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The Natural History of Child Signals of Need in Utila, Honduras

An Exploratory Study

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Abstract
To gain support, children use signals to communicate their needs and wants to parents. Infant signals of need, particularly infant cries, have been extensively studied in diverse populations. However, the full range of potential child signals of need, which extend beyond cries, has rarely been investigated in a single study of children of all ages. To help fill this gap, we collected mother and other primary caregiver reports of three common types of child signaling from 131 families with 263 children on Utila, a small island off the coast of Honduras. In exploratory analyses, we found that child signaling was common in both sexes and across all ages, although it decreased with age and neighborhood quality and increased with the frequency of conflict between children and caretakers. Consistent with signaling theory, children who were sad more frequently were perceived as needier within the household and were more likely to receive investment. Caregivers were less likely to respond positively in situations of family conflict or child transgressions, and more likely for injuries and illness. Our results suggest that evolutionary theories of signaling can help explain patterns of child sadness, crying, and temper tantrums.

Keywords Costly signaling · Sibling competition · Parent–offspring conflict · Parental investment · Child behavior · Conflicts of interest

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Introduction

Compared to chimpanzee mothers, human mothers in hunter-gatherer societies have shorter interbirth intervals and produce offspring that require many more years of parental care (Davison & Gurven, 2021, 2022). Unlike chimpanzee offspring, human offspring in ancestral populations therefore often grew up with multiple older and/or younger siblings who were potential competitors for parental investment and yet who could also provide (or require) allocare (Helfrecht & Meehan, 2016; Lawson & Borgerhoff Mulder, 2016; Hagen & Barrett, 2009). Juveniles in humans, unlike chimps, therefore evolved in families with multiple siblings simultaneously dependent on parents and others for essential care, likely intensifying selection for credible signals of need (Leonard et al., 2000; Harper, 1986; Neuenschwander et al., 2003).

Although infant signals of need, particularly infant cries, have been extensively studied in many populations (Barr et al., 1991; Fouts et al., 2005; Konner, 1974; Kruger & Konner, 2010; Kushnick, 2006; Meehan et al., 2017; Müller, 2021; Tronick et al., 1987), the full range of potential child signals of need, which likely extend beyond cries, has never been investigated in children of all ages. In particular, how and when older children signal need has rarely been investigated (for one exception, see Syme & Hagen, 2023). The aim of this study was to help fill these gaps by investigating three common types of signals of need in children and adolescents.

Conflicts of Interest within the Family

Although the fitness prospects of children and their familial caretakers are largely intertwined, evolutionary theory predicts that disagreements about the amount of investment from parents and other close kin will be ubiquitous (Bossan et al., 2013; Fouts et al., 2005; Godfray, 1995; Godfray & Parker, 1992; Trivers, 1974) because each child shares more genes with themselves through recent common descent (100%) than with their full siblings (50% on average), half-siblings (25% on average), and stepsiblings (0%). Due to this asymmetry, children are often expected to attempt to elicit more investment from parents than is optimal from the perspective of the parent, while parents are expected to attempt to invest less than is optimal for each child in order to invest in their other children, whom parents are expected to value identically, all else being equal (Bossan et al., 2013; Trivers, 1974).

For the same reason, siblings have both confluences and conflicts of interest with one another, with each expected to prefer more resources for themselves than others. Sibling competition is evident across taxa and can range from relatively benign forms like strong begging competition in chicks (Caro et al., 2016a, 2016b) to siblicide in birds, mammals, and sharks (Salmon & Hehman, 2014). In humans, sibling competition is largely estimated by counts of siblings, and large numbers of siblings have been associated with decreased growth (Hadley et al., 2011; Hagen et al., 2006; Salmon & Hehman, 2014), survival (Lawson et al., 2012; Meij et al., 2009; Strassmann, 2011), and reproductive success (Gibson & Gurmu, 2011; Mace, 1996) in multiple populations, highlighting the likely significance of sibling competition for

resources, even if this does not always manifest with behavioral conflict (Bateson, 1994).

Whereas parent–offspring conflict and sibling competition are likely ubiquitous, the resources being contested will vary across human groups. In relatively egalitarian and food constrained populations, conflict over resources is likely to be centered on food, which probably explains the negative impacts siblings have on child age-specific heights and weights among the Shuar of Ecuador (Hagen & Barrett, 2009), although similar effects have also been found in industrialized populations (Lawson & Mace, 2008). In societies with greater inequality, competition is more likely to be over wealth, as is the case with older brothers in pastoralist communities like the Gabbra and Arsi Oromo limiting the marriage prospects of laterborn sons (Gibson & Gurmu, 2011; Mace, 1996). Compared to large-scale investments like bride price or inheritance, little is understood about smaller transfers of wealth to younger children despite the potential importance of such transfers to 1) facilitate the development of embodied capital outside of growth and fat reserves or 2) help children succeed in their peer groups.

Cooperation within the Family

Humans are a uniquely interdependent species among the living primates (Tomasello et al., 2012) in that both sexes' fitness prospects depend greatly on a network of close kin and other social allies (Apicella & Silk, 2019; Syme & Balliet, 2024). This need for others is most intense with children, who are born highly altricial and require many years of investment to develop to the point where they can obtain enough food to survive on their own and develop the social skills needed to succeed in their communities (Kaplan et al., 2009; Rosenberg, 2021; Schniter et al., 2015). Much of this investment comes from mothers and fathers (Kramer & Veile, 2018). However, grandparents, aunts, uncles, and non-relatives also provide significant investment in children in many societies (Kramer & Veile, 2018; Sear & Mace, 2008), which was likely favored due to a combination of inclusive fitness benefits, reciprocity, and reputation management (Gurven et al., 2000; Schniter et al., 2023). Children also often serve as alloparents, helping to raise their younger siblings via direct care, food collection and preparation, and other family tasks (Hrdy, 2009; Meehan, 2009; Sear & Mace, 2008) despite still requiring substantial amounts of investment themselves (Kramer, 2018).

Children's potential to invest in their families can also cause conflicts with their parents. Older children can provide greater allocare, but might prefer to spend their time investing in romantic or other social relationships, or learning valuable skills, whereas parents might prefer them to care for their siblings, acquire or prepare food, or complete other household chores (Lowe, 2003; Syme & Hagen, 2023). Conflicts of interest over investment in the family can even involve adult children who are starting to have their own children (Emlen, 1995; Kushnick, 2023). Parents can potentially benefit from delaying the reproductive careers of certain offspring to gain more allocare for their other children (Emlen & Wrege, 1992; Flinn, 1989) or

speeding up a child's departure from the household to provide more parental investment to other children (Kushnick, 2023).

Signals of Needs and Wants

In order to elicit more support, children often use signals of needs and wants. Across the tree of life, signals evolve to reveal agents' private information to other agents when doing so benefits both the signaler and the receiver (Caro et al., 2016a, 2016b; Maynard-Smith & Harper, 2004; Preuschoft & Schaik, 2000; Setchell & Jean Wickings, 2005; Zahavi, 1975). Children often have needs and wants, where needs involve avoiding potential fitness costs, such as poor nutrition, injuries, or threats to status, and wants involve acquiring potential fitness benefits, such as highly nutritious foods and valuable artifacts. Needs and wants (hereafter needs) are often not apparent to caregivers, i.e., they are private information, and hence children must signal them to receive help. Signals differ from cues in that signals were favored by natural selection due to their ability to alter the behavior or perceptions of others in ways that benefit the signaler, on average, whereas cues are information organisms use to influence their behavior or physiological state that did not evolve for communicative effect (Maynard Smith & Harper, 1995). Crying when injured is likely a signal of need, for instance, whereas bleeding would be a cue of need.

When the fitness interests of signalers and receivers are aligned, i.e., there are no conflicts of interest, child signals of need are expected to be what Maynard Smith and Harper (1995) refer to as "minimal signals," signals whose cost is no greater than that needed to transmit the information effectively. In other words, although minimal signals might involve some cost (e.g., energy for a loud scream), they do not require any additional mechanism to enforce honesty.

When conflicts of interest over investment exist, however, there may be much to gain from deception (e.g., crying despite the lack of need) so that one could receive the benefits that come from being seen as needy (Zahavi, 1993). Unchecked, deceptive signals could result in receivers ignoring all signals. Credible signals can nevertheless evolve and be maintained in multiple ways, such as when signals cannot be faked (i.e., indexical signals). Credible signals can also evolve when the benefits of sending a signal outweigh the costs for individuals with the underlying quality or state, but otherwise the costs outweigh the benefits (Spence, 1973; Zahavi, 1975; Chisausky et al., 2023). Such signals are often termed "costly," although what is costly is deception, not necessarily signaling per se (for discussion, see Chisausky et al., 2023).[1]

In the context of child signals of need, a child has access to information about their internal state, which is unavailable to others, that allows them to estimate their valuation of additional investment. When there are conflicts of interest between children and their caregivers, children might need to use signals whose costs outweigh

[1] Even when a mechanism is needed to ensure honesty, it is possible for signal cost to be zero at equilibrium because it is the potential cost of deceptive signaling, not honest signaling, that ensures honesty (Chisausky et al., 2023).

the benefits of additional care for those not in need, but would result in a net benefit to those with genuine needs. In doing so, the child reveals their resource valuation to potential caretakers who may be skeptical of the child's claims. With the information revealed by the signal, caretakers should generally be more likely to provide additional support due to their fitness interest in the child's wellbeing.

However, even credible signals of need might not result in a beneficial response because belief in a child's need is not the only factor determining the form and amount of support given by caregivers. Instead, caregivers are expected to weigh the costs and benefits of support, which would take into account the reproductive value of current and future offspring, against other options (Daly & Wilson, 1983, 1987), with selection favoring the allocation of parental investment to current and future offspring that equalizes marginal fitness returns to the parent (Clutton-Brock, 1991; Daly & Wilson, 1983; Dawkins, 1976; Hagen, 1999; Beaulieu & Bugental, 2008; Frankenhuis & Amir, 2022).

Additionally, a parent may also decide against investing in a child, despite deeming that investment worthwhile, if the time is not right (e.g., if a mother preferred to breastfeed during rest rather than when foraging). When this is the case, outward conflicts might not reflect genuine conflicts of interest and instead involve parents teaching children ways to behave that benefit them both (Altmann, 1980). Finally, caregivers often have better information about the costs and benefits of various items and actions and, therefore, can make more beneficial decisions for a child than the child can herself (e.g., preventing a child from playing with matches).

Sadness

Sadness is an internal affective state that also has signaling functions in the form of facial expressions and other behavioral manifestations. It is generally thought to arise from loss (Horwitz et al., 2017; Levenson, 1999; Smith & Lazarus, 1993), especially when one has little power to reverse or mitigate the loss without help (Emanuel & Eldar, 2023; Gunderson et al., 2021). Sadness and low mood, like other forms of psychological pain, probably evolved to motivate victims of adversity to shift their attention to the causes of adversity to mitigate its negative fitness consequences and to learn to solve or avoid similar events in the future (Andrews & Thomson, 2009; Nesse, 1990; Thornhill & Thornhill, 1989). Low mood, for example, is often thought to be adaptive in situations when activity is dangerous or unlikely to result in benefits, with anhedonia, pessimism, and fatigue all helping reduce behavior that may not be worth the costs or that may cause additional problems (Nesse, 2019; Nettle, 2009; Trimmer et al., 2015). It may also encourage the reappraisal of one's circumstances after new information comes to light that one's current strategy is not working (Nesse & Ellsworth, 2009).

Through the reduction in behavior and attention in one's usual interests that can accompany sadness and low-mood (Nettle, 2009), one's relatives and other social partners would likely gain some indication, in the form of cues, that the sad individual was experiencing adversity and could benefit from increased support. In addition to this cue-based information, sadness also results in facial expressions and crying, both of which probably evolved to signal need (Balsters et al., 2013; Bowlby, 1980;

Reed & DeScioli, 2017; Darwin, 1872). Such expressions seem to be important to conveying this information as is seen by skeptical responses to those who cannot produce certain elements of facial expressions like tear production (Hasson, 2009; Nesse, 2019) or certain facial movements (Bogart & Matsumoto, 2010; Bogart et al., 2012). We conceptualize infrequent and transient sadness signals as minimal signals of need (per Maynard Smith & Harper, 1995). Frequent or prolonged sadness, however, is likely a form of withdrawal or depression, both of which might be effective costly signals of need when there are conflicts between the child and their caregivers (Gaffney et al., 2022; Syme & Hagen, 2023).

Crying

Crying is the most studied way children signal need. Crying is a human universal (Gracanin et al., 2018) with few suspected non-signaling functions outside of the role vocal cries might play in the development of vocalization (Wells, 2003) and the functions tears have in cleaning, protecting, and lubricating the eye (Murube, 2009; Sznycer et al., 2023). Hunger, pain, anger, fear, and separation are all common causes of crying (Vingerhoets, 2013; Wells, 2003), although tear production also often happens with joyful events (Sznycer et al., 2023; Vingerhoets, 2013; Zickfeld et al., 2020).

Infant cries increase amounts of care, resources, and attention infants receive, as well as increase their proximity to parents (Lin & McFatter, 2012). For example, Karo Batak infants who cried more were breastfed more, and the length of crying bouts predicted the time mothers breastfed (Kushnick, 2006). Similarly,!Kung San mothers frequently respond to crying infants by providing comfort and breastfeeding access, with comforting behaviors being far more common than behaviors restricting infants (Kruger & Konner, 2010). Although Kruger and Konner (2010) found mothers were the most common responders, siblings, fathers, and other adults frequently stepped in so that 88% of crying bouts were responded to, with most of the cries ignored lasting under ten seconds. Similar responsiveness has also been reported among the Aka (Hewlett et al., 1998), the Mbendjele (Chaudhary et al., 2024), the Efe (Tronick, Morelli, and Winn 1987), and the Aché, among whom young children have been described as "win[ning] most conflicts with parents simply by crying and whining" (Kaplan & Dove, 1987). Studies examining the potential for long-term benefits are rare and difficult to achieve. However, during a time of high infant mortality in a sample of 13 Massai infants, those with easy temperaments were more likely to die (5/7) than those with difficult temperaments (1/6), an outcome that is consistent with signals eliciting beneficial treatment (de Vries, 1987).

Crying does not always succeed in eliciting benefits, however. Compared to the previously mentioned groups, the Ngandu (Hewlett et al., 1998) and the Hadza (Jones, 1993) have been found to be more likely to ignore the cries of infants and young children, and concerns that being too responsive will spoil children are reasonably common in some Western populations (Barnett et al., 2010; Burchinal et al., 2010; Chaudhary et al., 2024; Frankenhuis & Amir, 2022; Maute & Perren, 2018). Crying can also lead to negative responses beyond being ignored (Barr, 1990; Soltis, 2004; Zeifman & St James-Roberts, 2017). It has been found to increase parental

distress, the likelihood of maternal depression, and the child's risk of maltreatment (Frodi, 1985; Fujiwara et al., 2011; Howard et al., 2006; Lin & McFatter, 2012; Soltis, 2004). For example, in a sample of 3,259 Dutch parents with infants under 6 months old, 5.6% self-reported smothering, slapping, or shaking their babies in response to their crying, outcomes that were more likely among parents who were single, unemployed, or deemed their infant's crying to be excessive (Reijneveld et al., 2004). Excessive infant crying, i.e., colic, has also been found to be a risk factor for multiple negative outcomes (Zeevenhooven et al., 2018), including abuse, shaken baby syndrome (Kurth et al., 2011), and earlier cessation of breastfeeding (Howard et al., 2006).

Although it is widely accepted that crying is a signal, there is no consensus on if or when it should be conceptualized as a minimal signal, a costly signal, an indexical signal, or a deceptive (manipulative) signal. Contact calls between parents and offspring have evolved in numerous species, so cries might simply be a means for infants to elicit attention from caregivers (Mehr et al., 2021), which would be a type of minimal signal. Demonstrating vigor and health early in life was likely vital for much of our evolutionary history due to the risk of neglect or infanticide experienced by children with poor survival prospects (Daly & Wilson, 1984; Soltis, 2004). As crying comes with physiological costs (Rao et al., 1997; Thureen et al., 1998), it could serve as a credible signal of vigor if these costs are too high for unhealthy infants to bear (Furlow, 1997; Lummaa, 1998; Soltis, 2004; Wells, 2003). Children with severe medical conditions also produce acoustically distinct cries, suggesting that some elements of crying are indexical (Soltis, 2004). Alternatively, crying might impose costs on caregivers by, e.g., attracting predators or interfering with important activities, motivating caregivers to invest more to stop the crying (so-called blackmail or bargaining models, Zahavi, 1977; Lummaa, 1998; Eshel & Feldman, 1991; Bergstrom & Bergstrom, 1999; Kennedy & Radford, 2021).

For older children, the relatively insignificant energetic costs of crying might not be enough to ensure it is a credible signal when there are conflicts of interest. For this reason, crying among older children might be more similar to adult crying, which can increase support and empathy but sometimes comes with social costs (Cornelius & Labott, 2001; Cretser et al., 1982; Hendriks & Vingerhoets, 2006; Jesser, 1989; Vingerhoets et al., 2016; Glasberg & Aboud, 1981, 1982; Zeman & Garber, 1996). Such costs could be a means by which crying can still be a credible signal of need if they dissuade potential fakers from making the signal when there are conflicts of interest (Sznycer et al., 2023).

Temper Tantrums

Temper tantrums may also be the result of adaptive strategies by which children can elicit more support from parents (Koch, 2003). They are common in children from 18 months to 4 years old (Potegal & Davidson, 2003) but are also exhibited by older children, albeit with decreased frequency (Macfarlane et al., 1954; Barbarin, 1999; Ward, 1970; Österman & Björkqvist, 2010; Goodenough, 1931; Bhatia et al., 1990). Temper tantrums vary in their severity and include behaviors ranging from crying, shrieking, and screaming to violent bodily movements, aggression, and self-harm

(Potegal & Davidson, 2003). Similar behaviors are also seen in other young animals, often surrounding feeding or weaning conflict (Altmann, 1980; Goodall, 1986; Schaller, 1964). Tantrums have been reported in many societies with different forms of subsistence systems, political organization, and norms surrounding anger and parenting (Albino & Thompson, 1956; Salameh et al., 2021; Fouts et al., 2005; Henderson, 1966; Hilger, 1957; Konner, 1974; Ward, 1970; Johnson, 2003; Bhatia et al., 1990; Myers, 1988; Bois et al., 1944), suggesting they might be a human universal (Potegal, 2019). As with the other proposed signals of need, they are capable of eliciting a wide range of responses, including pro-child responses (e.g., parents giving in to a child's wishes), neutral responses (e.g., parents ignoring the child, Hilger, 1957; Johnson, 2003; Konner, 1974), and negative responses like abuse (Schmitt, 1987).

Temper tantrums are closely linked to anger (Potegal & Davidson, 2003), suggesting conflict with caregivers, and have high costs even when the tantrum is brief. Thus, temper tantrums might be useful when there are substantial and immediate gains to be had from a credible signal of need. This distinguishes them from sadness, and even crying, which are often unrelated to conflicts and have low costs when short-lived.

The costs of temper tantrums could be energetic or come from the risk or implication of self-harm (Lummaa, 1998). For example, Utilian mothers reported in focus groups that some temper tantrums involved children banging their heads on things when they do not get what they want, behaviors that have been reported in other populations (Belden et al., 2008; Burrows & Spiro, 1953; Daniels et al., 2012; Dennis, 1940; Van den akker et al., 2022). Similarly, young chimpanzees have been observed to beat their heads on the ground when refused access to breast milk (Goodall, 1986), and American white pelican chicks have been found to throw themselves on the ground, flail violently, and bite at their own wings when begging for food (Schaller, 1964). Such behaviors could credibly signal need if the benefits of care for those who are truly in need outweigh the signal costs, whereas for those who are not in need, the benefits of care do not outweigh the signal costs, thus deterring deceptive signaling (Hagen et al., 2008).

Alternatively, because tantrums impose direct costs on caretakers by interfering with important tasks (Altmann, 1980) like finding or preparing food or taking care of other children, they might be more akin to a strategy to coerce caretakers into providing more support.

Study Aims

This study aimed to establish the natural history of child signaling in Utila, Honduras, by measuring various indices of adversity, children's conflicts with caregivers, the frequencies of three common child signals of need, and various types of caregiver responses. From these, we used signaling theory to explore 1) the causes of child signals of need, 2) how and why signal costs might vary, 3) how caregivers respond to indications of child need, 4) how signaling behavior changes with age

and sex, 5) and if there were differences in child signaling and parental responses in two subpopulations that face different levels of social and economic adversity.

More specifically, we hypothesized that children have evolved strategies to tailor their signals of need to 1) their valuation of a given resource, 2) the presence of existing information about a child's needs and wants (i.e., potential to benefit from a resource) and 3) the extent of conflicts of interest with caretakers, which should influence the decision to use minimal signals or signals whose costs would deter deception. Such strategies can lead to some combination of verbal requests for more support and facial sadness, which we consider to be minimal signals, or withdrawal, temper tantrums and self-harm, which we consider "costly" signals. Crying might be considered a "minimal" signal in some circumstances, such as when a child needs a loud auditory signal to attract attention on a noisy playground, but a "costly" signal in others, such as lengthy bouts that incur physiological costs in infants signaling vigor and social costs in older children signaling need. Similarly, infrequent sadness would be a minimal signal, but frequent sadness might be better conceptualized as costly withdrawal or depression.

A major challenge when studying signals of need is the fact that such signaling is expected to 1) be more common in times when individuals can benefit from increased investment (e.g., when they are facing major adversity or when a fitness-relevant opportunity arises) and 2) result in benefits to the signaler on average. This hypothesized causal, bi-directional relationship between investment and signaling makes it difficult to isolate the effects of signaling behavior on investment in children, especially given the lack of prior studies on signaling by older children in low-income settings. For this reason, all analyses of these unique data were exploratory and meant to lay the foundation for future studies of child signaling.

Methods

Study Population

This study of children aged 5–20 and their parents and other primary caretakers was conducted in Utila, Honduras, one of the country's small Bay Islands in the Western Caribbean. Participants in the study were sampled from two populations that face different levels of economic and social adversity: 1) a long-standing English-speaking community primarily comprising descendants of British immigrants who arrived on the island in the 1800's, and 2) a more recent community of Spanish-speakers, mostly from mainland Honduras. Compared to the former, the latter are more likely to live in crowded and suboptimal conditions, face active discrimination and increased stress (Garcia et al., 2017), and experience economic uncertainty due the predominance of low paying, seasonal jobs primarily related to the island's diving tourism industry (Garcia, 2018; Stonich, 2000). Such inequality appears to be increasing in response to recent growth in the tourism industry, with the majority of wealth from tourism flowing to a small portion of native English-speaking islanders and other Westerners (Davis, 2014).

Focus Group Interviews

To inform development of our survey questionnaire on child signaling, focus groups of parents of families living in Utila were held in July 2022. Parents indicated frequent sibling competition and various ways children might signal need. Both Spanish-speaking and English-speaking moms reported that fighting between siblings was extremely common, with fights over toys, gifts, and phone time being the most reported causes. In both populations, crying and various forms of sadness and withdrawal were listed as the most common responses to a child not receiving investment or support, followed by temper tantrums. In response to these hypothesized signals, discipline was common. Although the mothers generally reported that children were treated equally, needier children were described as getting more resources from parents, perhaps due to differences in signaling among children as well as information caretakers gained from cues of need.

Sampling

Participant caregivers for this study were recruited through convenience sampling. JH recruited early participants with the help of primary informants and the use of snowball sampling. Participants were also recruited via Facebook posts.

In all forms of recruitment, participants were informed of the purpose of the study, what they would be asked to do, and the inclusion criteria, such as being 18 or older, having permanent residence on Utila, and having a child between 6 and 18 years old.

Participants

One hundred thirty-one primary caretakers provided data on 263 children. All participants for the survey portion of the study met the inclusion criteria. Most participants were the biological mothers of one or more children in the study. Several participants were caring for children younger than 6 or older than 18. We collected caregiver reports of signaling for all children 5–20 years old.

The Ethics

All participants provided informed consent. The surveys, which included many topics outside of child signaling, were designed to last about an hour, plus 20 min for each additional child. Participants were paid 350 lempiras ($13.84 at the time of writing) for the survey portion of the study.

This study was approved by the WSU and BU IRBs.

Survey

The data for this study were collected as part of the Utila Child Health Project. Participants could choose to do the survey in English or Spanish. All questions were read to them and recorded by a research team member.

Child Signaling Frequency and Cost, Alloparenting Contributions, and Conflicts with Caretaker

We used six-point Likert-type scales to get caregiver reports on the frequencies of 1) various types of child signaling, such as sadness and crying, 2) conflict between the caretaker and each participating child, 3) and child allocare of other children in their household. See Table 1 for exact wording. We gave children an alloparenting frequency of "never" if they were the only child within a household. We also calculated the summed frequency of child alloparenting contributions by other children within the household.

From these count variables we created two composite signaling variables. The *frequency of signaling* was the sum of the frequencies of child sadness, crying, and temper tantrums. *Signal cost* was the sum of the frequencies of these three signals weighted by their relative costliness (i.e., *Signal cost* = *frequency of sadness* + 2 × *frequency of crying* + 3 × *frequency of temper tantrums*). Although we treated *signal cost* as a continuous variable, we conceptualized low signal cost values (e.g., infrequent sadness or crying) as more likely to be minimal signals, and high signal cost values (e.g., frequent crying or temper tantrums) as more likely to be "costly" signals. For each child we also summed the frequencies of conflict with caretakers and signaling cost for all other children in the household, termed *other children conflict* and *other children signal cost,* respectively.

Relative Neediness of Children and Relative Investment in Children within the Family

We used six-point Likert scales for caretaker reports of 1) the relative neediness of children within the household, and 2) the relative investment they provide to each participating child compared to the rest of their children. Both questions were framed need as involving time, effort, and resources. See Table S1 for exact wording.

Table 1 Variable names and question wording for measures about the frequency of signaling, allocare, and conflict

Variable	Survey question wording
Crying Frequency	How often does your child cry?
Sad Frequency	How often is your child sad?
Tantrum Frequency	How often does your child throw temper tantrums? (e.g., scream, throws things, or throws themselves on the floor)
Running Away Frequency	How often does your child leave the house without telling you when they get mad?
Parent/Child Conflict Frequency	How often do you have conflicts with your child?
Child Alloparenting Frequency	How often does your child take care of their other siblings?

All questions had the following labels attached to each point on its Likert scale: Never; Once a month or less; More than once a month but less than once a week; More than once a week but not daily; Daily; Multiple times per day. For analyses, we converted these categorical variables to numeric frequencies per month as follows: never = 0; once a month or less = 1; more than once a month = 3; more than once a week = 8; daily = 30; multiple times per day = 60

Caretaker Perceptions of Child Health and Ability to Avoid Illness

Caretakers were asked about the frequency of their child missing school and their child's history of medical problems in general terms (i.e., the extent to which they experienced a "variety of medical issues"). Both questions were slightly modified from Hill et al. (2016) and involved the use of five-point Likert scales, the scores of which were averaged for use in analyses. See Table S2 for the wording of these variables.

Caretakers were also asked three questions using a five-point Likert scale about their child's susceptibility to illness, all of which were slightly modified versions of questions from the Perceived Vulnerability to Disease Scale (Duncan et al., 2009). We reversed the scores on two measures so that a score of 5 corresponded with the lowest susceptibility to illness before we averaged the scores of these to create a mean *illness avoidance* variable. In the 1 instance in which we only had data for two of the measures, we still calculated the mean but used a numerator of 2. See Table S3 for the wording of these variables.

Caretaker Perceptions of Home Sanitation, Neighborhood Quality, Home Instability, and Food Security

Affirmative caregiver responses to the following questions about their home were summed to create a home sanitation index: having an indoor bathroom, having a bathroom that is not shared with anyone outside of the household, having a flush toilet, having running water to wash hands in the bathroom, and having a home which did not flood in the last year.

Caregiver perceptions of neighborhood quality were measured using ten questions modified from the Neighborhood Characteristics Questionnaire (McGuire, 1997). These questions covered the safety and suitability of their neighborhood for raising children and included questions explicitly asking about neighborhood quality, e.g., "Sometimes I hear about illegal drug activity in my neighborhood." The mean of these values was used in analyses as a neighborhood quality index. Levels of home instability were measured with four questions covering the degree to which the caregiver's family had/has to move homes and whether people move in and out of their homes frequently. For wording of these items, which used five-point Likert scales, see Table S6 and Table S5.

We used a modified version of the USDA Food Security Questionnaire (Blumberg et al., 1999) to measure food insecurity, with the most significant changes being converting the measures to a five-point Likert scale and averaging them for a food insecurity index. See Table S4 for the wording of these variables.

Causes of, and Responses to, the Last Instance of Child Signaling of Need

We asked caretakers about the last time each participating child was sad or cried. Caretakers provided a free response of the reason(s) for the emotional display, and their responses to it. The researcher then binned responses into at least one of 31 categories which included positive, negative, and neutral responses (from the child's

perspective). For the full list of options see Table S7. We then created a *caregiver response* variable, which was coded as 1 for a positive response (e.g., helping child), 0 for a neutral response (e.g., not responding), and −1 for a negative response (e.g., punishment; all from the child's perspective). MG and KS also coded the causes for the presence or absence of 17 elements (e.g., whether the cause involved *punishment*, *family conflict*, and/or *discomfort, pain, injury, or illness*).

Demographic Questions

The survey also included many demographic questions about the caretakers and their households. Those used in this study included the (1) ages of those in the household, (2) sexes of those in the household, (3) kinship ties within households, (4) partnership status of the primary caregiver, (5) number of adults who provide childcare within the household, (6) highest level of education of the primary caregiver, (7) immigration status (in regards to Utila), (8) monthly household income, (9) neighborhood of residence, (10) current job of the primary caretaker, and (11) ownership of various possessions (e.g., homes, washing machines, or cellphones; see Table S8 for full list). These data allowed us to calculate the number of children (total, younger, and older) and adults within the household as well as the genetic relatedness between siblings.[2] We also created a variable for residence in Camponado, a low-SES, densely populated neighborhood on the island with less sanitation access mostly comprising individuals from the mainland (Garcia et al., 2017).

In one instance where data for caregiver age was missing, we set the missing value to the mean. This affected data for two children.

Statistical Analyses

All statistical analyses were exploratory. Whereas confirmatory studies test prespecified hypotheses generated blind to the data, exploratory analyses are data-driven and prioritize discovery: they risk overfitting the data, generating false positives, but can reveal unexpected yet potentially important relationships that warrant future investigation (Tukey, 1977).

The overall structure of our data was analyzed with principal components analysis (PCA), Bayesian graphical models (BGM), and minimum spanning trees (MST). PCA is a linear transformation of the data to a new orthonormal coordinate system in which the first principal component (PC1) corresponds to the axis of maximum variance, the second principal component (PC2) corresponds to the axis perpendicular to the first of the maximum of the remaining variance, and so forth. Among other uses, PCA identifies the linear combinations of variables that account for most of the variance, thereby providing a lower dimensional representation of high dimensional data. In BGM, variables are nodes in an undirected graph, and edges represent their conditional dependencies. Specifically, an edge indicates that two variables are

[2] Because we wanted a relatedness value for all ego children, including those without siblings, this measure included the focal child (r = 1) in calculations of average child relatedness within households.

dependent, conditional on the other variables; edge weights indicate the strength and sign of the relationship. Importantly, the absence of an edge indicates that two variables are conditionally independent (Huth et al., 2023). The graph can therefore identify clusters of dependent variables that are independent of other variables. From the graphical models identified with BGM, we extracted an MST, i.e., a subset of the graph in which each node (variable) is connected without any cycles and with the minimum total "distance" between the nodes (more strongly dependent variables, i.e., those with larger absolute weights, having lower "distances"). The MST is therefore typically a dramatically simplified representation of the original graph that often identifies the most important edges among the nodes, which in our case are the most important dependencies among the variables.

To investigate the associations between potential causes of child signaling and conflict with caretakers and caregiver reports of child behavior, we used elasticnet regression models. Elasticnet models are useful in cases where the number of predictor variables (p) is large relative to the number of observations (n). These models, often referred to as penalized or regularized regression (e.g., lasso and ridge regression), aim to limit overfitting the data (variance) by allowing some bias, i.e., by optimizing a bias-variance tradeoff. In particular, lasso regression sets the coefficients of uninformative variables to exactly 0, thereby serving as a form of variable selection (Zou & Hastie, 2005).

Elasticnet regression models of signaling and conflict frequency, which were overdispersed count data, were fit using the glmnet package (Friedman et al., 2010; Wurm et al., 2021) and the quasipoisson error family. Predictors included demographic, household, health, and neighborhood variables that might cause signaling behavior or conflict between children and caretakers. All variables were centered and standardized by one standard deviation prior to fitting.

Parental responses to child signaling, their perceptions of child need, and their reported investment in the child were coded as three-level ordinal variables, either negative, neutral or positive; or less than other children, same as other children, or more than other children. We analyzed these outcomes using ordinal logistic regression with elastic net penalties, fit with the ordinalNet package (Wurm et al., 2021).

All analyses were conducted with R version 4.4.2 (2024–10-31).

Results

One hundred thirty-one primary caretakers (females = 123, males = 8) took the survey and provided signaling data for at least one child. Two hundred sixty-three children had frequency data for at least one signal, with 259 having data for all three. Among those with at least one record of signaling frequency, 133 were female and 130 were male. For summary statistics of study variables see Table 2 and Table 3.

A PCA of primary study variables found that the child signaling variables and the sociodemographic and ecological variables loaded primarily on PC1, in a direction

Table 2 Summary statistics for child variables

Variable (continuous)	N	Range	Mean	SD	Histogram
Child age (years)	263	5-20	10.5	3.4	
Sad frequency (times/month)	260	0-60	5.0	11.3	
Crying frequency (times/month)	262	0-60	7.3	12.8	
Temper tantrum frequency (times/month)	262	0-60	8.5	14.6	
Frequency of child's own alloparenting effort (times/month)	244	0-60	12.5	18.6	
Frequency of other child alloparenting (times/month)	244	0-360	25.3	62.1	
Frequency of conflict with focal caretaker (times/month)	261	0-60	6.7	12.1	
Frequency of signals summed (times/month)	263	0-180	20.7	31.1	
Signal cost	263	0-360	45.0	66.7	
Other children signal cost	263	0-737	67.8	107.8	
Other children conflict	261	0-90	7.8	14.2	
Child relatedness	263	0.2-1	0.6	0.2	
Child medical problems index	261	1-5	1.8	1.2	
Child illness avoidance index	262	1-5	3.7	1.2	
Variable (categorical and ordinal)			**Category**	**N**	**%**
Child sex			Female	133	50.6
			Male	130	49.4
Relative need (w/in household)			Much less	1	0.4
			Less	26	9.9
			The same amount	106	40.3
			More	58	22.1
			Much more	10	3.8
Relative investment (w/in household)			Much less	0	0.0
			Less	28	10.6
			The same amount	151	57.4
			More	20	7.6
			Much more	4	1.5

suggesting that greater signaling covaried with more adverse environments. Household composition variables loaded primarily on PC2, covarying with child signaling variables in a direction suggesting that larger households covaried with less signaling. See Fig. 1.

We then estimated a BGM for all study variables, extracting the MST, which revealed that signaling variables clustered together, conflict was positively associated with signal cost, and child age negatively associated with crying frequency. See Fig. 2.

Distributions of Signaling Behavior, Alloparenting Effort, and Conflict

Child sadness, crying, and temper tantrums were common and highly correlated with one another. See Fig. 3 and Fig. 4. Caregivers reported that 64 children (25%) were sad at least once a week, 102 children (39%) cried at least once a week, and 100 children (38%) threw temper tantrums at least once a week. A small subset of children engaged in these signals/states at least daily; sadness:

Table 3 Summary statistics for adult and household variables

Variable (continuous)	N	Range	Mean	SD	Histogram
Caregiver age (years)	135	20-68	34.9	8.5	
Children in household	135	1-9	2.4	1.4	
Number of adults in household	135	1-5	2.0	0.9	
Household adults who provide childcare	135	0-5	1.8	0.9	
Household adults who provide, food, housework, and other necessities	135	0-5	1.7	0.8	
Caregiver education level (years)	129	0-17	8.3	3.8	
Monthly household income (Lempira)	133	2500-120000	11710.5	13017.2	
Household food insecurity	135	6-30	20.5	8.7	
Neighborhood quality index	135	1-5	3.7	1.1	
House sanitation index	134	0-5	3.9	1.3	
Possession score[a]	135	0-8	3.9	2.0	
Variable (categorical)			**Category**	**N**	**%**
Caregiver sex			Female	123	91.1
			Male	8	5.9
Primary language			English	14	10.4
			Spanish	121	89.6
Immigrant			No	29	21.5
			Yes	106	78.5
Partnered status			No	41	30.4
			Yes	94	69.6
Residence in Camponado			No	74	54.8
			Yes	61	45.2
Stay at home mother			No	97	71.9
			Yes	38	28.1

16 children (6.2%); crying: 31 children (12%); and tantrums: 42 children (16%). However, many children were reported to never engage in these signals/states; sadness: 78 children (30%); crying; 58 children (22%); and tantrums: 90 children (34%). For a visualization of how signal frequencies varied within children see Fig. S1.

Conflict between children and caretakers was also common, with 92 children (35%) having conflicts with parents more than once a week. However, 109 children (42%) were described as never having conflicts with parents. See Fig. S2. Conflict was also associated with higher signaling frequencies. See Fig. 1 and Fig. 4.

The frequency of child alloparenting effort, which previous research has linked to parent–child conflict, was bimodally distributed, with 137 children (56%) reported to never engage in it (36 instances were due to a child being an only child) and 78 children (32%) reported to help with childcare at least once a day. See Fig. S2.

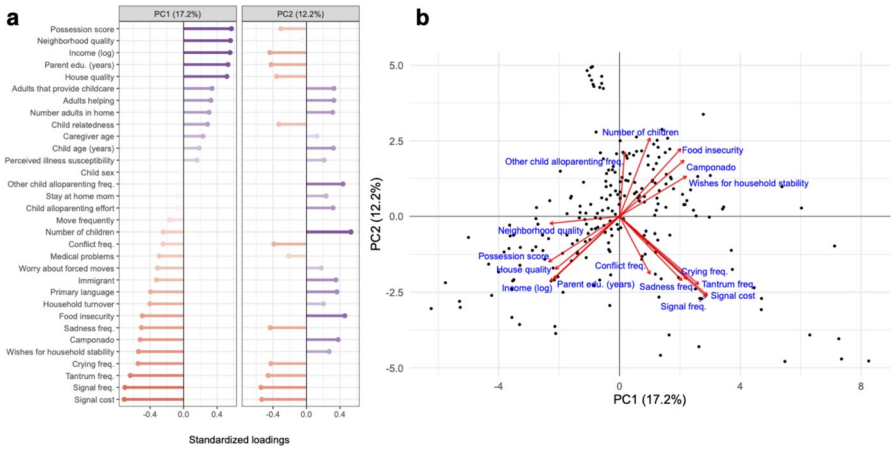

Fig. 1 **a** Loadings of each variable on PC1 and PC2. **b** Biplot map of PC1 and PC2. Each point is one child. Arrows represent the loadings of each variable on PC1 and PC2. Variables with small loading factors not displayed

Fig. 2 Minimum spanning tree derived from a Bayesian graphical model of child signaling and variables thought to cause differences in signaling strategies. Purple edges represent negative partial correlations between variables. Orange edges represent positive partial correlations between variables. Line weights represent partial correlation coefficients. Red dots indicate the two variables (child age and conflict) that are closest to the signaling variables. Blue text represents our interpretation of the main clusters

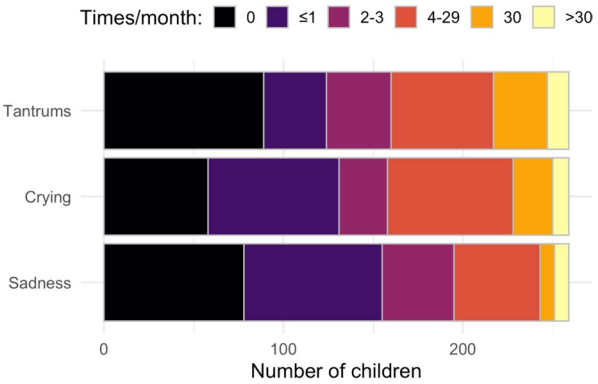

Fig. 3 Frequencies of child sadness, crying, and temper tantrums per month as reported by the primary caretaker. Frequency key: 0 corresponds to "never," < = 1 corresponds to "once a month or less," 2–3 corresponds to "more than once a month but less than once a week," 4–29 corresponds to "more than once a week but not daily," 30 corresponds to "daily," and > 30 corresponds to "multiple times per day"

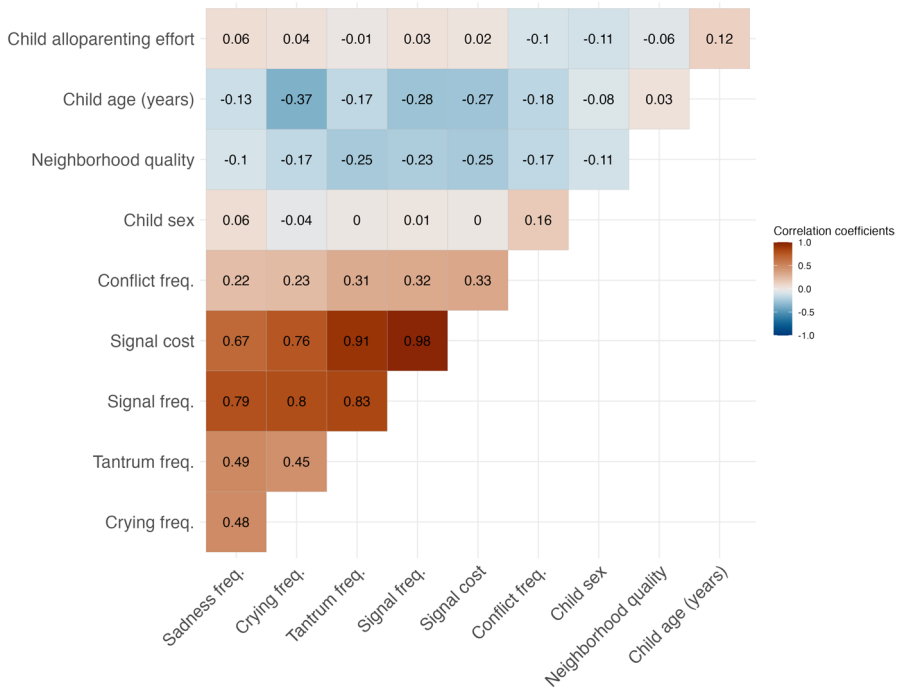

Fig. 4 Correlation matrix of the frequencies of signals/states covered in the study with sex, child age, and the frequency of conflict between children and primary caretakers. For a more complete correlation matrix of study variables see Fig. S3

Predictors of Signaling Frequency and Conflict Frequency

Using lasso regression, we explored all potential predictors of each child signal frequency, as well as of conflict frequency. Child age was a strong negative predictor of all frequencies, and *Neighborhood quality* was too, albeit less so for *Crying* and

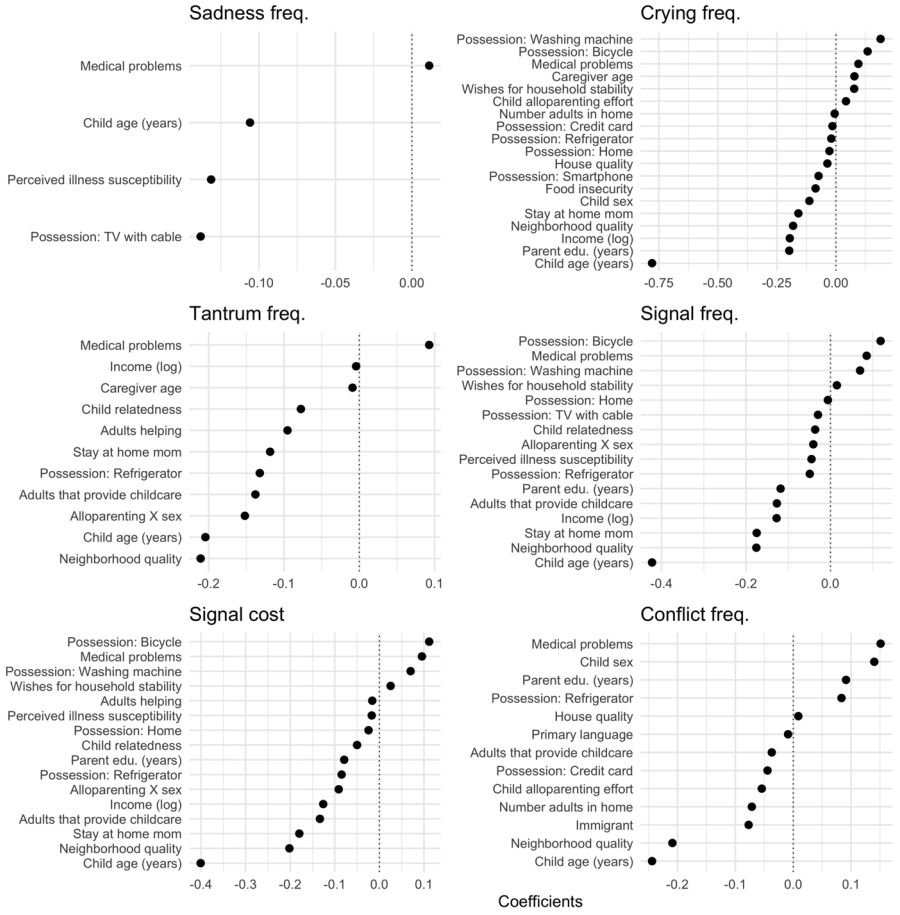

Fig. 5 Lasso regression models of each child signaling frequency and conflict frequency. Variables whose coefficient values were shrunk to 0 are not displayed. Models fit using quasi-Poisson regression

not for *Sadness*. *Medical problems* was a weak positive predictor for all frequencies. Possession of a bicycle or washing machine was a positive predictor of *Signaling Frequency"* and *Signal Cost*, whereas some other possessions were negative predictors of various frequencies. Possession of a TV with cable was the strongest negative predictor of *Sadness*, for example. Male sex was associated with higher *Conflict frequency* with the primary caretaker. See Fig. 5.

The effects of particularly large and consistent risk or protective factors for child signaling identified by the lasso regressions (Fig. 5) are shown in Fig. 6 and Fig. S4.

Although child age was negatively associated with all signaling frequencies, a general linear mixed effects negative binomial model showed that the negative association was strongest for Crying and for males (Fig. S5).

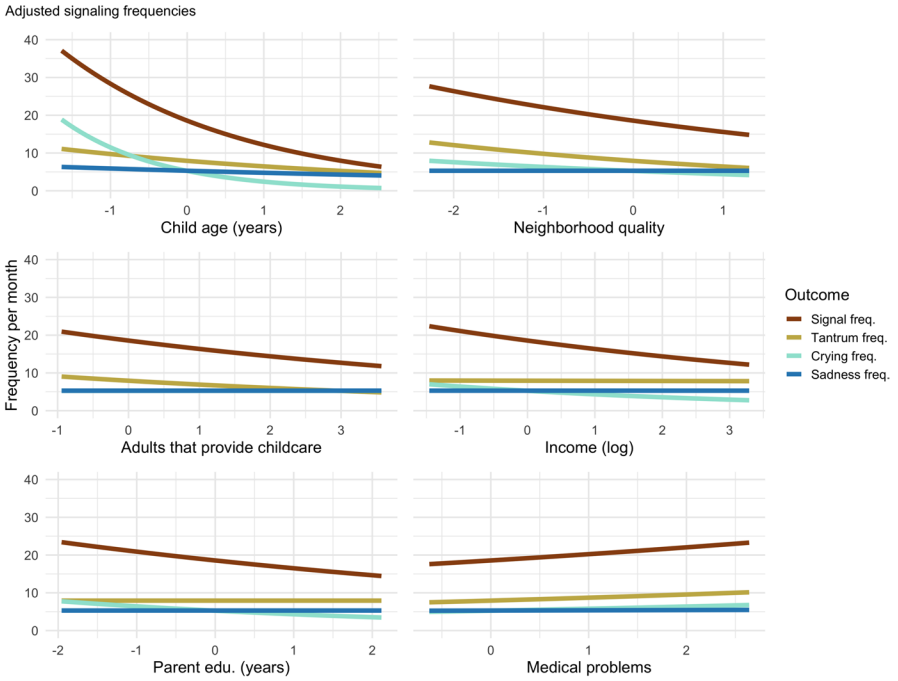

Fig. 6 Effects of selected predictors of child signaling frequencies when holding continuous variables at their mean and factor variables at their mode

The effects of particularly large risk or protective factors for conflict frequency are shown in Fig. 7.

In general, older child age and better neighborhoods were associated with less conflict and less signaling, whereas medical problems were associated with more conflict and more signaling. There was little evidence for a sex difference in signaling, except that alloparenting frequency was positively associated with signaling for girls, and negatively for boys. Male sex was associated with more conflict.

Positive Associations Between Child Age and Signaling Frequency and Perceptions of Child Neediness

Primary caretakers rarely described a child as "much less" (1 child) or "much more" needy (10 children) needy compared to their other children. Therefore, we collapsed "less" and "much less" into a "less" factor and "more" and "much more" into a "more" factor. The result was 27 less needy children, 106 children who were as needy as their siblings, and 68 more needy children.

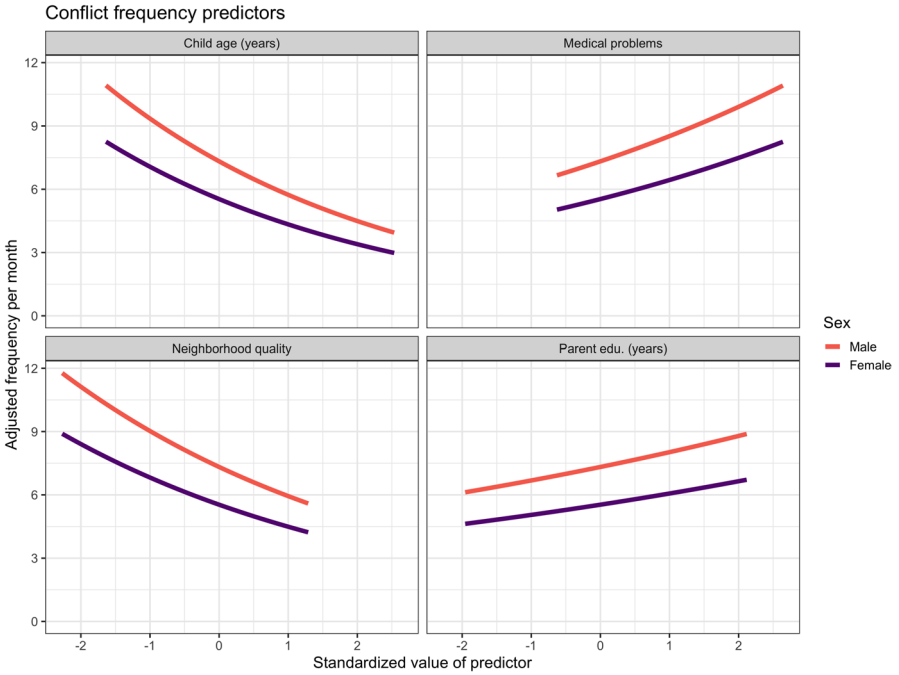

Fig. 7 Effects of selected predictors of child-parent conflict frequencies when holding continuous variables at their mean and factor variables at their mode

There were positive relationships between perceived relative neediness within the family and both child age and the frequency of child sadness. See Fig. 8.

Relative Need Predicts Relative Investment

Signals can elicit better treatment because the information they provide alters the behavior of signal targets in ways that benefit the signaler. For this reason, we tested the association between caretaker perceptions of relative child need within the household and the caretaker's relative investment within the household. Consistent with signaling theory, our model predicts a greater proportion of caretakers investing more in children who they deem needier and a greater proportion of caretakers investing less in children they deem less needy, controlling for the age of the child, and household demographics. See Fig. 9.

Caregiver Responses to Most Recent Signal of Need

There were 6 instances in which a caregiver's response involved acts which were both negative and positive from the child's perspective. These were excluded from analyses due to their rarity.

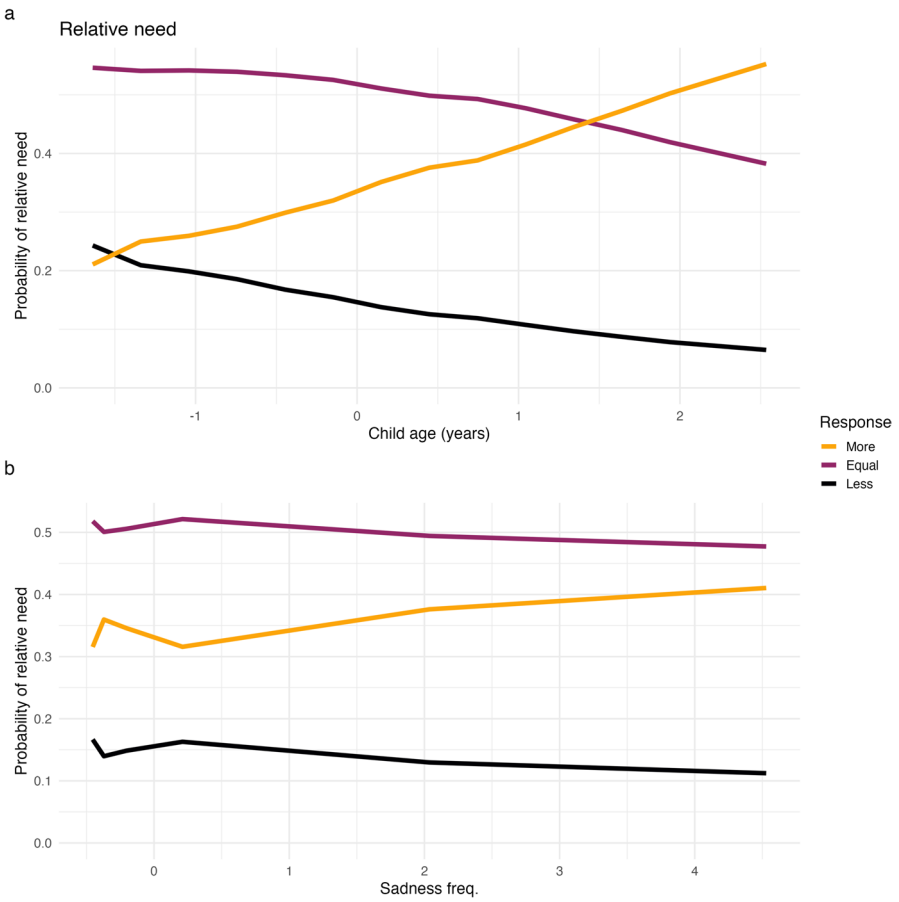

Fig. 8 The proportion of children perceived by caretakers as being more needy, as needy, or less needy than a caretaker's other children when holding continuous variables at their mean and factor variables at their mode. a: Effect of child age on the probability of relative neediness. b: Effect child sadness frequency on the probability of relative neediness. Outcome variable question wording: How much time, effort, and resources does this child need compared to your other children?

Our models found no evidence of relationships between, child age, child sex, the number of children in the household, and log family income and the valence of parental responses (positive, neutral, or negative) from the child's perspective. However, primary caretakers were more likely to respond positively towards a child when they attributed the cause of signaling to discomfort, pain, injury, or illness, and less likely to respond positively when they attributed the cause of signaling to family conflict, child punishment, child transgressions, or a child losing an item or privileges. See Fig. 11.

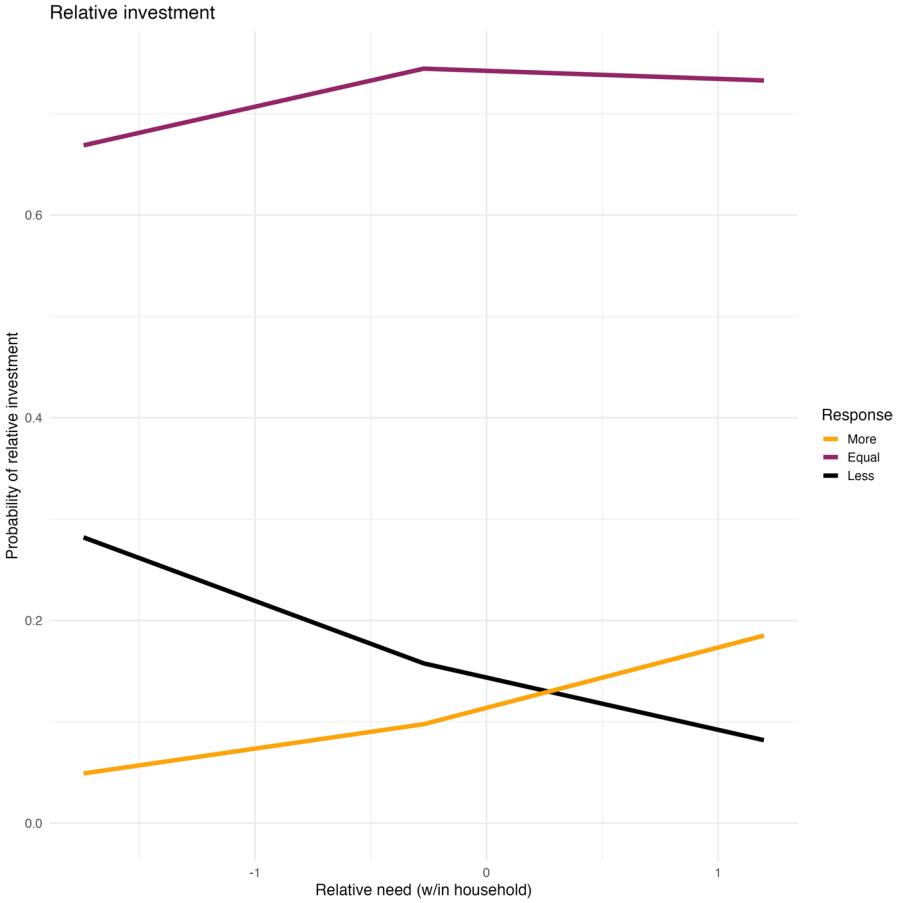

Fig. 9 The effect of perceived need (in terms of time, effort, and resources) on the probability of relative investment within the household when holding continuous variables at their mean and factor variables at their mode. Outcome variable question wording: How much time, effort, and resources do you put into this child compared to your other children?

Discussion

Caregivers reported a wide range of child signaling frequencies. About half of children were reported to cry or throw tantrums more than once a month, and almost 40% were reported to do so more than once a week (Fig. 3), with higher frequencies in younger children, lower frequencies in older children, and particularly steep age-related declines for crying and for all types of signaling by males (Fig. S5).

Our bivariate correlations, PCA, MST, and lasso regression analyses all provided a consistent pattern of results: child age was a strong negative predictor of signaling frequency and cost; conflict with the primary caretaker was a positive predictor of signaling frequency and cost; and multiple indices of adversity, such as low

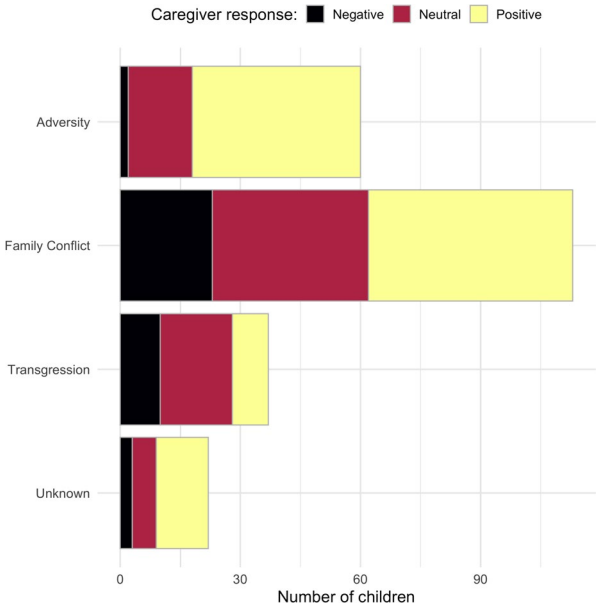

Fig. 10 Frequencies of caregiver response to the last instance of child signaling by the cause of the signaling. Categories of causes were based on cluster analysis of more fine-grained cause variables. See Fig. S6 for cluster dendrogram and Table S9 for the frequencies of causes and caregiver responses

neighborhood quality, low household income, and medical problems, were positive predictors of signaling frequency and cost (Fig. 1, Fig. 2, Fig. 4, Fig. 5, Fig. 6).

Contrary to expectations, immigration status, residence in Camponado, and primary language (Spanish or English as proxies for cultural differences), did not predict child signaling in our lasso regressions, despite the differences in wealth, job certainty, discrimination, and living conditions between those from the mainland and English speaking Utilians (Davis, 2014; Garcia et al., 2017; Garcia, 2018; Stonich, 2000). These variables correlated with neighborhood quality, however, which was retained in our models, and lasso regression tends to retain only one of a set of correlated predictors (Zou & Hastie, 2005). Additionally, families from Camponado appeared to be willing to care for children outside their immediate families, which might have reduced children's needs.

Consistent with signaling models that emphasize the role of conflicts of interest in favoring the use of signals with honesty-enforcing mechanisms (e.g., "costly" signals), caregiver perceptions of conflict and child signaling frequency were positively correlated (Fig. 4), and family conflict was the most common cause of a child's recent signaling episode (Fig. 10). Conflicts, in turn, were negatively associated with child age and higher neighborhood quality, and positively associated with male sex, medical problems, and (oddly) caregiver education (Fig. 7). Although conflicts of interest do not always lead to overt behavioral conflict (Altmann, 1980; Bateson, 1994), it is likely many, if not most, conflicts are ultimately caused by conflicts of interest.

Consistent with the need signaling hypothesis, more frequent sadness was positively associated with perceptions of relative child need within the household (Fig. 8). Higher perceived need, in turn, was associated with higher relative

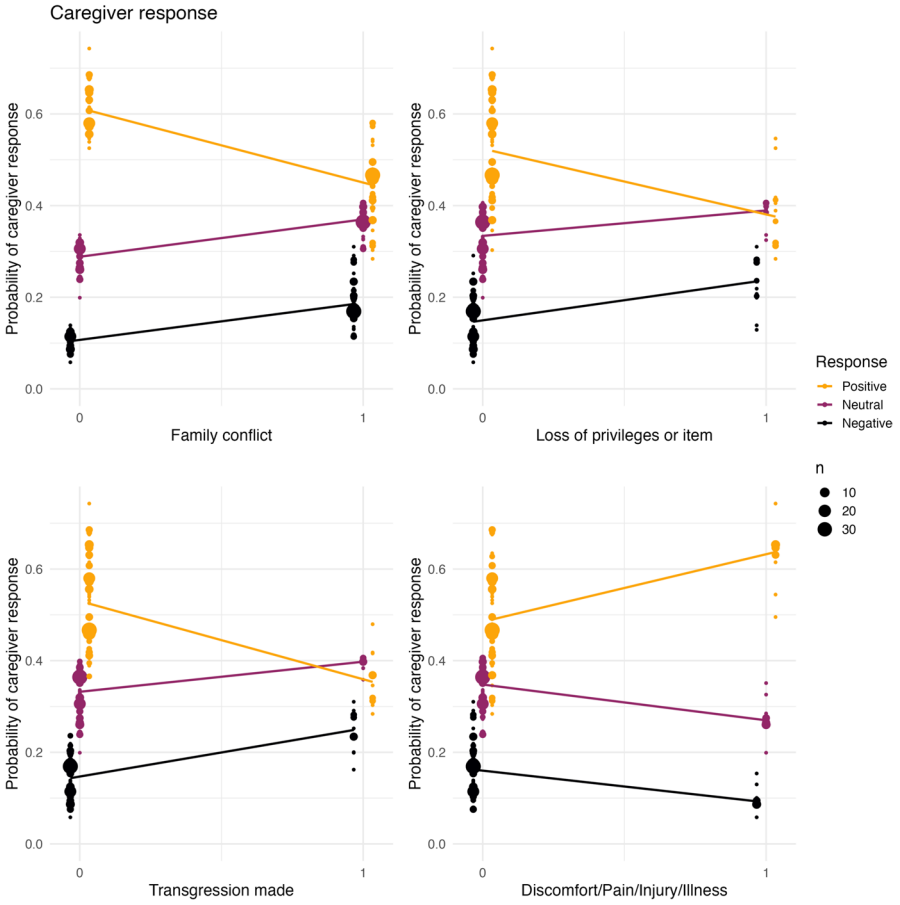

Fig. 11 Effects of selected predictors of the probability of positive, neutral, and negative responses to the last time a child became sad or cried when holding continuous variables at their mean and factor variables at their mode. 1 = evidence of the cause in the caregiver report; 0 = no evidence. The endpoints of the lines are dodged slightly for greater visibility. Dot size represents model predictions for each participant given their values of predictor variables. See Fig. S7 for the effect of the cause involving punishment

investment (Fig. 9). Crying and tantrums were not associated with higher perceived need, likely due to their high correlation with sadness and the propensity of lasso regression to retain only one of a set of correlated predictors (Zou & Hastie, 2005). Signaling behavior did not predict differences in relative caregiver investment beyond its effect on perceived need (Fig. S9), similar to an experimental vignette study that found that the likelihood of costly support was largely mediated by the effect of costly signaling on belief in need (Gaffney et al., 2022).

Interestingly, older children were perceived to be needier than younger ones (Fig. 8). One likely reason for this might be that caretakers perceive the types of investment older children seek as more costly. In line with this reasoning, multiple

caretakers mentioned that older kids need more money and advice and get into trouble more often. It might also be that caretakers see investing in older children as relatively costly when they seek to redirect investment to younger children, whose needs might be perceived to be more legitimate.

Keeping in mind possible biases, caregiver self-reported responses to signals of need were generally positive or neutral, more so for situations involving injury and illness, and less so for situations involving family conflict, loss of privileges, and transgressions, which had greater proportions of negative responses (Fig. 10; Fig. 11). These patterns probably reflect a combination of shared interests vs. conflicts of interest between child and caretaker, some of which might represent caretaker investment in some children more than others, and greater caretaker certainty about need in cases of injury and illness. Negative responses, e.g., punishment, can be used to change future child behavior that is costly to the caregiver (e.g., harming siblings or wasting resources), and possibly also to signal the costliness of providing the desired support (Hagen & Syme, 2024; Gaffney et al. (Gaffney, et al., 2022)). That said, our model predicts positive responses in 35% of cases involving transgressions, suggesting that children are successful in negotiating better outcomes at least some of the time.

Our results parallel those of previous studies of infants and young children that found that, outside of peaks in infancy and early childhood, the frequencies of crying and temper tantrums decrease with age (Macfarlane et al., 1954; Ward, 1970; Österman & Björkqvist, 2010; Vermillet et al., 2022; Barr et al., 1991; Potegal & Davidson, 2003; Bhatia et al., 1990). Studies examining crying and tantrums in later childhood and adolescence are rare, especially for crying (Rottenberg & Vingerhoets, 2012; Zeifman, 2013). Our findings suggest the frequency of crying continues to decrease into childhood, dropping precipitously as children grow older. The frequency of temper tantrums also declined, as did the frequency of child sadness, albeit at a much slower rate (Fig. 5, Fig. 6). Our results also align with studies examining responses to the crying and fussing of infants that have shown that they often lead to increased support (e.g., breastfeeding, attention, or maintaining proximity, Lin & McFatter, 2012; Kushnick, 2006; Kruger & Konner, 2010; Hewlett et al., 1998; Chaudhary et al., 2024; Tronick et al., 1987), but can also lead to negative responses like abuse (Zeevenhooven et al., 2018; Kurth et al., 2011; Howard et al., 2006; Soltis, 2004).

Our results are consistent with the hypothesis that sadness, crying, and tantrums are signals of need, that children's need is higher in adverse environments and at younger ages, that costly signals rather than minimal ones are often needed to ensure credibility when there are conflicts of interest between caregivers and children, and that signals of need are effective at increasing caregiver perceptions of need that ultimately lead to increased investment in children.

Many models designed to explain signals of need (e.g., the begging of young birds) predict that offspring who are worse off or are receiving less investment have more to gain from signaling than those with more (Caro et al., 2016a, 2016b; Godfray, 1991; Godfray & Johnstone, 2000; Mock et al., 2011) and multiple game theoretical models examining parent–offspring conflict have found that parental resources have a modest impact on the evolutionary stable value for offspring

demand for resources (Bossan et al., 2013; Mock & Parker, 1997). In line with this reasoning, children in lower income households and riskier environments might benefit more from signaling effort if they experience greater levels of adversity or perceive themselves as disadvantaged compared to other children.

One possible reason for the negative association of signaling with age, which is also seen in more industrialized settings (Koch, 2003; Macfarlane et al., 1954; Potegal & Davidson, 2003; Zeifman, 2013), is that as children mature, they are more capable of fulfilling their own needs, more able to verbalize what they need (Österman & Björkqvist, 2010), and less vulnerable to threats. The effects of age on signaling are also likely due to how age influences the costliness of signaling need. For example, although the energetic cost of crying might be costly for the youngest children, it is likely insignificant for older children. Older children might instead need to weigh the potential social costs of crying or otherwise expressing sadness (Glasberg & Aboud, 1981, 1982; Zeman & Garber, 1996) against the potential increase in social support, which is consistent with our result that the age-related decline in signaling was steepest for crying. The age-related decline in signaling was also generally steeper for males than females (Fig. S5).

Previous research has shown family demands, such as caring for younger siblings (alloparenting), is an important source of parent–offspring conflict (Syme & Hagen, 2023). Although there was little evidence for sex differences in signaling overall (perhaps because sex differences typically emerge in adolescence, and our sample of adolescents was small), there was evidence that sex interacted with alloparenting effort. We found that higher frequencies of alloparenting by girls was associated with a higher frequency of tantrums and overall signaling costs, whereas for boys this relationship was slightly negative (Fig. S4). In many societies, girls do more alloparenting than boys (Barry & Paxson, 1971; Helfrecht & Meehan, 2016; Turke, 1988; Weisner & Gallimore, 1977), which matches reports from our focus groups of mothers. It is plausible that older girls are pressured to do more care of their younger siblings, in line with other studies finding an association between household responsibilities, like caregiving, and parent–offspring conflict (Lowe, 2003; Syme & Hagen, 2023). If so, girls with excessive alloparenting responsibilities might be signaling their need for more time to invest in peer relationships and status seeking behaviors outside the household. Although our study found a small negative association between girls' alloparenting and caregiver reports of conflict (Fig. 5), when girls do what caregivers want, caregivers plausibly report less conflict.

Limitations

Although this study was broader than most in that it examined sadness, crying, and temper tantrums across much of childhood and adolescence, it did not cover all the ways that caregivers might infer need, such as cues of injury. It also did not investigate all potential signals of need. For example, Spanish-speaking mothers reported in focus groups that refusing to do homework was a common tactic. Pained facial and bodily expressions (Vigil & Strenth, 2014; Craig, 2009; Cano & Williams, 2010; Schiavenato & Craig, 2010), self-harm outside of temper tantrums (Hagen et al.,

2008; Nock, 2008), and suicidality (Syme et al., 2016) have all been suggested to credibly signal need in times of conflicts of interest and may be viable strategies for children, at least at certain ages. Running away has received similar treatment, especially in instances when it comes with substantial risk (Shostak, 1981) or is seen as a suicide-threat (Fischer, 1950; Syme & Hagen, 2023). English-speaking mothers in our focus groups emphasized self-harm (e.g., a child slamming their head on the ground) and running away. However, in Utila running away often involves children visiting neighbors or aunts and is much less risky than it would be in many parts of mainland Honduras (Dávila-Cervantes & Pardo-Montaño, 2024).Despite the relative safety of Utila, young children may still face risks out on their own due to proximity to the ocean and the presence of dogs, motorcycles, golf carts, and tuk-tuks (auto rickshaws) on the narrow roads typical of much of populated parts of the island. Due to uncertainty on how to conceptualize the risks involved, we did not include running away in our analyses.

The main limitation of this study is self-report bias: all data come from caregiver reports, and therefore, reflect the biases of caretakers, whatever those might be. For example, caregivers might have reported more investment in children or fairer distributions of resources than was actually the case. In addition, questions about neighborhood quality lacked a reference, so some caregivers might have compared their neighborhoods to mainland neighborhoods and others to island neighborhoods.

Another important limitation is that this study was exploratory: such data-driven analyses can reveal unexpected relationships and inspire new theory but also risk overfitting the data, suggesting associations that might not exist. Our study was also cross-sectional, further limiting our ability to make causal inferences. In particular, there is likely a bidirectional relationship between child signaling and caregivers' perceptions of conflict that our study design could not disentangle. Furthermore, our penalized regressions included many variables, some of which might have been colliders, inducing spurious associations between outcome and predictor variables. We also assumed a priori that, at least in young children, infrequent sadness and crying were minimal signals not requiring a costly honesty-enforcing mechanism, whereas frequent sadness and crying, as well as tantrums, were costly signals.

Our use of convenience and snowball sampling is also a limitation as it resulted in a non-probability sample which may not be representative of the broader population. This could happen if there was selection bias so that those who participated differed from the rest of the population in how they interacted with their children or how they assessed, remembered, and reported child behavior.

Conclusion

Children face the challenge of eliciting support from others in times of adversity and opportunity. On the island of Utila, child signaling strategies were highly correlated with each other, and were exhibited by children of all ages, albeit more frequently by younger children and those living in more adverse conditions, who plausibly had greater need. Consistent with signaling models that emphasize the role of conflicts of interest in favoring the use of costlier signals, child signaling effort was positively

correlated with the frequency of conflict with caretakers and with perceptions of need, and greater perceptions of child need predicted greater investment in a given child. Our results suggest that evolutionary theories of signaling can help explain patterns of child sadness, crying, and temper tantrums.

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Author Contributions All authors contributed to the study conception and design. Material preparation was performed by Michael R. Gaffney, Edward H. Hagen, Aaron D. Blackwell, Carolyn R. Hodges-Simeon, Jessica K. Hlay, and Steven A. Arnocky. Data collection was performed by Jessica K. Hlay and Izabel Rodríguez James. Analysis was performed by Edward H. Hagen, Michael R. Gaffney, and Kristen L. Syme. The first draft of the manuscript was written by Michael R. Gaffney and Edward H. Hagen, and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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Data Availability Study code is available at https://github.com/michaelrgaffney/utilasignaling. Data on caregivers and children in this small community contain identifiable information and are therefore in a controlled access repository. For the terms of access, please contact Carolyn R. Hodges-Simeon (crhodges@bu.edu).

Declarations

Conflicts of interest The authors declare that they have no conflict of interest.

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