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A developmental approach to voice science

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Vocal development had been studied mostly with a focus on speaking, and only rarely, on singing. Traditional theories on singing development are often based on wrong premises, e.g. eurocentrism, and reliable analyses of singing are missing or selective. A new theory - inspired by the principles of Piaget's theory -, and a new methodology - based on acoustic measures - are proposed.
The voice starts to self organise at birth, and gradually adapts to the cultural surrounding and its conventions concerning language, music, and social rules. Vocal and musical behaviour are highly adaptive and constructive, and concern two symbolic systems: music and language. The child develops the voice by playing and imitating. The development proceeds from sensori-motor activities towards more and more conscious actions and thoughts. In order to study children's singing, computer aided programs were devised to analyse and represent pitch, timing, pitch qualities, and syllables. This method yields complex configurations of these parameters describing children's song singing. Detailed descriptions allow to reconstruct the strategies children apply to invent or learn new songs. The empirical results from children at various ages demonstrate that the focus on the analysis of the organisation of the vocal expression is a promising research strategy.

1 Introduction

Weeks before birth, the human ear is physically functioning already. And birth, the first cry is the starting point of the vocal development. The infant starts hearing her or his own voice, and gradually begins to co-ordinate the hearing with the vocalization. Social interaction and emotional attachment are necessary conditions for a 'normal' infant to develop speaking and singing, or more abstract: language and music of a specific cultural surrounding. At early age, the infant is ready to adapt to one or more language und music system. The high plasticity of the brain and the enormous speed of brain growth and neuronal differentiation go along with the infant's physical activities. The physical development, e.g. motor movements, vocalization, stimulate brain development, and vice versa, brain development stimulates the infants activity potential.

Vocal development is among the most amazing domain in infant development: The voice is an important means to express emotional or affective states and to build up communication with caregivers. Furthermore, the voice is the first means for playing: infants extensively explore their vocal potential and play with the growing expressive possibilities. The self-organised vocal play shows the infant's high and intrinsic interest in using and developing the vocal expression. Complementary, the infant has a high ability for vocal imitation: Kessen, Levine & Wendrich [1] showed experimentally that infants are able to imitate accurately pitch. Both, imitation and play are important self organised activities of the infant to boost the vocal development. The caregivers stimulation in form of intuitive parenting and later on with 'motherese' are also necessary conditions in this process. The infant's rapid vocal adaption to the social stimulation gives rise to speculate about some deeper biological or evolutionary functions of the voice in general, and of the early vocal development for the individual in particular.

There are theoretical arguments and empirical evidences that for the infant, singing is easier and, therefore, earlier possible than speaking. The theoretically crucial point in this discussion is the definition of singing and of speaking. Dowling [2] suggested incidentally defining singing as a prolongation of vowels, whereas in speaking, the vowels are short. Since this criterion, the duration of vowels, is probable culture-free and in addition, acoustically verifiable, it is a helpful orientation. Yet, it is still very difficult to decide, whether an infant's vocalization is more like singing or more like speaking. Additional criterions need to be defined.

However, there is hardly any research into the process, how a child starts differentiating between singing and speaking. The data from case studies and from observational reports [3] show that it is easier for infants to produce identifiable melodies by modulating the pitch of vowels than to pronounce words. In other words: singing is more primitive and easier than speaking.

Probably the first research into the beginning of singing had been carried out by H. & M. Papousek [4]. There studies of infant-parent communication revealed that this peculiar setting encompasses a lot of musical elements. H. & M. Papousek discovered that musicality starts very early to develop, and that vocal play and vocal games in the parent-infant interaction are a hidden source for the development of musicality, of vocal communication, and of the building up intimacy and social attachment.

Recent research into language development recognizes that it is the prosodic or melodic contour of an utterance that helps the infant or toddler to understand and create meaning. It is the prosody or melody that provides units for identifying segments and their repetitions.

Compared to the huge research body on language development, the one on singing is rather poor. This situation mirrors the importance given to language. But we do not know whether the early singing supports or facilitates the development of speaking. At least we know that singing precedes speaking, because it is much easier to produce. But more insights into the development of singing would not only be useful for language development, but also for many other domains we do not yet fully understand. The following analyses of existing theories on singing development and on methodology suggest new directions in an under-researched area.

2 Previous theories

When analysing the research literature with respect to the theories or assumptions about the developmental process or sequence, three different ideas were found (cf. 5, 6,]:

The ‚interval acquisition theory' assumes that humans possess innate musical structures. Some individuals are more musically gifted than others. Singing development

occurs by progressively organising the tonal space in a fixed order: Initially, singing emerges around the scale's dominant (v or so), followed by a descending minor third (III or mi), then one tone above the dominant is added (VI or la), etc. This invariable sequence is seen as being derived from the harmonic structure of sounds. Analogous to Chomsky's ‚Language Acquisition Device', tonal structures are seen to develop according to a universal innate program

The idea of a ‚linguistic primacy' reflects a common agreement of researchers that in song acquisition and singing development, words appear first, followed by rhythm, contour, and intervals, in that order.

Davidson's [7] conception concentrates on the ‚contour schema' meaning the highest and lowest pitch of a phrase sung. According to Davidson, development proceeds by increasing the pitch span of a phrase beginning with the interval of a third and, by age 6 or 7, arriving at the size of a sixth.

The shortcomings of these theories are uncovered when confronted with detailed analyses of children's singing at different levels or ages. Here, I only raise three objections:

A) Detailed analyses of singing neither corroborated an invariable sequence of musical intervals nor any universals in this respect. Intervals turn out to be insufficient for analysing and describing singing since deviations are tolerated for aesthetic reasons or unnoticed by categorical perception. To avoid an ethnocentric view and bias toward the occidental system, it is necessary to have more differentiated access to analyse and describe non-western and pre-conventional singing.

B) Often, attempts to formalise singing development combine an additive sequence of musical intervals with the chronological age. According to these theories, a child's age would suggest certain intervals to be present or absent. Young children would reduce any song containing large intervals to the allowed intervals of their age-related stage. Yet, empirical analyses do not confirm such assumptions .

C) Likewise, it is not true that children would learn additive song components by starting with the lyrics. Since a song's components (lyrics, melody, and their synchronised timing) are interrelated and organised in parallel hierarchies [8], an additive conception is inadequate to describe actual song singing and its structures.

Facing this shortcomings, there are two important questions: a) how can the methods for analysing and describing singing be improved, and how can developmental principles be applied to re-analyse or interpret reliable empirical data and to build up a more adequate theory on singing development?

3 Analysing singing

We designed a new method on the basis of acoustic measures [9], and later, we improved the computer programs. The internet address for downloading two programs provides detailed instructions:

http://mmatools.sourceforge.net/.

The aim of this new method was to gain a reliable description of *what* children sing in terms of *how* a child organises the various relevant features during song singing. As relevant features we consider the following: pitch, pitch quality, timing, and syllables. We deliberately consider pitch and its timing to be more important for a structural analysis of song singing than intensity and timbre.

Apart from the analyses of the social interaction in which singing is usually imbedded, the method is based on two computer programs: one allowing to analyse the acoustic features, and the other – called Notation Viewer - allowing to visualise the data gained by the acoustical analyses,

Pitch analysis: There are various ways to analyse pitch, for instance, praat [10] is a very powerful computer program for analysing speech and related parameters including pitch. Our pitch analyzer is specialized on analyzing melodies, and it is less powerful and less complicated than praat. We devised two kinds of computer programs: one for the analysis of pitch at the basis of two different algorithms (Hess, 1983) which has been published (Stadler Elmer & Elmer, 2000). Figure 1 shows this program at work. The second program provides a detailed graphic notation of acoustic parameters at the basis of a data structure resulting from the acoustic analysis. We used this program since the beginning, but only recently, in 2006, it was improved and made easier for the public.

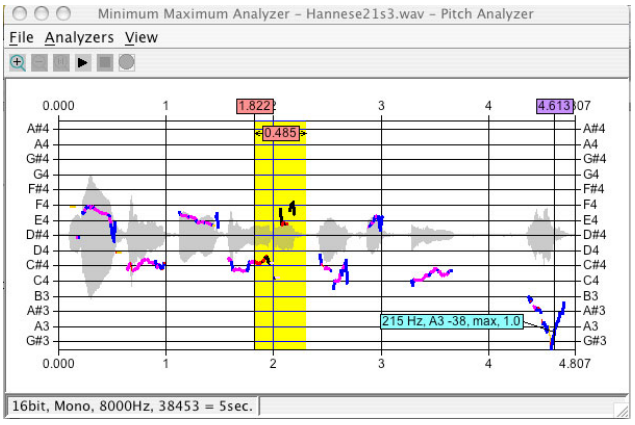

Fig. 1: Our Pitch analyzer. Acoustic analyses on pitch (Hz and cents) and time are given. For instructions see: http://mmatools.sourceforge.net/.

Notational system: Conventional music scores suggest that a melody consists of a sequence of single notes consisting each of a stable pitch with well defined distances. But sung or instrumentally produced melodies usually deviate from such notation, and furthermore, they hardly ever show as stable pitch categories of our tonal system that could be quantified. Rather, the pitch patterns are influenced by the accompanying syllable and by the previous and the subsequent sound. Yet, our categorical perception creates stable pitch categories that are not present as such in the signal. Hence, the conventional music notation is not adequate to describe performed melodies. We need a more detailed notation system that represents the measured acoustic parameters (pitch and time).

Table 1 shows the symbols we invented to reduce the information given by the acoustical analysis and to represent graphically. Figure 2 shows the result of applying the new methodology, the analysis of a song sung by a six years old boy. The data structure that allows producing this figure with the program "notation viewer" is given in Table 2. Again, instructions on making such a structure at the basis of the pitch analyzer (pitch, time, syllables, phrases etc.) are given at http://mmatools.sourceforge.net/

Code	Symbol	Description
1	•	Stable pitch
2	↗ ↘	Stable pitch, ending with upward or downward glissando
3	↗ ↘	Stable pitch, starting with upward or downward glissando
4	/ \	Unstable pitch, but clear upward or downward glissando
5	|	Unstable pitch with glissandi in any direction and/or unidentifiable, fuzzy pitches within context of singing (prolonged vowel)
6	W	Pitch of a spoken syllable
7	X	Estimation on the basis of disturbed signales
8	H	Syllable sung by the researcher
+10	○	Joint singing

Table 1: Symbols used to denote measures and additional features in the figures.

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Meta, inv. 5, 10.45 secs
2
9
 1 18.3 18.3  0.10 Ich
 2 21.4 19.0  0.50 bin
 1 13.8 13.8  1.30 der
 2 16.3 17.0  2.10 Mann
 1 20.9 20.9  2.56 der
 5 22.1 23.7  3.14 Ge-
 1 21.3 21.3  3.58 ruem-
 3 17.4 19.7  4.48 pelt
 1 19.0 19.0  5.38 hat,
7  5.59
 1 24.2 24.2  6.23 fuer
 1 21.1 21.1  7.17 die
 1 21.2 21.2  7.51 gan-
 3 16.9 18.7  8.30 ze
 3 17.8 19.1  9.10 gros-
 3 16.1 17.1  9.53 se
 4 16.1 18.0 10.10 Stadt.
   10.45
End
```

Table 2: Example of the data structure yielding Figure 2. The symbols shown in Table 1 are encoded.

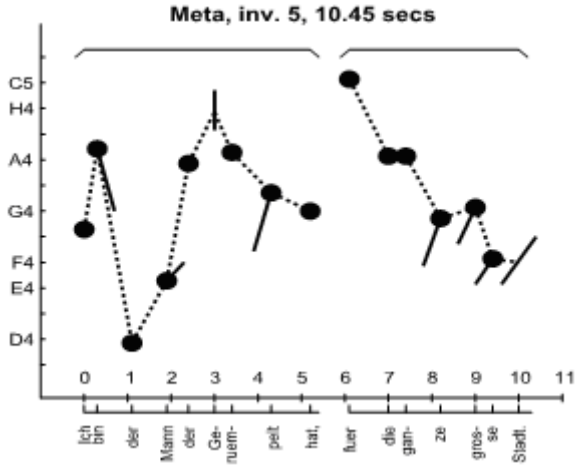

Fig. 2: Example of a description of a child's song invention. This figure is the result of the data structure given in Tab. 1. Such figures – together with the analysis of the social context – are the basis for analyzing step by step a child's strategies in organizing pitch, time, and syllables.

4 Singing development

The following description of the developmental course of singing is a synthesis of previous studies, and it is the result of theoretical considerations. The latter are inspired by the structural genetic constructivism in the tradition of Piaget [5, 6]. So far, six stages are conceptualised, which are subdivided into three large phases: pre-conventional, conventional, and post-conventional phase. They describe the sequence in which new qualities emerge in how a child organises his or her actions and thoughts related to music and singing. Note again that chronological age or musical norms can not serve as descriptive criteria. Individual differences and cultural diversity do not allow generalising across age groups and across cultures. The stages allow interpreting a person's musical or singing behaviour in terms of developmentally relevant criteria such as growing consciousness, growing control increasing differentiation and integration, growing de-contextualisation, and growing control underpin the development in this domain as well as in others. The aim is to provide criteria and guidelines for further research.

Stage 1: Beginning co-evolution of innate expressive predispositions with the social environment

From early on the infant is able to hear, to vocalise, to execute motor movements, and to start co-ordinating these actions. Vocalisation serves to express and elicit affection and emotion. The infant is highly susceptible and adaptable to sounds directed to her by parent's intuitive use of ‚motherese'. ‚Musical' features such as melody or prosody and rhythmic patterns play an important role 11, 12, 13]. They are a source for joyful exchange. The universal presence of specific features of intuitive parenting, e.g. the musical elements, gives rise to assume innate predispositions in both, parents and infants [14]. The infant's extensive exploration of the vocal potential (alone or in dialogues) represents the original form of playing. Infant-parent dialogues show a high incidence of reciprocal imitative sequences including vocal patterns [e.g. 14].

Stage 2: Deferred imitation, emergent rituals, and extended vocal play

Vocal dialogues (infant-parent) promote simultaneously the infant‘s pre-linguistic and pre-musical communicative competence [e.g. 12]. Repeated experiences of similar sound patterns and rules established between parent and infant yield some kind of intimate ‚rituals‘ that are based on mutually expected interactions. Often, prosodic features can not be distinguished from melodic ones. Established rules also concern turn-taking and simultaneous matching of vocal sounds. Repeating vocal patterns is a basic activity in early dialogues and in the infant‘s monologues. The latter reveal an increasing integration of vocal patterns that had previously occurred in dialogues, and vice versa, patterns of vocal play are transferred to dialogues. Such observations identify deferred imitations that indicate emergent mental representations of the sensori-motor structures (singing) Normally around 10 to 14 months, we can observe that a child had started to differentiate between the more speech-like and the more singing-like sound patterns. Often, adults are not sensitive to a child‘s (pre-)musical utterances but to speech. Singing-like phonation of vocal sounds proceeds gradually from glissandi-like or continuously gliding pitches to a differentiation of stable and sustained pitches and pitch patterns, whereas for speech-like sound shorts vowels are characteristic.

Stage 3: Sensori-motor strategy: auditory-vocal co-ordination to produce song fragments or entire songs

Children‘s early song singing year has the following characteristics: The child may join in singing accurately by adapting pitches, syllables, and their timing to another person‘s singing. When sung alone, standard songs may as well appear reasonably clear. Deviations from conventional rules do not concern a particular song component but any details, e.g. omitting or replacing phonems, simplifying rhythm and melody. The child concentrates on co-ordinating listening with vocalising and thereby focuses the overall sounds. This sensori-motor strategy, as we call it, does not yet include mental concepts meeting conventional musical and linguistic rules and meaning to guide and monitor the singing structure. Thus, attention may be paid to irrelevant sound features at the expense of culturally relevant ones.

It is hardly predictable how and what a child selects to imitate. Still, for her, certain events are easier to grasp, e.g. familiar patterns, small units with repetitive syllables and notes, and cues at hierarchically favourable positions (beginning, ending (rhymes), metrical weights, accents) in comparison to long and rich variations of speech and melodic sounds and of their timing.

The sensori-motor strategy yields productions that show accurate parts but as well the child‘s lack of understanding of conventional rules (e.g. parallel hierarchy) and linguistic and musical concepts. E.g. breathing may occur at any time the child wishes. By that, the rule may be violated that breathing should takes place between phrases [6]. Although the building blocks or units of ones own singing are not yet understood, the ability to co-ordinate listening and vocalising make possible for certain qualities in joint and solo song singing, even for songs with lyrics in a foreign language. This type of imitative performance is typical for this stage. Metaphorically, it may be compared to the function of a tape recorder. The child fixes sound in memory like a die, said Jakobson [15] about the same phenomenon in children‘s speaking. Outcomes of this strategy are easily overestimated (a child prodigy) or underestimated by that accurate song singing is mistakenly expected later. Apart from imitation, the child at this stage may extensively exert vocal play with amazing stamina, integrate and vary imitated features from previously sung songs, accompany invented stories with singing, and create a rich and unconventional variety of sound patterns.

Stage 4: Generalising examples, idiosyncratic song repertoire and idiosyncratic singing rules

Both, songs acquired and invented remind of features present at the situation the song was originally encountered. For the child, each song is a unique exemplar and connotes a particular place, mood, people, or other peculiarities. Orientation on examples is observable when she replaces a new song partly by familiar song components. While learning a song, the child at this stages combines the sensori-motor strategy of the previous stage with adopting already acquired exemplary patterns. She has not yet integrated some kind of general song singing rules. Pre-conventional singing structures may concern all song components, the lyrics, melody, and their timing. Unclear articulation, neologisms, omissions, incompatible semantics, repetitive melodic parts, levelling out metric and melodic nuances, reducing interval sizes, etc. are characteristic. Her invented and spontaneous singing particularly well show that she uses idiosyncratic and inconsistent rules. At this stage, conventional rules on song singing are largely ignored or changed according to highly subjective criteria.

Stage 5: Conventional rules on song singing are implicitly integrated

The growing repertoire allows more variety in generalising exemplary songs and idiosyncratic rules. More general rules emerge and are generalised across various singing contexts, including inventions. Conventions such as isometric verses, rhymes, endings on tonic (major or minor), tonic structures within melodies, larger and complex organised phrases, stable key due to stable pitches, are gradually and implicitly integrated into singing. Pre-conventional features such as neologisms, micro-intervals, glissandi, key instabilities etc. diminish. The conventions are not consciously reflected, but normative and aesthetic rules, e.g. ‚accurate-inaccurate‘ are implicitly known and used to control singing [16]. The child starts to understand that singing is a socially shared activity guided by conventions. Growing self-control starts inhibiting spontaneous, playful and (unconventional) creative singing. Taste and preferences start to be influenced by the social (sub-)group and contribute to build up a personal and social identity.

Stage 6: Beginning reflection of actions, means, symbols and concepts

Previously implicit structural knowledge manifested in song singing becomes subject to conscious reflection. Failure and success cause thinking about how the means used yield certain outcomes. At this level, the person begins to conceptualise and understand the necessity to have symbols representing musical sound for communication. As a generalised cultural tool, sound symbols are increasingly used in various ways to create and reproduce music (e.g.

songs) and to participate as a member of a socio-cultural group or society. Linguistic and musical symbols connected with singing (and other musical actions) support growing consciousness. Conventional rules, musical (and linguistic) concepts, historical backgrounds, ethnical origins, and cultural relativism belong to issues evolving more consciously at this stage. The reflection of actions and the growing awareness of cultural rules give way to post-conventional thinking and creative handling of symbolic means.

5 Conclusions

Independent of the theoretical background that is applied to the phenomenon of singing development, it is important to use a reliable method to analyse and describe the structure of this expressive behaviour. Only detailed and reliable descriptions allow studying the strategies a person uses while organising the relevant parameters. It is not some single and quantitative parameters that allow understanding development, but it is the way of organising a complex action. By describing the configuration of relevant parameters of an action like singing, it is possible to gain access to the intentions and thoughts of the producer, because they are manifested in the repeated patterns of a sequence of actions. The stable, instable and varied parts reveal the strategies a person uses habitually. Interestingly, only late in development, the strategies become more and more conscious. The proposed methodology allows an application to other cultural music systems, and to bi-cultural and cross cultural contexts. Research into the voice and its potential musical expression should try to understand human beings within their cultural context, but from a possible universal perspective.

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