Table 1 (Hagen). *Descriptive statistics*

Variable	N	Min.	Max.	Mean	S.D.
How much does your baby cry?	129	0	5	2.5	1.15
How much in love are you with your baby?	129	0	6	5.7	0.71
Doctor rating of health	128	3	6	5.8	0.56
Worry about health	128	0	6	2.1	1.70
Gut feelings about health	129	3	6	5.4	0.75
Health problems since birth	129	Yes: 43 (33%), No: 86 (66%)			

Table 2 (Hagen). *Association of quantity of infant crying with mother's emotion towards the infant and infant health variables*

	All infants (3–32 weeks old)	Infants 3–12 weeks old (n=82)	Infants with no health problems (n=86)
How much in love are you with your baby?	$r_s=-.20$, p=.023	$r_s=-.15$, p=.17	$r_s=-.19$, p=.085
Doctor rating of health	$r_s=-.20$, p=.026	$r_s=-.10$, p=.35	$r_s=-.18$, p=.097
Worry about health	$r_s=.17$, p=.063	$r_s=.18$, p=.12	$r_s=.14$, p=.20
Gut feelings about health	$r_s=-.11$, p=.23	$r_s=-.094$, p=.40	$r_s=-.11$, p=.30
Health problems since birth	Z=−1.13, p=.26	Z=−1.04, p=.30	

The same tests were performed for infants with no known health problems since birth. There was no change in sign and little change in effect size, although, again, no results were now significant.

Results of a study not designed to test the vigor hypothesis should be taken with a grain of salt. A careful evaluation of the association between excessive crying, perceptions of infant health, and parental emotions towards the infant that distinguished between crying and other temperament and health problems, that assessed cry acoustics, and that incorporated Soltis' distinction between Wessel's colic and Wessel's plus colic, might indeed reveal more positive perceptions of infant health and more positive parental emotions towards infants who cried excessively but had no other problems. It might also be the case that mothers who experience high rates of infant morbidity and mortality, as ancestral human mothers certainly did, would have a different, and positive, response towards excessive crying (with normal acoustic quality) relative to Western mothers who experience little infant morbidity and mortality (cf. Scheper-Hughes 1992).

I incline towards the view that excessive infant crying is one extreme of a continuum (target article, sect. 5.2), and therefore is not, in and of itself, an adaptation. I will nevertheless throw one more functional idea about parental manipulation into the ring. Soltis correctly notes that models of offspring manipulation of parents must include the possibility that parents evolve to resist manipulation (sect. 2.3). He is a bit too quick, however, to dismiss a manipulative function for excessive crying in young infants based on the argument that parent-offspring conflict (POC) is low for young infants (sect. 6.1). In fact, POC can be high for young infants. POC decreases as the value of the offspring to its parents increases. Because child mortality decreases with age, offspring value increases with age, implying that POC decreases as the infant ages. Rates of infanticide are correspondingly highest in the first three months of life, decreasing thereafter. When resources are plentiful, offspring inclusive fitness may actually increase when parents divert investment to new siblings, reducing weaning conflict. Even the costly and therefore honest signal of vigor hypothesis favored by Soltis assumes parent-offspring conflict (otherwise, the signal could be cheap).

In the environment of evolutionary adaptedness (EEA), excessive crying could have directly and indirectly manipulated parents. Crying might have attracted predators, which would have reduced not only offspring fitness, but also the fitness of parents and siblings. Crying could also have interfered with parents' conversations and ability to concentrate on other activities. These direct costs would have motivated parents to attend to the offspring. Further, because these costs would also have been imposed on other group members, they would motivate the group to coerce parents to care for their crying offspring.

Solid evolutionary reasoning has been missing from most of the developmental literature since Bowlby's important contributions over 30 years ago. Soltis' efforts here are therefore extremely welcome. Despite my few quibbles, they form an excellent foundation for future work.

Sleep-wake processes play a key role in early infant crying

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Abstract: The crying curve across early infancy may reflect the developing interaction between circadian and homeostatic processes of sleep-wake regulation. Excessive crying may be interpreted as a misalignment of the two processes. On the basis of the proposed mechanism, excessive crying may be an honest signal of need, namely, to elicit parental resources to modulate the behavioral state.

Soltis presents an interesting approach to understand the purpose of early infant crying by using evolutionary reasoning. When searching for the crying function, however, we need a clear idea of what the phenomenon essentially is. Examining the physiological properties of crying is a promising way to understand its meaning. For example, Soltis uses acoustic characteristics of crying as a phenomenological description to propose an evolutionary model for the crying signal.

In this commentary, I propose an alternative explanation for excessive infant crying. I agree with Soltis that developmental processes of sleep-wake behavior may underlie the temporal pattern of crying across the first months of life. But the fundamental

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question relates to the contributing mechanisms. My perspective suggests that we may better understand infant crying by examining ontogenetic changes of sleep-wake regulation.

Crying is commonly considered to be a behavioral state of high arousal (Prechtl & Beintema 1964; Thoman 1990; Wolff 1987). Mechanisms modulating and controlling behavioral states like sleep and wakefulness evolve over the first months of life (Prechtl 1984). Appropriate models providing a conceptual framework to examine how such regulatory mechanisms may develop have rarely been provided. This gap is rather surprising, since models describing putative sleep-wake processes in adults have been used for many years (Akerstedt & Folkard 1995; Borbély 1982, Borbély & Achermann 2000; Daan et al. 1984).

The clock-like circadian process and the sleep-wake dependent homeostatic process play pivotal roles in the control of vigilance states in the adult (Borbély & Achermann 2000). The circadian process determines diurnal levels of alertness and sleep tendency independent of prior waking and sleep (Dijk & Czeisler 1995; Folkard et al. 1985). Alertness reaches its maximal levels in the early evening and its trough in the early morning, corresponding to the course of the core body temperature (Folkard et al. 1985). The homeostatic process mediates the rise of sleep pressure during waking and its dissipation during sleep (Borbély 1982; Daan et al. 1984). The longer the waking period lasts, the higher sleep pressure becomes. In the adult, the rise of homeostatic sleep drive during waking is opposed by the increasing circadian alertness in the course of the day, allowing adults to maintain constant levels of vigilance throughout the waking period (Achermann & Borbély 1994; Daan et al. 1984; Edgar et al. 1993). Conversely, during sleep, the rising circadian sleep tendency counteracts the declining homeostatic sleep pressure, ensuring maintenance of sleep (Dijk & Czeisler 1994). The alignment of the two processes is thus a prerequisite for the biphasic sleep-wake cycle across the adult 24-hour day.

The circadian rhythm of core body temperature appears at four weeks and increases in strength over the first few months of life reflecting the infant's developing circadian process (Glotzbach et al. 1994). The increasing circadian drive may generate a rise in alertness across the day providing the basis for predicting the late afternoon and evening clustering of infant crying. The diurnal rhythm of crying becomes progressively more distinct, reflecting the increasing strength of the circadian drive.

The developmental course of the homeostatic process during early life remains minimally elucidated. Animal experiments have demonstrated that homeostatic sleep mechanisms are present already in the first postnatal weeks (Alföldi et al. 1990; Frank et al. 1998). Studies in human infants have reported that sleep electroencephalographic markers reflecting sleep homeostasis appear as early as in the first 2 months of life (Jenni et al. 2004; Salzarulo & Fagioli 1992). I hypothesize that already in young infants sleep tendency increases in the course of the day despite intermittent decreases of sleep pressure as a result of daytime naps. Daytime waking episodes are longer than daytime sleep episodes and therefore may increase global homeostatic sleep pressure across the day.

I propose that the developing ability of the infant to increase sleep pressure during the day may counteract the circadian alertness in the early evening to maintain a balanced vigilance state. In other terms, hyperalertness and excessive crying may occur, when circadian alertness is not opposed by homeostatic sleep pressure.

The typical crying curve across the first months may reflect the developing interaction between the circadian and homeostatic process, while the evening clustering of crying may be driven mainly by the circadian drive. This hypothesis favors the notion of independent processes for the diurnal peak and the age-related 6-week peak of crying. Other cry characteristics, such as the high interindividual variability (Barr 1990c), could also be explained with individual differences in the initial occurrence of homeostatic and circadian processes and their alignment. The day-to-day variation may be driven by the homeostatic process depending on waking and sleeping behavior across individual days. In the described perspective, excessive crying may be interpreted as a misalignment or lack of coordination between the two processes, in particular at the end of the day. In contrast to Soltis' view, I believe that such a perspective supports the idea that excessive crying is primarily an honest signal of need, namely, to elicit additional parental resources and attention to modulate the behavioral state.

Soltis argues that infant care practices affect early infant crying despite the global validity of the crying curve. In fact, comparative ethnographic analysis opens the possibility to study diverse caretaking and sleep practices and their influence on behavioral state regulation and crying. In many traditional cultures, infants are carried continuously, are able to sleep under any circumstances and cry less (Worthman & Melby 2002). In these societies, polyphasic sleep-wake cycles are predominant and long periods of wakefulness for gathering and socialization processes occur at night. From an evolutionary perspective, the adaptive pressure to become entrained to the biphasic 24-hour sleep wake rhythm may be higher in Western cultures, where most activities are scheduled in the daytime hours. Thus, intrinsic biological processes may exert less influence on behavioral state regulation in the traditional societies, where infant regulatory demands are fulfilled by extrinsic mechanisms of the caretaking environment.

Ontogenetic and phylogenetic changes of sleep-wake processes play a key role in understanding crying behavior. Future studies in which sleep and wakefulness during early infancy are manipulated will shed more light on the development of circadian and sleep homeostatic processes, and eventually on excessive infant crying and its function.

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Imagine imaging neural activity in crying infants and in their caring parents

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Abstract: Soltis' paper contains little data on the underlying neural substrate of the discussed signal function of early infant crying – probably because there is amazingly little known about it. We here discuss the interest of functional neuroimaging as an objective measurement of brain activity in (1) early infants during crying and (2) parents hearing their offspring cry.

Soltis proposes a model for the signal effect of cry acoustics on parental response, based on human and animal evolutionary history. We enjoyed reading this comprehensive review summarizing vast literatures ranging from bioacoustics and ethnography to animal and infanticide data. We largely agree with the author's claims and doubts. In this commentary, we add to the discussion the role of functional neuroimaging in elucidating some of the remaining questions and in testing the proposed model. We will discuss the interest and possibilities of measuring brain activity in (1) the crying infant and (2) the parent hearing the cries.

Soltis addresses the issue of the communicative content of crying in terms of *honest* signaling of need or vigor, or *manipulative* signaling. We regret the use of the term *manipulation* in that it might have a negative connotation. It implicitly assumes that the cries are dishonest and that the infant somehow "voluntarily" undertakes a shrewd or devious action for its own advantage. It is still a matter of debate at what age human infants show signs of engaging in activities for which conscious awareness is thought to be

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