body, came from or was delivered to the body of the mother. To be sure, the baby's nervous system has many highly developed functions, but the mother's is vastly more complex and autonomous. How could the baby possibly have known something the mother did not know a hundred times more precisely? Moreover, if an infant's crying depended on the ability of the infant to give caregivers information they lack, we would expect infants to cry more as they become more knowledgeable about the relation between the world and self. In fact, they cry less.

An advantage of the A/M perspective is that it is ultimately physiological, not psychological, in its imagery. It focuses on organisms as regulatory systems, responding to cue variables that stand in for variables of interest to their survival and reproduction. It thus provides an account of the evolution of signals based on a system of regulatory interactions between parties, not on the exchange of mythic commodities between them.

Soltis' theory that laryngeal braking is the origin of infant crying is compatible with the idea that "communication" arises from assessment/management cycles. Laryngeal braking may be a regulatory maneuver that augments gas exchange in the lungs by elevating intralung pressure, and so may feed the increased metabolic rate needed to heat a cooling animal. (For an alternative maneuver, see Blumberg & Sokoloff 2001.) From an assessment/management point of view, laryngeal braking or some similar regulatory compensation for cooling seems a reasonable first step in a historical account of the evolution of mother-infant "communication." It is characterized as part of a regulation in which an assessment of cues to the consequences of cooling causes the infant's physiology to use the respiratory apparatus to compensate for those changes.

But – the A/M account would continue – the sounds made in the course of laryngeal braking provide opportunities for assessment by the mother. Features of laryngeal braking thus themselves become cues that the baby is in need of thermoregulatory assistance. That such a cue is available makes it possible for the mother to manage the baby's thermoregulation by bringing the baby more closely to her body.

Now the fact that the mother is assessing the laryngeal braking itself provides management opportunities for the baby. By enhancing those features of laryngeal braking that the mother is assessing, the baby is able to manage the speed and quality of the mother's response. This in turn selects the mother for assessing these emphasized features more exclusively.

The final step comes when the baby increases the range of circumstances in which these emphasized features are deployed. This liberates the cry features from the context of hypothermia and makes it possible for them to be correlated with other features of the baby's circumstances that are crucial to the mother's fitness.

We think a thermoregulatory account provides a much more satisfactory management/assessment explanation for the origins of infant crying than the respiratory drama hypothesis that Thompson and his collaborators have offered. In that account, babies' cries arise because mothers are assessing the respiration of their infants and infant cries broadcast their respiratory patterns. Not only have we been unable to confirm the most interesting implications of this theory (e.g., Falcon et al., under review), but, on reflection, we believe the theory has a flaw which the Soltis laryngeal braking hypothesis lacks. The respiratory distress hypothesis invokes the problematic breathing apparatus of human infants, which is a compromise between avoidance of choking and the demands of speech, which begins to develop around 4 months. Not only does this theory imply that crying would be greatly diminished or absent in the early months, but, more important, it implies that crying should be a uniquely human activity. While it is true that humans cry more than other mammals, human infant crying does not seem all that discontinuous with the crying of other primates, particularly when one takes into account the fact that first-world human infants are being cared for in an environment very different from that for which they were designed (Owings & Zeifman, in press). That being the case, an assessment/management account based on the more phylogenetically general hypothesis that mothers are tracking infant thermoregulation seems to be more plausible. By emphasizing the role of low vagal tone in the mediation of cry pitch variation as well as other responses to stressors, Soltis also offers an explanation for how a mother's attention to thermoregulation could lead by short steps to cries becoming cues to other forms of infant regulatory challenges.

Theremoregulation seems particularly plausible as the anlage for infant crying. What a mother should be assessing is neither the fitness of her offspring nor its present level of distress (in exclusion), but a relation between them, the value to her own fitness of delivering an additional packet of parental effort to the present offspring. This relation is a complex function of current fitness, short-term distress, and the resources mother has available for self-maintenance and caregiving. Cues to greater infant need or fitness should not always lead to greater deployment of care. For example, if the mother has limited resources, then cues to greater need might actually result in termination of care, since the level of resource demanded would be greater than the level the mother is capable of providing. Even if the mother has adequate resources, cues to greater fitness will elicit less care if the infant is so fit that additional care will not result in a proportionate increase in the mother's fitness. Thermoregulation seems a particularly suitable mediator of these relationships: The fact of thermoregulation is a cue to current distress and the ability to thermo regulate is a cue to long-term fitness, since this ability requires energy resources that can be mobilized through muscular activity. By crying vigorously, the infant therefore not only provides cues to the damage to mother's long-term fitness, of not providing immediate assistance, it also provides cues to the long-term value of aiding this infant as opposed to other present or future ones.

Developmental changes of infant cries – the evolution of complex vocalizations

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Abstract: The signal functions of infant crying cannot be understood properly without due attention to their ontogenetic development. Based on our own research on the development of infant cries, we argue that the controversies in cry literature will not be solved by static models, but that progress will made only when considering ontogenetic changes in interpreting cry data.

There is a remarkable increase of research within the field of pre-speech development. This has been stimulated mainly by new findings of language-relevant perceptive abilities during early infancy (Friederici & Wessels 1993; Jusczyk 1997; Jusczyk et al. 1993). Although there is a general agreement on the importance of earliest pre-speech phases for later speech and language development, we are still confronted with a great bias toward studies focusing on babbling and later sound productions. Soltis' article is highly relevant as its reevaluation of the state of the art serves to promote the somewhat underrepresented cry research. However, Soltis' attempt "to illuminate the human infant cry from an evolutionary perspective" (target article, Abstract) lacks a crucial aspect, namely, the consideration of ontogenetic changes of cry features.

There are a number of reports dealing with developmental processes in infants' crying, but most of them investigate simply aspects of quantity (e.g., the amount of crying during the first weeks or months). In our studies (e.g., Lind & Wermke 1997; Mende et al. 1990; Wermke 2002; Wermke et al. 1987; 1996), we focused on structural changes of infant cries. We could show that

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the developmental changes of structural properties (e.g., fundamental frequency modulation and related variables) in spontaneous ("mitigated") cries follow a unidirectional program: One of the first building blocks of cry melody development is a simple rising-falling cry melody (melody = time function of the fundamental frequency). A first differentiation of spontaneous cries happens by a combination of these rising-falling melody patterns to pattern sequences created by a simple repetition or concatenation. The simplest form of complexification is a double-arc cry melody. Beyond duplications we also observed multiple repetitions within one cry to form ever more complex patterns (cries consisting of multiple-arc melodies).

Further refinement of laryngeal coordination and the mastering of tuning between the melody and resonance frequencies (Wermke et al. 2002b) during the first weeks of life provide several elementary abilities, which are at the disposal of other pre-speech vocalizations. A "training" process of this type is an important prerequisite for speech and language acquisition, especially for the acquisition of prosodic primitives.

A recent study investigating the melodies of 780 harmonic cries in 30 (14 male) healthy monozygotic twins[1] strongly supports the above mentioned developmental principles. The melodies were grouped into single-arc melodies and multiple-arc melodies and the frequency of occurrence displayed over the age of the infants (Fig. 1).

The most obvious tendency shown in Figure 1 is the nearly steady increase in the frequency of occurrence of complex (multiple-arc) melodies. This reveals a relatively continuous, unidirectional development from the early prevailing simple cry structures (single-arc-melody) to complex melodies. It is easy to understand that such developmental changes will influence the "classical" cry parameter. It could also be shown in this twin study that the synchronicity and the concordance in the melody development for monozygotic twins is much higher than that for unrelated pairs of subjects of the same sex and age from the same sample (Wermke 2002). The monozygosity, and hence the higher synchronicity of development, resulted in a much clearer manifestation of the universality of development than would have been the case in an average population. The melody changes sketched here are a strong argument for the relevance of the developmental aspects of human infants' cries important for evaluating recent attempts to illuminate the human infant cry from an evolutionary perspective. The described melody development probably reflects a specific signal function of human infants' cries that is at least as important from an evolutionary perspective as the functions summarized by Soltis.

The disparate and highly inconsistent values for cry parameters provided in the literature are not mainly a result of the different methods applied, as Soltis argues, but are, in our view, at least partially attributable to the fact that the majority of cry researchers did not adequately consider developmental changes of cry features. Hence, a reevaluation of the data in the cry literature under consideration of the now well-described developmental changes (including *reorganization phases*) might be helpful in resolving the paradoxes thematized by Soltis. Such a developmental perspective may have the potential to reveal the hidden consistency of the available cry data. This would clearly go beyond the signaling vigor hypothesis proposed. Note that we are not claiming that the model proposed by Soltis is inadequate, only that some of the data on which his interpretations are based are inadequate or insufficient for drawing the respective conclusions. The fact that the signal functions of the human infant cry have been shaped by a long evolutionary adaptation process also means that these signal functions are strongly related to the acoustic cry features. Yet exactly these sections in the target article are quite unsatisfying (sects. 4.1. and 4.3). Although referring to the lack of standardization in cry analysis and to some methodological controversies, Soltis implicates that we know the "normal infant cry characteristics" and moreover that we might be able to differentiate between "normal" and "abnormal" cry variables in individual infants. This is simply not valid. There has been invaluable work in this field over the last 40 years, but as long as cry researchers do not "correct" their cry scores with specific respect to the rapidly ongoing developmental processes during the first weeks of life, a cry-diagnosis will fail and we will not solve the controversies in the cry literature. It is not only the field of cry-diagnosis which suffers from the fuzziness of cry scores, but there is also an impact on the fields of research related to developmental biology, pre-speech development, child abuse, and infanticide.

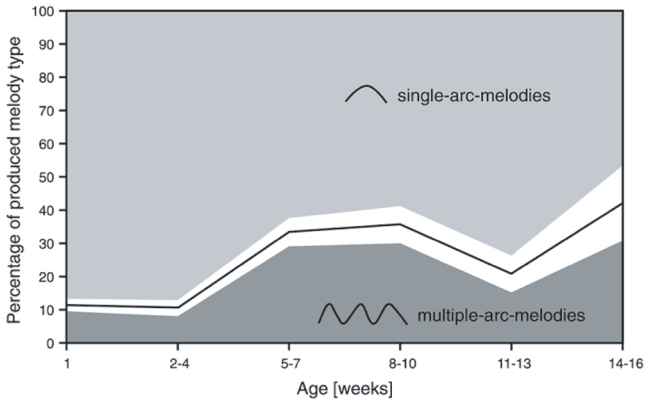


Figure 1 (Wermke & Friederici). Developmental changes of the relative frequency of occurrence of single-arc-melodies (upper part) versus multiple-arc-melodies (lower part) from all infants over the first 16 weeks of life (total amount of arc-like melodies: N=781; standard errors marked by the white region).

In our longitudinal studies, we strongly correlated all cry parameters to the age and the maturational state of the infant (e.g. Mende et al. 1990; Wermke 2002; Wermke et al. 1987; 1996; 2002a; 2002b; Lind & Wermke 2003) and obtained quite stable prognostic results as well as data consistency when retrospectively reanalyzing cry data under consideration of the developmental outcome of the children (first results: Wermke & Friederici 2004). We found that the relative percentage of multiple-arc melodies produced in cries during the first 14 weeks is a significant predictor of spontaneous word production performance at 18 months.

We fully agree with Soltis' prospect conclusion, that much remains to be learned about the signal functions of early infant crying. However, we strongly recommend an inclusion of structural developmental data before further testing any hypothesis.

NOTE

1. Spontaneous cries of the twins were recorded several times during their stay at the hospital. Recordings were repeated in six-week intervals (+/− 2 weeks) in the home environment. In total, 1,100 cry signals of infants between birth and the 16th week of life were investigated and cries containing large regions of subharmonics or noise were excluded from the melody analysis (N=386). The remaining 714 cry melodies could be assigned to melody types (single- vs. multiple-arc-melodies). Spectral analysis and melody computations were made using a CSL-Speech Lab 4300/ MDVP (Kay Elemetrics).

On the utility of an evolutionary approach to infant crying

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Abstract: Soltis' analysis of signal functions of young infants' cries stimulates testable questions regarding abuse, neglect, and infanticide. Nevertheless, his evolutionary perspective oversimplifies the cry event, and does little to promote developmental analysis of crying during infancy. Studies of the cry in its behavioral and developmental context are needed if we are to understand the proximate causes of optimal and suboptimal care.

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