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Review Article

Children's competition in a natural setting: evidence for the ideal free distribution ☆

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Abstract

Little is known of the foraging abilities of children in modern cultures, especially when children forage in groups. Here we present a test of optimal foraging theory in groups of street children working for money. The children we observed were selling bottles of water to drivers distributed in two lanes at a crossroad of Istanbul, Turkey. As predicted by the ideal free distribution (a model of optimal group foraging), the ratio of children working in the two lanes was sensitive to the ratio of cars (and therefore the ratio of potential buyers) present in each lane. Deviations from the ideal free model arose largely from numerical restrictions on the set of possible ratios compatible with a small group size. When these constraints were taken into account, optimal behavior emerged as a robust aspect of the children's group distribution. Our results extend to human children aspects of group foraging that were previously tested in human adults or other animal species.

Keywords: Ideal free distribution; Children; Foraging; Competition

1. Introduction

Some of the salient characteristics of human life histories are an extended period of juvenile dependency and a delayed age of first reproduction (Gurven & Kaplan, 2006; Kramer, 2002; Sear & Mace, 2008; Walker et al., 2006). From an evolutionary perspective, an individual's most important developmental goal is to reach reproductive age in optimal conditions (Bjorklund & Pellegrini, 2000; Bjorklund & Pellegrini, 2002). Accordingly, human life histories may have evolved so that children display morphological and behavioral features that are advantageous to reproduction (Ellis, 2004; Kaplan & Gangestad, 2005; Vigil, Geary & Byrd-Craven, 2005).

Human children's extended period of dependency on adults, for example, may allow juveniles to acquire food procurement abilities that are complex and time consuming to master (Bock & Johnson, 2004; Bock & Sellen, 2002; Gurven & Kaplan, 2006; Walker, Hill, Kaplan & McMillan, 2002). The advantages derived from accessing diets that are technologically difficult to acquire but rich in energy could compensate for the costs of a delayed reproductive onset (Kramer, 2002; Lancaster, Kaplan, Hill & Hurtado, 2000). Even very young children can acquire simple foraging or food procurement techniques (Horner, Whiten, Flynn & de Waal, 2006; Rakoczy, Tomasello & Striano, 2005), however, and differences between children and adults in food gathering efficiency may depend more on children's smaller body size or slower gait than on the mastery of specific skills (Bird & Bliege Bird, 2000; Bird & Bliege Bird, 2002; Blurton Jones & Marlowe, 2002).

An extended period of juvenile dependency also has fitness costs. During this period, children may become orphans though natural disasters, wars or conflicts among groups (Hill, Hurtado & Walker, 2007; Wrangham, Wilson & Muller, 2006). The parents may also abandon their children in poverty. Another source of potential fitness costs is the presence, within the same family, of children of different ages and energetic needs (Lawson & Mace, 2009). Competition among siblings may have major effects on development through a reduced quantity and quality of parental care. Some data suggest that younger children tend to be less fed (Horton,

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1988) and that child mortality increases with birth order (Modin, 2002). A child's educational level (Blake, 1989) and probability of vaccination (Lewis & Britton, 1998) may also decrease as a function of family size. Finally, family size may impact negatively on the time taken by the parents to look for assistance in situations of urgency (Schwartz, Eidelman, Zeidan, Applebaum & Raveh, 2005).

Because of these disadvantages, economic hardship can favor a child's autonomy and an active role in the economy of human societies. In cases of severe poverty, it may even become evolutionarily advantageous for children to leave their family and look for resources without the parents' assistance (Panter-Brick, 2004). Consistent with this hypothesis, in some cases better growth and health indices have been reported for children living on the streets of cities as compared to children remaining in their family (Panter-Brick, Todd & Baker, 1996; Raffaelli, 1999). In such situations, children may find it advantageous to contribute as soon as possible to their own feeding, as has been observed in some hunter–gatherer societies (Bliege Bird, Bird & Beaton, 1995; Blurton Jones, Hawkes & Draper, 1994; Blurton Jones, Hawkes & O'Connell, 1997; Tucker & Young, 2005; Winterhalder & Smith, 2000). Working on the streets may also contribute to kin strategies through which the economic resources gained by one child are redistributed to his or her younger siblings (Bock, 2002; Cain, 1977; Kramer, 2002, 2005).

To the extent that the acquisition of sparse resources affects survival, growth and reproduction (Charlesworth, 1996), some behavioral mechanisms allowing children to compete effectively with non-kin may be present early in development (Sulloway, 2001). Thus, Charlesworth and La Freniere (1983) studied groups of four children in a situation in which they were to distribute different roles among themselves. Two children were to press a button so as to allow a third child to watch a short movie, whereas the fourth child had no particular role to play. Notable disparities in the time spent on different roles were observed among children. Time of access to the movie revealed dominance hierarchies and changed with age (Liddell & McConville, 1997) as well as friendship relations (La Freniere & Charlesworth, 1987).

In an actual foraging context, as opposed to experimental simulations or role playing, studies of economic competition among children are nonexistent. In this context, competition can take different forms. Stealing and other actions that contribute directly to another child's losing resources can be classified as *competition by interference* (Pianka, 1994). Aside from interference, the mere fact that the children must share a limited pool of resources results in *competition by exploitation*. If, for example, two children visit the same patch at different times, the first child to visit the patch (and to consume some of its resources) necessarily reduces the acquisition rate of the second child. Thus, the competitive sharing of resources has important implications with respect to optimal behavior.

In optimal foraging theory (Stephens & Krebs, 1986), competition by exploitation or interference is addressed by a model known as the *ideal free distribution* (hereafter, IFD). The IFD model (Fretwell & Lucas, 1970) makes a number of simplifying assumptions about foraging. The model assumes that all individuals have the same competitive ability, move freely between sites, are fully informed of the resource amounts and maximize their own gains. Based on these assumptions, the IFD model predicts that the foragers will distribute themselves among patches so that all sites provide the same gain per individual (Fretwell & Lucas, 1970). The IFD predictions are especially straightforward if the n_i individuals that exploit a site i share its resource amount (W_i) proportionally. In these conditions, equality of gains in sites i and j implies $W_i/n_i=W_j/n_j$, or, equivalently:

$$n_i / n_j = W_i / W_j. \quad (1)$$

According to this simple IFD model, the ratio of foragers exploiting two sites should match the ratio of resources available in these sites (Pulliam & Caraco, 1984).

Eq. (1) has been tested with human adults and in game-like situations that simulate foraging (Critchfield & Atteberry, 2003; Goldstone & Ashpole, 2004; Kraft & Baum, 2001; Kraft, Baum & Burge, 2002; Madden, Peden & Yamagushi, 2002; Sokolowski & Tonneau, 2004; Sokolowski, Tonneau & Freixa i Baqué, 1999). IFD predictions have also been assessed in natural settings (Gillis, 2003; Kennett, Anderson & Winterhalder, 2006), but none of the latter studies involved children. The aim of the present study was to evaluate how children competed for resources in a natural setting and, in particular, to assess the extent to which children's group behavior adhered to Eq. (1). In accordance with the IFD assumptions, this implied finding a situation in which the children competed for the same resource, could move from an area to another with minimal traveling costs, and in which the resource amounts in each site were clearly visible (Fretwell & Lucas, 1970).

The children who sell bottles of water on the streets of Istanbul, Turkey, face this sort of competition. Most of the children working on the streets of Istanbul come with their family from rural areas of the country (Aksit, Karanci & Gündüz-Hosgör, 2001). The majority of these children are less than 12 years old. Their tasks involve shoe-shining, garbage collection or recycling, and selling food or other products. The children often work in small groups of two to six individuals in order to play together and avoid aggressions. These children, who work "on the street," are not children "of the street" who would work and live entirely outside any home (Panter-Brick, 2002). In a 2001 ILO-IPEC survey (Aksit et al., 2001), 63% of a sample of 101 street children in Istanbul gave their daily gains (then equivalent to US$3 to US$10) to their parents, for a working schedule that ranged from 2 to 14 h/day.

2. Methods

The groups of children in our study were observed at a street intersection in the Taksim district on the 8th, 9th and