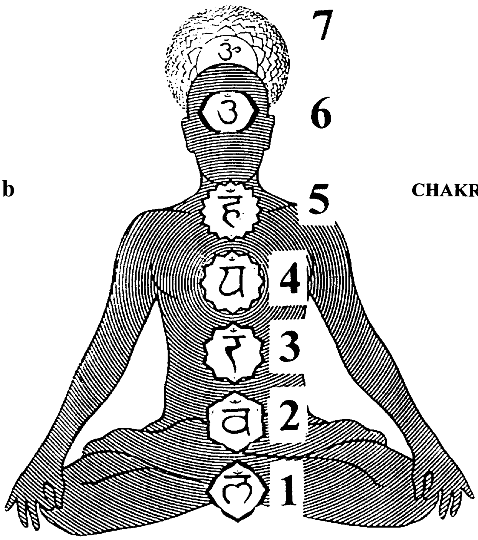

CHAKRA	BIJA MANTRA	TONE	VOWEL	FREQUENCY
7	OM	H	m	high
6	KSHAM	A	i	↑
5	HAM	G	e	
4	YAM	F	a	
3	RAM	E	o	
2	VAM	D	/o/	
1	LAM	C	u	low

Fig. 4. (**a**) Historical Tibetan representation of the human chakra-nadi-network (Sharamon and Baginski 1977). (**b**) The main chakras 1–7 and the corresponding bija-mantras, tones and vowels. The path to enlightenment has the direction from the lower to the higher temporal and spatial frequencies (Sharamon and Baginski 1977).

leads us on its path through the other chakras to the sacred sound corresponding to mantra OM and the corona chakra in the spiritual body. In occidental sound therapy the sacred sound is very related to the "sound of life" (Tomatis) which fills every cell and resides in frequency domains beyond 8 kHz. In order to perceive the sound of life, a humming silence must prevail and it should be more the silence of a starlit night and not the silence of a sound-proofed chamber. J.E. Berendt (1989, 1990) showed in his inspiring books a lot of other similarities between oriental and occidental sound therapy.

John Cage, who was intimately familiar with traditional music from India, called the sacred sound the "sound of silence" (as Simon and Garfunkel did). He frequently used periods of silence in his compositions: here sound and silence have become interchangeable and sound prepares us to listen to silence such as mantra meditation prepares us to reach the sacred sound and the stage of enlightenment. We see now that an auditory based proto-developmental stimulation has a similar direction: it prepares sensitive listening in different channels, strengthens the neuronal network and unfolds the potentials of the human genotype. One genotype and a multitude of phenotypes: Let us first study new phenotypes before we allow a manipulation of the genotype.

Methodology

The *Leonardo 180* sound stimulation program has been designed, applied and evaluated by Leonardo Publishers in co-operation with some Maternity Child Hospitals (MCH) in China. Promoted by the Sun Yat Sen University of Medical Sciences in Guangzhou, the program could initially be tested at the MCH of Shunde, a very modern hospital in province Guangdong where the participating mothers and fathers-to-be, with their unborn and newborn children and the doctors and nurses soon formed a very motivated and creative group which determined the final version of *Leonardo 180*. The pieces for the sound stimulation program were chosen from a broad repertoire consisting of classical music, old and contemporary folk songs, nursery rhymes and dances from Europe, China and India. This wide range has been condensed into a program lasting 180 minutes and containing 45 pieces, each between 3 and 5 minutes long.

The grouping of the pieces into 8 program units, each of about 22 minutes used criteria such as vocal and instrumental music, richness in overtones, lower and higher frequencies, slower and faster rhythms. The 8 program units were recorded onto 2 mc's each of 90 minutes, and they were designated as follows:

1A1 = First unit, recorded on mc 1, first half of side A.
1A2 = Second unit, recorded on mc 1, second half of side A.
1B1 = Third unit, recorded on mc 1, first half of side B.
1B2 = Fourth unit, recorded on mc 1, second half of side B.
2A1 = Fifth unit, recorded on mc 2, first half of side A.
2A2 = Sixth unit, recorded on mc 2, second half of side A.
2B1 = Seventh unit, recorded on mc 2, first half of side B.
2B2 = Eighth unit, recorded on mc 2, second half of side B.

Table 1. Listening schedule for the 8 units: 1A1, 1A2, 1B1, 1B2, 2A1, 2A2, 2B1 and 2B2 of the program *Leonardo 180*. Here the low frequency units are marked as *1A1* and *1A2* and the high frequency units as 2B1 and 2B2.

Prenatal (week, G.A. – program unit)

16 – *1A1*	21 – 1B2	26 – 1B2	31 – 1A2	36 – 1B2	41 – 1B2
17 – *1A2*	22 – *1A1*	27 – *1A1*	32 – *1B2*	37 – *1B1*	
18 – 1B1	23 – *1A2*	28 – 1A2	33 – *1B1*	38 – 1A2	
19 – *1A1*	24 – 1B2	29 – 1B2	34 – 1A1	39 – *1B2*	
20 – 1B1	25 – 2B1	30 – 1B1	35 – *2B2*	40 – *1A1*	

Postnatal (week, post – program unit)

1 – 2A1	6 – 2A2	11 – *1A2*	16 – 2B2	21 – *2B2*
2 – 1B1	7 – *1A1*	12 – *1A1*	17 – 1B1	22 – 1B2
3 – 1B2	8 – 1B2	13 – 2A2	18 – 2A2	23 – 2A2
4 – 1B1	9 – *1A2*	14 – *2B2*	19 – 1B2	24 – 2A1
5 – *1A2*	10 – 1A2	15 – *2B1*	20 – *2B1*	

According to this labeling system, units 1A1 and 1A2 contained pieces with slow rhythms and basic frequencies in the lower range. Pieces with more varying rhythms and medium frequencies were placed on units 1B1, 1B2, 2A1 and 2A2 and all sounds and compositions in the higher frequency range could be found on units 2B1 and 2B2. Furthermore, 10 pieces were selected which were the favorites in all our experimental groups and which were inserted amongst the units to serve as musical mantras, structuring the entire program. These following 10 pieces have been selected for the program *Leonardo 180*:

Barbara Allen (Alfred Deller, English folksong)
Foggy, Foggy Dew (Alfred Deller, English folksong)
Nanni Bay (Chinese folksong)
Fisherman song (Chinese folksong)
Let the bright Seraphim (G. F. Händel / Kathleen Battle & Wynton Marsalis)
Erbarme Dich (J. S. Bach / Marian Anderson)
Trumpet Tune (Henry Purcell / Maurice André)
Tum Pukar Lo (Hemant Kumar / Lata Mangeshkar)
Love of my life (Freddy Mercury, love song)
Sieh nur die Sterne (Rolf Zuckowski, children's song)

The listening schedule for *Leonardo 180*, which is shown in Table 1, guaranteed that the favorite pieces or musical mantras would be repeated in a particular order, suitable for memorization. And also the prenatal part of the program progresses from the lower to higher basic frequencies. This progression was repeated in the postnatal part.

After several tests to ascertain the acceptance of the program in several experimental groups in Shunde as well as in Shanghai, an experimental field study with *Leonardo 180* was carried out at the First Maternal Child Hospital, Shanghai. This study involved 45 families with their unborn/newborn children and lasted approximately 14 months. Using our listening schedule, the expectant mothers

Fig. 5. Photo of a group of expectant mothers, listening in their rocking chairs to a unit of the program *Leonardo 180* (Shunde MCH, Guangdong).

began listening with their unborn children between the 16th and 20th week of gestational age and they continued until the 24th postnatal week. During the postnatal period, the stimulation was accompanied by developmental tests from the Denver Scale and from the Early Language Milestone Scale (after J. Coplan et al. 1982). The prenatal part of the program took the form of daily individual sessions at home (mc's and stereo-player) and weekly sessions with groups between 4–6 mothers-to-be, held in the prepared sound-room of the hospital.

For home sessions expectant mothers following the listening schedule played the appropriate unit at least once a day. They placed themselves in a comfortable rocking chair with a distance of about 50 cm from the speakers of their stereo-player and laid their hands on the abdominal surface to notice the movements of their unborn babies. The fathers joined in these prenatal home sessions wherever possible, which normally took place late afternoon at a fixed time. The mothers signaled the start of the program by means of a gong, thereby hoping to gain a maximum attention from the unborn baby. By the final weeks of pregnancy, most of the mothers and fathers had the impression that their child was waiting the given time for the sound stimulation to begin. These home sessions in their best performance became rituals in which the highly motivated parents attempted to pass on to their child a maximum of their own creative energy. As a parallel to these individual home sessions which were monitored by home visitors from our staff, group sessions in the hospital were carried out once a week combined with lectures on pregnancy, nutrition, hygiene and child development. In the sound-room which we had installed in the hospital, a group of 4–6 expectant mothers were surrounded by a chain of speakers, wired and programmed to create both a conventional stereo-effect and a moving-sound-effect for the training of spa-

AE 5 MONOSYLLABIC BABBLING

CONTROL: 25% PASSED AFTER 125 DAYS
EXP. : AFTER 125 DAYS, 44 SUBJECTS HAD PASSED

44/45 = 98% ooooooooooooooo

Q(A) = 98% : 25% = 3,92

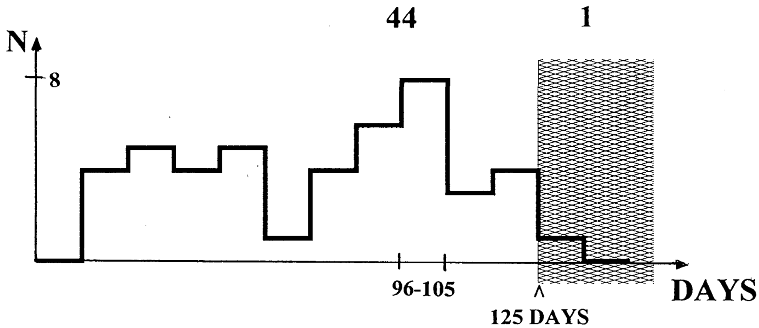

Fig. 6. Activation quotient Q(A) for the milestone "monosyllabic babbling". Normative data from a multi-ethnical control group (Coplan et al. 1982) show that the first 25% will pass the milestone within the first 125 postnatal days. In our experimental group (N = 45) we found that 44 subjects passed the milestone within the first 125 postnatal days (white part of the histogram) and that only 1 subject needed more than 125 days (shaded part of the histogram). 44 subjects represent 98% of our experimental group. We calculate Q(A) = 98% / 25% = 3.92. For Q(A) the following criterion was used: we assumed an effect of our sound stimulation program *Leonardo 180* on the milestone test only if Q(A) was greater than 3.0.

tial listening. In Fig. 5, a photo of such a group session is shown with some of our expectant mothers, sitting relaxed in their rocking chairs and listening with commitment.

The postnatal group and home-sessions had a similar structure, they began for each mother 2–3 weeks after birth with the mother sitting in her rocking chair and holding her baby in her arms. The postnatal sessions were continued in this way and ended in the 24th postnatal week.

In order to assess possible developmental effects as induced by *Leonardo 180*, we applied single tests from the ELM and Denver Scale, which had the advantage of a distinct and simple identification of selected sensomotoric milestones such as "monosyllabic babbling" or "sitting without support". To evaluate the data of our experimental group, we used control data from literature (Coplan et al. 1982) and constructed a so called quotient of activation Q(A), as explained with Fig. 6, using the milestone "monosyllabic babbling".

In literature we find that in a large, multi-ethnical control group (n = 191) the first 25% (first quartile) of the 191 subjects had passed this milestone after the 125th postnatal day, as indicated in Fig. 6 by the left borderline of the shaded surface. On the other hand we observed in our experimental group of 45 subjects, that after 125 postnatal days, 44 babies (98%) had passed the milestone "monosyllabic babbling". In Fig. 6, the white part of the histogram represents the number of the subjects which passed after the 125^{th} day. From these data we calculated the activation quotient as follows: Q(A) = 98% / 25% = 3.92, and to introduce a high threshold, we decided that if Q(A) was greater than 3 we would assume an activation effect, i. e. an effect of our sound stimulation on the sensomotoric milestone as measured in the test. All data were evaluated in this way in close co-operation between the parents and our staff.

Results

For the postnatal analysis of *Leonardo 180* we selected 9 single tests from the ELM and Denver Scale, which can be separated into 5 tests related to the early auditory-phonological development and 4 tests on visual and gross-motoric milestones.

The results from the first two tests related to the child's early vocalization are shown in Fig. 7a. Here the milestone "baby blows bubbles" is marked by AE4. We see in the histogram at the top of the figure that within the first 55 postnatal days 25% of all subjects of the control group had passed the milestone; within 55 days, 41 out of 45 subjects or 91% of our experimental group have passed the milestone and 4 subjects needed more than 55 days to pass. From these data we calculate Q(A) as 91% / 25% = 3.64, which exceeds our threshold of 3 and therefore expresses a distinct activation effect.

An even greater effect is measured for the milestone "monosyllabic babbling" (baby makes sounds like "ma, ba, da, goo"), represented by the histogram at bottom in Fig. 7a. Here the resulting activation quotient is Q(A) = 98% / 25% = 3,92.

The next 3 tests, marked as AR4, AR5 and AR/ are related to spatial listening in the following way:

- AR4 = Bell Test 1
  Sit facing the baby, with baby in parent's lap. Extend both arms so that your hands are behind the baby's field of vision and at the level of the baby's waist. Ring a small bell first with one hand, then with the other and repeat 2–3 times. Pass if baby turns head to the bell side at least once (cf. Fig. 7b, AR4 at left margin).

The histogram representing our data for the Bell Test 1 is shown in Fig. 7b, top left. Here within 60 days, when 25% of the control group had passed, we observed in our experimental group that 43 out of 45 subjects or 96% had passed the milestone, resulting in Q(A) = 96% / 25% = 3,84.

The second stage of the bell test includes a more differentiated response: The baby here must turn its head first to the side of the bell and then down (cf. Fig. 7b, top right, AR5). It is shown that within the given 115 days 42 subjects or 93% of our experimental group passed the milestone which results in an activation quotient of Q(A) = 93% / 25% = 3.72.

Finally, the third stage of the bell test includes a very precise spatial sound localization. Here the baby passes only if it turns its head directly diagonally to lo-

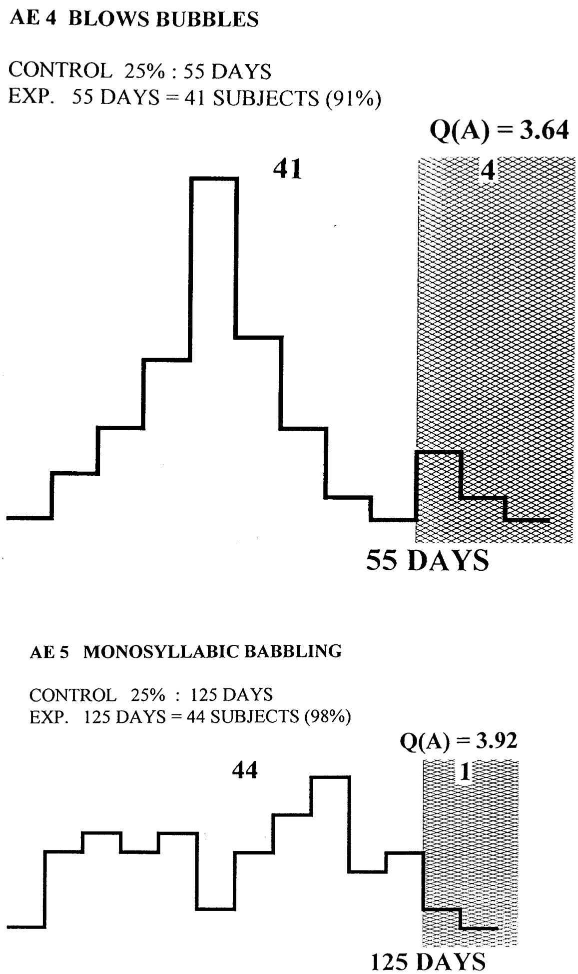

Fig. 7a. Q(A) values for the milestones "AE4 – Blows Bubbles": Q(A) = 3.64 and "AE5 – Monosyllabic babbling": Q(A) = 3.92. In both cases Q(A) is greater than 3.0 such that we can assume effects of the sound stimulation on the milestone tests.

calize the bell at least once (cf. Fig. 7b, AR7 at left margin). The related histogram AR7 at the bottom of Fig. 7b shows that within the given 190 days all 45 subjects or 100% of our experimental group passed the milestone resulting Q(A) = 100% / 25% = 4. For all 3 stages of the bell test, therefore, we can assume a significant effect of our sound stimulation program.

Our last four selected developmental milestones describe visual and gross-motoric functions. The related histograms are shown in Fig. 7c. The test V5 on horizontal and vertical visual tracking was carried out in the following way:

- Engage child's gaze, move slowly back and forth, pass if baby turns head about 60 degrees to left and right from midline; further move slowly up and down, pass if baby elevates eyes about 30 degrees from horizontal: must pass horizontal and vertical condition to pass item.

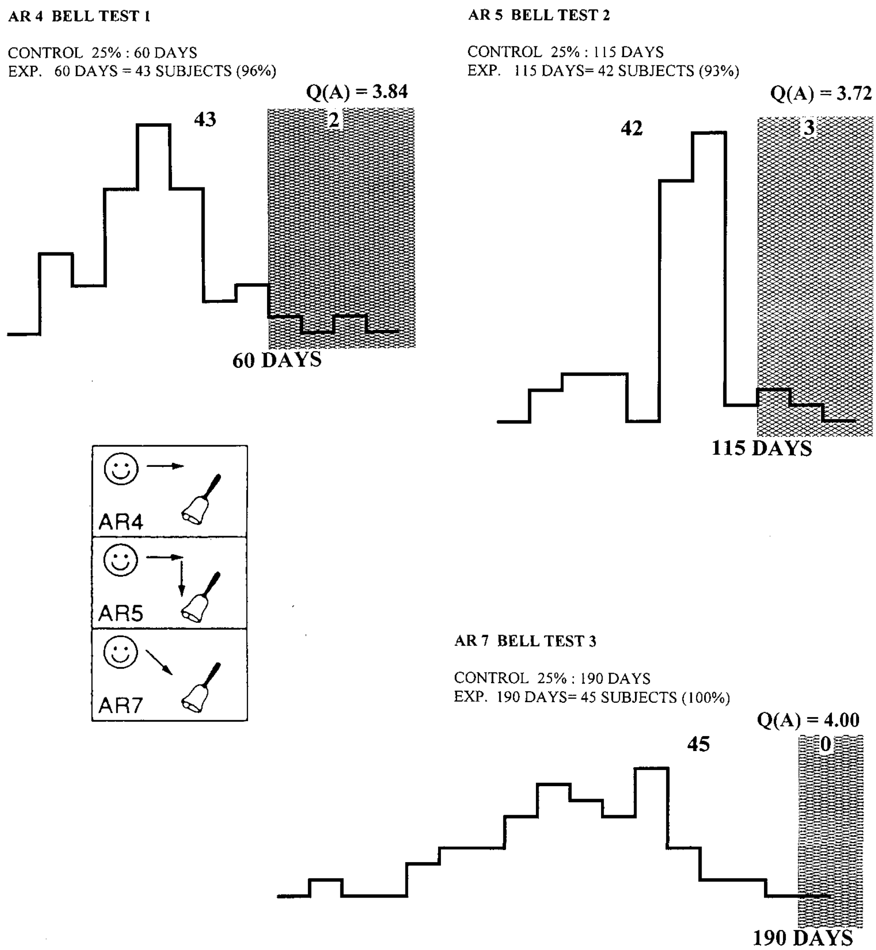

Fig. 7b. Bell tests 1–3 (AR4, AR5 and AR7): Ringing a bell in a bottom left position behind the baby makes the baby at an early developmental stage look only to the (left) side of the bell (AR4). At a later stage the baby looks first to the left and then down to the bell (AR5) and at the final stage it looks directly diagonal to the bell's position (AR7). For all three stages of the bell test our Q(A) values were greater than 3.0. For AR4: Q(A) = 3.84, for AR5: Q(A) = 3.72 and for AR7: Q(A) = 4.0.

The histogram V5 in Fig. 7c, top left, shows that within the given 40 days, 40 subjects or 89% of our experimental group passed the milestone from which data we can calculate Q(A) = 89% / 25% = 3.56.

Tests GM1 and GM2 are concerned with the early gross-motoric development. Milestone GM1 is called prone position: here the baby lies in an abdominal position supporting its body with the elbows and raising its head at angle of approximately 90 degrees. Milestone GM2 indicates the position of stable sitting: The baby sits upright with an unsupported head. Our evaluation of GM1 and GM2 resulted in the histograms shown in Fig. 7c at the bottom left and right. Even here, in both cases we were able to calculate activation quotients greater than 3:

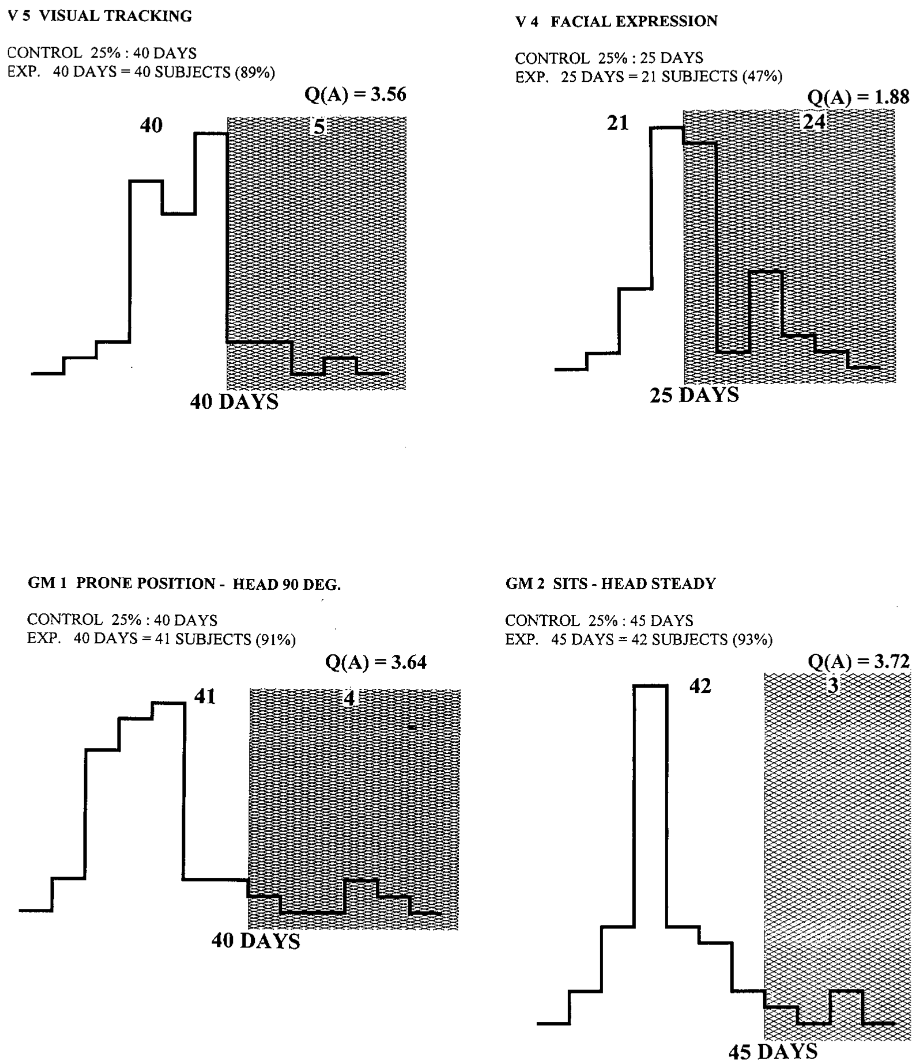

Fig. 7c. Q(A) values for milestones "V5 – Visual tracking": Q(A) = 3.56; "V4 – Facial expression": Q(A) = 1.88; "GM1 – Prone position, head 90 degrees": Q(A) = 3.64; "GM2 – Sits without support, head steady": Q(A) = 3.72; only for V4 (baby responds to facial expressions Q(A) was significantly smaller than 3.0 and a sound stimulation effect couldn't be assumed. However we believe that 25 postnatal days are too short a period to measure reliable effects within relatively small experimental groups.

for GM1 Q(A) was 3.64 and for GM2 it was 3.72. Variable results were achieved with test V4, in which the baby's reaction to facial expressions was measured:

- Engage baby's gaze and attempt to elicit a smile by smiling and talking to the baby. Pass if there is any change in baby's facial expression.

The related histogram is shown in Fig. 7c, top right. Here, in the control group the first 25% passed within the first 25 postnatal days. In our experimental group by the 25^{th} day only 21 subjects of 45 or 47% had passed. This resulted in an activation quotient of Q(A) = 47% / 25% = 1.88 which does not fulfill our criterion "Q(A) greater or equal 3". Perhaps 25 days are too short a period to make any reliable measurements on the level of developmental tests. Furthermore, a milestone like "reaction on facial expressions" includes a certain degree of stability in emotional maturation. Perhaps emotional development might be strongly affected by ethnic differences as compared with general sensomotoric development.

In summary, our data analysis showed significant effects of the pre- and postnatal sound stimulation especially on auditory, phonological, and gross-motoric milestones. We note similar results from proto-developmental field studies carried out by Chairat Panthuraamphorn and his group in Bangkok (1995, 1998). Panthuraamphorn used prenatal auditory, tactile and vestibular stimulations and showed on the level of the Denver developmental test that significant enrichment effects could be achieved in the domains of early vocalization, spatial listening and the expression of emotions.

Future Research and Discussion

Proto-developmental programs such as *Leonardo 180* in which larger experimental groups have to be organized over a longer pre- and postnatal period are very difficult too carry out from a technical point of view. It is essential that proto-developmental studies include long-term observation as well as large experimental groups. However, because of the great variability of data collected in the developmental tests, other and more precise psychophysiological methods should be applied.

From our experience with psychophysiological methods we believe that the method of evoked potentials can be used successfully in proto-developmental research (Blum 1991). This noninvasive method which has been proved to be a high priority in neonatal research is based on latency analysis and a reliable matching of latencies in the experimental group compared with latencies of control groups published in the literature. Among the different evoked potentials (those of longer, medium and shorter latencies), the components of brain stem potentials such as component V with very short latency can normally be identified in neonates within a 10-millisecond-window. These measures seem very promising for proto-developmental studies. This component has been shown to depend on the maturation of the subcortical auditory pathway. If there are any morphological prenatal or neonatal effects related to early sound stimulation, then the subcortical auditory pathway should be affected, resulting in a shorter latency of some components of brain stem potentials as compared with published norms.

In our new proto-developmental program, *Leonardo 240*, which we hope to apply in a larger field study in Sri Lanka, our data analysis will include evoked potential registrations. This new program consists of the proven sound stimulation program *Leonardo 180* adapted to new experimental groups and additional stimulation programs as follows:

1) a high pitch unit (Tomatis 1991), in which in selected pieces of vocal and instrumental music the lower frequencies will be masked to induce a sensitive listening in the higher frequency domain above 8 kHz. Training of listening to higher frequencies starts with the training of some muscles in the middle ear (e. g. muscle stapedius), resulting in a higher adaptability and dynamics of sound perception;
2) a unit for listening to pure Pythagorean intervals which is to sensitize the transition from consonant to dissonant intervals such as the transition from a small third (5:6) and a small sixth (5:8) to a small seventh (5:9), a great second (8:9) or a small second (15:16). This unit is carried out postnatally using a special audio-somatosensory stimulator which can amplify the skin perception of sounds in the lower frequency range.

With *Leonardo 240* we will also investigate the child's musical likes and dislikes. The parents will keep a postnatal diary and note down over the first 12 postnatal month the attentional reactions to single pieces of music and especially to the carefully selected musical mantras. Parents are encouraged to supplement the program with sound and music of their own selection, to create a very individual early musical environment for their child.

To achieve a first résumé of our proto-developmental studies, we can assume that those postnatal effects resulting from our pre- and postnatal sound stimulation should be composed of (a) general bonding effects, related to a higher motivation and creativity in the young family; (b) special effects on the sensomotoric behavior of the child which might express a higher degree of differentiation of the central nervous system.

Using a predominantly auditory stimulation we can activate the somatosensory system of the unborn child at a very early developmental stage. The skin as the first and most sensitive human receptor organ processes early harmonic sound stimuli. Because of the early connectivity of all other sensory systems, the skin can be regarded as the distributor of these first stimuli, which should activate sensitive and differentiated sensomotoric function – the precondition for mindfulness and flexibility in judgement as we believe.

More than any other stimuli, sound stimuli can activate ratio and intuition as the basic components of our mind. As we know from Pythagorean philosophy, harmonic experiences are always based on the relationship of numbers, a highly harmonic sound corresponds to the relation 2 : 3 (fifth) or 4 : 5 (great third). With increasing numbers such as in the relations 5 : 9 (small seventh) or 15 : 16 (small second) the original harmony gets lost. In borderline between harmonies and disharmonies might be shifted by an early and adequate sound stimulation such that more dissonant sounds will become accepted in perception. Fantasy will be enriched in an analytical way.

According to Damasio (1994), human emotions first are to be understood as subcortical programs which are controlled by limbic brain structures such as the amygdala and the hypothalamus. Only at a later stage of development and after education these primary emotions can be transformed into so called secondary emotions, which now involve cortical processing. The somatosensory cortex plays an important role in the unfolding of secondary or analytical emotions. An early harmonic sound stimulation might be seen as adequate to activate those secondary emotions. Primary emotions, when exceeding a critical mass without being transformed into analytical emotions, are going to be dissociated from the individual self, then forming the substrate of collective group fantasies. Fundamentalism can be regarded as a lack of analytical fantasies, a lack of sophistication.

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