Soltis' attempt to explain all communicative crying within the first three months of life from an evolutionary perspective is both interesting and problematic. The fact that this perspective can address data from several disciplines makes it an attractive tool for synthesizing a diverse and sometimes contradictory literature. Even so, the perspective carries the potential to oversimplify infant crying, and to lead research efforts away from understanding the cry's role in both domain-specific (social and communication) development and the overall development of the child. In this commentary, I argue that: (1) Soltis' focus on the cry sound obscures the richness of the cry event; (2) an evolutionary perspective does little to stimulate developmental analyses of crying; (3) consideration of the complexity of the cry event, and its development, are necessary for understanding parent-infant interaction, both optimal and suboptimal.

Soltis describes the cry's function in general terms, considering only its evolution as a vocal signal of infant health or "vigor." Furthermore, the context in which the cry occurs is characterized rather simply: either the context favors infant survival, or it does not. While this approach has generated questions about the proximate causes of abuse, neglect, and infanticide (target article, sect. 7, "Conclusions and prospects"), it oversimplifies the cry event, which includes temporal changes in acoustics, as well as visual cues about the infant's level of distress and, indeed, about whether he or she is crying at all.

Crying from healthy young infants has a complex acoustic structure that changes during a long cry bout (Green et al. 1998). Moreover, acoustic changes over time relate to adults' ratings of infant distress (Wood 2002), and the cry's "aversiveness" (Zeskind et al. 1985), in ways predicted by the graded signal view of crying. Soltis argues that when crying is persistent and acoustics are outside the normal range (i.e., when a child is unhealthy), caregivers could opt to provide suboptimal care. What would happen if a healthy child were regularly left to cry for long periods (e.g., in a busy household)? Would the acoustics of the child's long cry bouts become "abnormal" and so aversive that adults would provide suboptimal care? Analysis of parent-child interactions during long cry bouts would provide this information, whereas an evolutionary perspective that focuses on the cries of unhealthy infants may shed little light on such matters.

Crying occurs in concert with facial expressions and other behaviors, and Soltis' concentration on the sound itself obscures this observation. Two studies are relevant here. Green et al. (1995) presented nonparent adults with cries and noncry vocalizations from 3-month-old infants in both an audio-alone condition (just the sound), and an audio plus video condition (which showed the infant producing the sound). The adults were significantly better at correctly identifying cries from 3-month-olds when the sounds were paired with the video than when they were played alone. This was not true for noncry sounds. When the videotapes were edited so that cry faces were paired with noncry sounds, and vice versa, adults labeled noncry sounds that were paired with cry faces as cries. The visual information (facial expressions) thus took precedence over the auditory information (the sounds themselves). In another study, nonparents were able to use only the facial expressions of crying 3-month-olds to distinguish very distressed infants from those who were less distressed (Irwin 1999). These studies show that young infants' cries occur within the context of other behaviors, and that these behaviors may have as much or more influence on cry perception as the sound alone. It is therefore useful for researchers to consider the cry as a "multiply specified signal" (Irwin 1999), which includes the infant's sounds and facial expressions. Moreover, the existence of such cry complexity at 3 months of age suggests that developmental changes occurred earlier, a point Soltis' perspective does not address.

Little is known about the development of crying in healthy children, especially with regard to qualitative changes during infancy (Hopkins 2000). Where changes are documented, their underlying mechanisms are not well understood. An evolutionary perspective such as Soltis' does little to stimulate needed inquiry into infant cry development. Indeed, Soltis' discussion is limited to crying in the first 3 months because "At about 3 months of age, infants undergo a developmental shift in which crying becomes more differentiated, interactive, and intentional" (sect. 1, para. 3). If we assume that crying during the first 3 months serves only to maintain proximity to the caregiver, and to signal the infant's health, then we neglect an essential question: What qualitative changes occur in the cries of young infants, both healthy and unhealthy, and how do the changes affect adult-child interactions? There is evidence that crying undergoes changes during the first 3 months (beyond those associated with the "cry curve") that may reflect the beginnings of "differentiation" or reorganization of existing communicative behaviors.

In a longitudinal study, Hopkins and van Wulfften Palthe (1987) showed that fussing (a vocalization whose definition often overlaps with definitions of crying; Hopkins 2000) and cooing appeared at 6 weeks of age. Between 2 and 3 months, fussing and cooing became a new vocalization, "interrupted fussing," characterized by alternations between the two kinds of vocalizations. Thus, the components of crying were reorganized before the infants were 3 months of age. Interestingly, Hopkins (2000) noted that the alternations between fussing and cooing were accompanied by changes in facial expressions (cry faces during fussing, smiles during cooing). This observation indicates that crying in healthy children is a complex communicative event, even before the third month of life. Studies that consider the entire event (not only the sound) can provide insight into the changes in young infants' crying, and the mechanisms for the changes.

Soltis provides a provocative analysis of the possible signal functions of early infant crying. While his evolutionary perspective generates questions, it overlooks the complexity and development of the cry event. An understanding of optimal and suboptimal parent-infant interaction depends on consideration of the cry in its behavioral and developmental context. An evolutionary perspective does not promote such consideration.

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Colic and the early crying curve: A developmental account

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Abstract: The hypothesis that excessive early infant crying evolved to reduce the risk of withdrawal of parental care is disputed on the grounds that excessive infant crying is irritating and imposes fitness losses rather than gains. Alternative explanations for the early crying curve that take into account development on the part of the infant and the emerging infant-caregiver bond are proposed.

Soltis should be commended for a comprehensive review and novel synthesis of the early infant crying literature. His review highlights the fact that we cannot yet adequately explain the early crying curve or the prevalence of colic. The author's claim that the weight of the evidence favors the "signaling vigor" hypothesis over other explanations, however, seems to overlook inconsistencies with the data and plausible alternative explanations.

The main premise of the signaling vigor hypothesis, that infants cry to advertise their health and stave off neglect or infanticide, ignores the highly irritating quality of crying. The negative reaction of adults to even normal infants' cries is reflected in, among other things, the adjectives used in rating scales to describe cries (e.g., grating, annoying, sickly). As a result of these negative reactions, colic has at least short-term negative consequences for infants that, had they occurred over the course of human evolution, would

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almost certainly have imposed fitness losses rather than gains. For example, colic is a frequent complaint brought to pediatricians and a common reason for giving up breast-feeding. When parents are confronted with a colicky infant, they usually seek medical help because of the perception that the infant is ill. Why would a signal of vigor so often be mistaken as a sign of illness? Although the noxiousness of infant crying is part of what makes it effective for mobilizing a parent's response, it is hard to imagine a scenario in which an infant's *continued* crying even after a parent picks it up would be helpful in thwarting abuse, abandonment, or infanticide.

While there is strong evidence that colic is not associated with long-term illness, there is no compelling evidence that colic is associated with increased vigor. It is misleading to argue from exceptional cases – cases in which impaired infants emit weak cries or do not cry at all – that excessive crying under normal conditions indicates better health. The strongest evidence for an association between vigor and crying is the report (de Vries 1984) that Masai infants with more difficult temperaments were more likely to survive a drought than their complacent counterparts. It is probable, however, that the infants who didn't cry much when the initial temperament measures were taken were already succumbing to the effects of poor living conditions and scarce resources. The study, in fact, was conducted at the height of a 10-year drought. The most dehydrated infants in the sample would have had difficulty emitting a costly signal, but this does not inform the signal function of crying under normal conditions. Sickly infants probably don't smile or urinate as much as healthy infants, but we cannot infer from these correlations that the function of smiling or urinating is to signal vigor. Under normal conditions, there are likely to be negative consequences for infants on either extreme of the crying continuum – those who don't cry enough to have their needs met, and those who cry excessively or inconsolably.

Soltis points to the similarity in the temporal pattern of early crying and probability of infanticide as further evidence supporting the view of crying as a vigor signal designed to dissuade parents from withdrawing care, but acknowledges that alternative explanations are possible. Developmental changes in the infant, and in the parent-infant relationship, may better explain the dramatic decline in infanticide rates at three months. At around three months, infants shift from expressing emotions primarily in response to changes in internal states to expressing emotions in response to external stimuli, including parents. For example, a newborn's smile, which is likely to occur during REM sleep, is replaced with a truly social smile in response to parents' prodding. Sustained eye contact makes its appearance, too, replacing the jerky eye movements of the newborn period, and infants stay awake for longer periods of time. Many parents report that their infants begin to seem human to them as a result of these changes in social responsiveness, and that they, in turn, are overcome with feelings of parental love (Stern 1977). The drop in infanticide risk after three months of age most likely reflects the emotional bond that has formed between the parent and infant, as well as the reality that it's more difficult to neglect or harm an infant who looks you in the eye, smiles, reaches toward you, and even giggles with delight when you enter the room, than one who is less developed.

If the decline in crying at three months is not a function of diminished infanticide risk, then what accounts for the near-universal pattern of early crying? The parent's experience of taking care of her infant, and the infant's experience of being cared for, may contribute to the decline in infant crying. The *n*-shaped early crying curve (Barr 1990c) may reflect a process whereby the infant and caregiver learn each other's habits and become increasingly coordinated. With the experience of being cared for in a predictable fashion, infants come to anticipate caregivers' actions in the first few months of life, and may be expected to cry less as a result. Because the transition from crying to calm is a highly motivated context for learning about the caregiver, caregiver characteristics – such as voice or scent – may also become powerful cues for arresting crying. For example, a newborn infant is likely to cry until experiencing the physical changes associated with having his or her needs met, such as the warmth of the mother's body or the taste of milk on the tongue. In contrast, an older infant may stop crying when a parent merely enters the room. Caregivers may contribute to reductions in crying as well, by becoming adept at anticipating and meeting the needs of their infants.

What then, in addition to promoting proximity, is the function of early crying? Infants typically become attached to the individual who has most reliably responded to their cries. Crying-soothing sequences are rewarding for parents as well in that the punishing sound of crying is arrested and the unpleasant autonomic arousal it triggers is attenuated. One function of early infant crying may be to bring the infant and parent together repeatedly in this emotionally charged situation, fostering an emotional bond.

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Author's Response

The developmental mechanisms and the signal functions of early infant crying

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Abstract: The majority of the commentaries focused on excessive crying and colic and included two major themes: the consideration of proximate physiological mechanisms, and challenges to my interpretation of the signal functions of early infant crying amount. I initially concluded that none of the competing signaling hypotheses enjoyed strong support, but I nevertheless favored the signaling vigor hypothesis above the signaling need and manipulation hypotheses. Consideration of the neurobiological causation of the n-shaped crying curve and further evidence and argumentation concerning the potential signal functions, however, do not allow for the elevation of any one of these hypotheses above the others, and it remains the case that none are strongly supported. Taken together, however, the target article and commentary do provide a solid foundation for further research. In the target article, I also proposed a model of how infant cry acoustics can influence patterns of care and abuse. Commentary has enriched this model by including the consideration of developmental changes in cry acoustics across early infancy, and by further integrating the cry signal with other modalities of communication and with later development. I trust that the foregoing will show that the joint pursuit of the proximate mechanisms and the potential signal functions of early infant cry amount and cry acoustics should prove fruitful. Before embarking on my reevaluation, however, I begin this response by addressing the issue of consciousness in evolutionary accounts of signaling.

R1. Signaling and consciousness

Three of the commentaries suggest that the signaling theory put forth in the target article implies, or requires, that 0- to 3-month-old infants consciously and voluntarily signal to caregivers, for example, to manipulate them or honestly signal to them, and for this reason conclude that such the-

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