

## Not by Strength Alone

### Children's Conflict Expectations Follow the Logic of the Asymmetric War of Attrition

David Pietraszewski · Alex Shaw

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**Abstract** The Asymmetric War of Attrition (AWA) model of animal conflict in evolutionary biology (Maynard Smith and Parker in *Nature*, 246, 15–18, 1976) suggests that an organism's decision to withdraw from a conflict is the result of adaptations designed to integrate the expected value of winning, discounted by the expected costs that would be incurred by continuing to compete, via sensitivity to proximate cues of how quickly each side can impose costs on the other (Resource Holding Potential), and how much each side will gain by winning. The current studies examine whether human conflict expectations follow the formalized logic of this model. Children aged 6–8 years were presented with third-party conflict vignettes and were then asked to predict the likely winner. Cues of ownership, hunger, size, strength, and alliance strength were systematically varied across conditions. Results demonstrate that children's expectations followed the logic of the AWA model, even in complex situations featuring multiple, competing cues, such that the actual relative costs and benefits that would accrue during such a conflict were reflected in children's expectations. Control conditions show that these modifications to conflict expectations could not have resulted from more general experimental artifacts or demand characteristics. To test the selectivity of these effects to conflict, expectations of search effort were also assessed. As predicted, they yielded a different pattern of results. These studies represent one of the first experimental tests of the AWA model in humans and suggest that future research on the psychology of ownership, conflict, and value may be aided by formalized models from evolutionary biology.

**Keywords** Evolutionary psychology · Developmental psychology · Resource conflict · Resource holding potential · Value · Ownership

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D. Pietraszewski (✉) · A. Shaw  
Department of Psychology, Yale University, Box 208205, New Haven, CT 06520-8205, USA  
e-mail: davidpietraszewski@gmail.com

Whether occurring among children on a playground or geopolitical actors on the world stage, conflict is part of life, occurring wherever organisms live in an environment with finite resources and overlap in time and space (Archer 1988; Hardy and Briffa 2013; Kortüm and Heinze 2013). Because of its ubiquity and real-world importance, conflict in humans (and its companion: aggression—the initiation of conflict) has been a topic of research for decades, cataloguing an impressive array of antecedents, consequences, and correlates of aggression in adults (Bushman and Huesmann 2010), children (Danby and Theobald 2012; Shantz and Hartup 1992), and groups (Brown 2000). However, because of historical accident and disciplinary isolation, models of conflict in humans have not yet fully integrated advances in game-theoretic and evolutionary models of animal conflict (Archer 1988; Sell 2005). In the current studies, we explore whether one particular component of the psychology of conflict—decisions to continue or withdraw from an ongoing conflict—can be understood and organized around one such evolutionarily informed model: the Asymmetric War of Attrition, which applies to the withdrawal of one organism before another in a conflict over a resource (Hammerstein and Parker 1982; Maynard Smith 1974; Maynard Smith and Parker 1976; Parker and Rubenstein 1981).

### **Conflict Viewed Through the Lens of Evolutionary Biology**

The contribution of modern evolutionary biology to our understanding of conflict bears little resemblance to the old and outdated models of conflict that appear in many psychology and social science textbooks (and that still have a residual influence on modern theories of conflict and aggression, including the frustration-aggression hypothesis, among others [Berkowitz 1989; Dollard et al. 1939; see Brown 2000 and Bushman and Huesmann 2010 for reviews]). These appeal to appetitive, instinctive, drive, or hydraulic models of behavior, in which organisms succumb (or are conditioned) to aggressive outbursts and urges (e.g., Lorenz 1950, 1966; for a review of the failings of these models see Archer 1988; Brown 2000; Sell 2005).

Instead, modern evolutionary biology combines models of selection dynamics (formal and informal analyses of which behavioral strategies would outcompete alternate strategies under a wide range of contexts) and an engineering approach (exploring if and how these strategies are implemented and expressed in flesh-and-blood organisms at the level of input-process-output contingency rules designed to interact with the environment). In this modern view, it is cost/benefit relationships over evolutionary time that design and organize the constellation of contingency rules that make up a behaving organism (including humans), not an internal homunculus or impetus that pushes or pulls against more-or-less evolutionarily relevant drives, instincts, or urges. That is, evolutionarily recurrent relationships in the world cause the rule-governed structure and logic of proximate cognitive systems; rationality, intelligence, and reasoning are not rivals of, independent from, or opposed to the structure of these proximate cognitive systems, they are folk-psychological re-descriptions of them.

So what relationships and rules govern conflict-related decisions? Evolutionary analyses of conflict suggest that two factors (among others) should strongly determine decisions about engaging in, continuing, or withdrawing from a conflict: (1) the relative ability of each side of the conflict to impose costs on the other (when, for instance, one

person is physically stronger or has more allies on their side) and (2) when the conflict is over a resource, the relative value ascribed to the resource (for instance, an organism will value a certain food more if it is starving than if it is sated; Hammerstein and Parker 1982; Maynard Smith 1974; Maynard Smith and Parker 1976; Parker and Rubenstein 1981; Sell 2005).<sup>1</sup>

These factors do not emerge from an interest in minimizing global conflict, but instead because each organism is designed by natural selection to maximize its expected benefits and minimize its costs (Maynard Smith and Price 1973; Parker 1974). If each organism can estimate the expected value of a resource (getting the food, winning the fight, and so on), and also track the costs that it will incur by competing for it, then it can ensure that its expected costs do not exceed its expected benefits by withdrawing when the cue structure of the environment predicts that expected costs will reach or exceed expected benefits (Enquist and Leimar 1987; Kokko 2013; Parker 1974).<sup>2</sup>

The first factor, Resource Holding Potential (RHP), is the relative ability of each side of the conflict to impose costs on the other. The RHP of each organism impacts conflict decisions because of asymmetries of cost: The organism with a higher RHP (a higher ability to impose costs because of size, strength, allies, etc.) will inflict costs at a higher rate, causing its competitor to more quickly reach the point at which its costs exceed its expected benefit. Thus, the organism with the lower RHP will leave the conflict first or avoid the conflict altogether. This is why larger or stronger organisms are more likely to win in conflict, and why weaker or smaller organisms often avoid conflict (Enquist and Leimar 1983).

The second factor is the relative value ascribed to acquiring the resource or winning the conflict. Relative value impacts conflict decisions because of asymmetries of benefit: Assuming an equal rate of cost infliction (assuming equal RHP), the organism that will gain less from the resource will more quickly reach the point at which cost exceeds benefit, and thus will withdraw sooner. This is why the organism that values a resource more is more likely to retain that resource in a conflict, all else being equal (Enquist and Leimar 1987; Parker 1974).

<sup>1</sup> Other factors include how much each contestant values the welfare of the other (see Cosmides and Tooby 2013; Lukaszewski 2013; Sell 2005, 2011; von Rueden et al. 2008) and whether the conflict falls within the bounds of formal and informal social contracts (reflected in the folk constructs of morality, reciprocity, and fairness: Adams 1965; DeScioli and Kurzban 2009, 2013; Neary and Friedman 2013; Shaw 2013; Shaw et al. 2012; Tooby and Cosmides 1988, 2010).

<sup>2</sup> Natural selection “tunes” proximate systems to generate conflict persistence thresholds designed around recurrent situations in which net costs would not exceed net benefits on average, as dictated by the dynamics of that species’ evolutionary history. Although at first glance it may appear simple, calculating optimal cost/benefit persistence thresholds is intractable without considering both game-theoretical dynamics (what you do depends on what others do) and also population-level feedback loops (costs and benefits change depending on the frequency and distribution of resources, severity of fights, number of owners versus non-owners, and so on; reviewed in Kokko 2013). These complexities need not be calculated within individual organisms, however (and it is unlikely the full set of dynamics is visible to any one organism within a single lifespan in any case). Instead, these complexities play out in the environment over evolutionary time, and natural selection produces phenotypes that generate persistence thresholds which de facto take them into account (by virtue of how they are designed to contingently interact with the environment, including design for cue-based ontogenetic calibration).

These simple and elegant relationships can be expressed in the following rule (Sell 2005):

$$V_x > V_y \cdot \left( \frac{RHP_x}{RHP_y} \right)$$

whereby organism  $X$  should engage in and remain in a conflict when the value of the resource to  $X$  ( $V_x$ ) is greater than the value of the resource to  $Y$  ( $V_y$ ), discounted by the ability of each organism to impose costs on the other (RHP). This rule governs the Asymmetric War of Attrition, the withdrawal of one organism before another in a conflict over a resource (Hammerstein and Parker 1982; Maynard Smith 1974; Maynard Smith and Parker 1976; Parker and Rubenstein 1981).<sup>3</sup>

As shown, RHP and value are integrated. This means they are fungible—the value of one can compensate for the value of the other. For instance, an organism with a much lower RHP than its competitor may still win a contest if it assigns a much higher value to the contested resource. For example, in a conflict over food, a smaller organism may win against a larger competitor if the smaller organism is starving and the larger one is sated. Therefore, it is the integration of both value and RHP—both of which can vary freely—that determines which organism will withdraw first and lose the contest (Enquist and Leimar 1987).

This rule represents a selection pressure or design criteria, which is then implemented in flesh-and-blood organisms based on the invariances in each particular species' environment and ecology over evolutionary time (Noble et al. 2002). How and whether a particular organism assigns value, what cues it used to assess RHP, and what types of RHP are relevant are all a function of the invariances in its long-term natural environment and the particulars of the proximate mechanisms engineered by natural selection to carry out this rule in flesh-and-blood organisms (Arnott and Elwood 2008). Regardless of these particulars, however, implementation of this rule generally requires cognitive systems that assess RHP in self and other(s), identifying and assigning value to resources, assessing value in other(s), integrating these assessments, and using the resultant output to modify motivations and decisions regarding continuation and withdrawal (Archer 1988; Arnott and Elwood 2008; Sell et al. 2009b). In the current studies, these processes will be assessed in humans.

## Current Studies

The Asymmetric War of Attrition (AWA) model of conflict has been used for decades to organize and predict an extensive set of findings and observations across taxa (Arnott and Elwood 2008), including humans (Sell 2011; see below for review). What has not been done before is to test the entirety of this model in a controlled and experimental manner in humans. This was done in the current studies. In particular, we examined if participants would be sensitive to determinants of both value and RHP, use these cues

<sup>3</sup> For simplicity we collapse several different animal conflict models, including the Hawk/Dove (or Hawk/Mouse) model, and within war of attrition models the Sequential Assessment Model, the Energetic War of Attrition, and the Cumulative Assessment Model. For an overview of the differences between these models see Hardy and Briffa 2013.

to predict conflict outcomes, and integrate them in accordance with the logic of the AWA.

In the studies reported here, children aged 6–8 years were tested. This age was chosen as an ideal study population—particularly in a Western, industrialized sample—because they face extensive interpersonal resource conflicts (Danby and Theobald 2012), often without adult intervention (Ross and Conant 1992), have less experience with adult social institutions designed to curtail violence and conflict (Shantz and Hartup 1992),<sup>4</sup> and are unlikely to have been exposed to the evolutionary logic of animal conflict in their education. Because it would be unethical to expose children to first-person resource conflict, children were presented with third-party conflicts and asked to predict who would eventually prevail in the conflict.

In the studies that follow, hunger is used as a determinant of value, and size, strength, and alliance strength are used as determinants of RHP. The effects of ownership—which, selection dynamic models suggest, should be another important determinant of conflict outcomes (and which may or may not be related to value and RHP; see below)—will also be examined. Findings related to each determinant will be presented as they come up in each study. In order to test for selectivity, expectations of conflict outcomes are also compared with expectations of search effort (which, as will be explained below, are predicted to yield different results).

### Study Set 1: Size, Ownership, & Hunger

Studies 1a and 1b featured cues of size, ownership, and hunger among individuals fighting over a contested resource. Previous work suggests each of these variables should be important determinants of conflict outcome.

#### Size as a Determinant of RHP

RHP is typically determined by size, strength, and fighting ability, with size typically being used as an initial and low-cost proxy for assessing strength and fighting ability (Archer 1988; Enquist and Leimar 1983). Differences in size as a determinant of conflict withdrawal and resource acquisition have been extensively documented across a variety of non-human animals (Enquist and Leimar 1983). Accurate assessment of one's own RHP and the RHP of a competitor reduces exposure to the costs of physical conflict, leading to selection pressures for proximate mechanisms for assessing RHP (McNamara and Houston 2005; Sell et al. 2009a).

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<sup>4</sup> Decision rules involving conflict are one part of a larger class of cognitive adaptations for resolving conflicts of interest and negotiating costs and benefits (e.g., Sell 2005; Tooby and Cosmides 2010). These adaptations enable the creation of socially negotiated agreements, such as allowing disinterested third parties to enforce property disputes and the establishment of different norms and expectations for different kinds of resources within a community (see Stake 2004 for a discussion of evolutionary models as a framework for understanding the folk and legal constructs of ownership, possession, and the codification of resource allocation; also Hirshleifer 2001). Because these negotiated rules attempt to dampen the conflict (and particularly to penalize the influence of physical RHP) in modern Western societies, it was desirable to assess expectations in a younger sample. If and how these expectations differ across cohorts, cultures, and resource types are interesting empirical questions.

In humans, larger size is associated with increased dominance and aggressiveness throughout the lifespan (Pellegrini et al. 2007; Raine et al. 1997; Tremblay et al. 1998; Felson 1996). Furthermore, dominance achieved through physical conflict predicts feelings of entitlement to and acquisition of valued resources in preschool children (Ross and Conant 1992), and size, strength, and fighting ability predict feelings of entitlement and proneness to anger in adult males (Sell 2005; Sell et al. 2009a). Recent developmental work further suggests that infants as young as nine months old expect size to predict withdrawal from spatiotemporal overlap, such that a smaller agent is expected to change trajectory when two agents are moving toward one another (Thomsen et al. 2010).

### Ownership as a Determinant of Conflict Outcome

Models of selection dynamics demonstrate that strategies factoring in possession and favoring owners will be selected for (Maynard Smith and Parker 1976; Parker and Rubenstein 1981), even when other determinants of value and need are held constant between the owner and the intruder (Maynard Smith 1982; Yee 2003). Under circumstances in which the costs of conflict are considerable, natural selection can favor withdrawal based on conventions such as deference to owner, sparing both contestants the costs of conflict, even when both organisms place the same value on the resource (this is called an *uncorrelated asymmetry*, meaning that ownership need not correlate with differences in the payoffs to each organism in order to become another determinant of resource conflict outcomes; Maynard Smith and Parker 1976; see Kokko 2013 and Maynard Smith 1982 for important qualifications). Thus, ownership can be thought of as an environmentally delivered coordination device for resolving certain classes of resource conflict.

Ownership-related decisions can also have reputational consequences (Daly and Wilson 1988; Gintis 2007), particularly in a coalitional species (Sherratt and Mesterton-Gibbons 2013). Because there is selection on proximate systems to use whatever criteria will lead to the greatest net expected benefit (for instance, using ownership-based conventions when dealing with a higher RHP agent and using RHP rather than ownership when dealing with a lower RHP agent), owners need to protect their “right” to an ownership convention via occasional RHP maintenance. Owners should therefore be designed to broadcast the continuity of ownership-based conventions for their possessions to the rest of the social world, and be motivated to continue to own their possessions, all else being equal. Thus, ownership can cause asymmetries in conflict attrition even in the absence of other value or RHP asymmetries over evolutionary time.<sup>5</sup>

<sup>5</sup> Whether or not ownership in fact reflects an uncorrelated (payoff-independent) asymmetry in any species, including humans, is an open empirical question (Kokko 2013), particularly if the reputational effects of ownership have long-term fitness effects (which would cause ownership to become a value determinant). For the purposes of the current paper, none of the predictions of the AWA model depend on whether cues of ownership are considered by proximate systems because they reflect a selective history of cost-saving convention or because they are also RHP and/or value correlates. However, these different selective histories do make different design predictions about the proximate psychology of ownership, and will need to be adjudicated in future research.

Both considerations suggest that proximate psychologies should incorporate ownership as a determinant of conflict outcomes and should factor into organisms' conflict-related decision-making along with RHP and value determinants (meaning that ownership should be integrated and fungible with RHP and value; see Archer 1988: Chapter 9 and Kokko 2013 for review and discussion). In fact, an owner/intruder asymmetry (that owners tend to prevail over non-owners), is well-documented across the animal kingdom, both in observational (Arnott and Elwood 2008) and in experimental studies (e.g., Williams et al. 2006). Ownership has also been shown to be fungible with RHP (Hammerstein 1981), as predicted by the AWA model. Evidence of ownership impacting AWA-relevant decisions can also be found in studies of humans. For instance, participants playing a simulated foraging video game featuring resource patches of varying quality were more willing to fight for and retain a contested resource when they were the possessor (DeScioli and Wilson 2011). Observational studies of preschoolers likewise show that children are more likely to resist a peer when they have possession of a contested object than when they do not (Ross 2012; Weigel 1984; see Gintis 2007; Ross and Conant 1992; Stake 2004 for reviews).

### Hunger as a Determinant of Value

Models of selection dynamics suggest that hungrier organisms will gain more value from food and thus will fight longer for it whereas the more sated organism will withdraw sooner, following a principle of diminishing marginal returns (Bishop et al. 1978; see McNamara and Houston 1989 for boundary conditions). Thus, hunger should also be a determinant of value. Indeed, in a variety of non-human animals, hunger has been shown to up-regulate the value of a food resource, thereby increasing success in conflict. Moreover, this effect is specific to food; hungry organisms are not simply more motivated to attain any and all resources (Arnott and Elwood 2008).

### Predictions

- Owners should be expected to win a conflict over non-owners.
- If this expectation is due to a more general rule about the owner, such as “the owner of one thing is more likely to become the owner of another,” then owners will also be expected to win in a contest over another, previously unowned resource. If, instead, as hypothesized, ownership is factoring into AWA assessments, then the ownership effect will be resource-specific, and owners will not be expected to win in contests over resources more generally.
- Hungry individuals should be expected to win a conflict over less hungry individuals.
- If, as hypothesized, hunger is factoring into AWA value assessments, then this expectation should only be applied to conflicts over food resources (or resources that readily afford access to food). This expectation should not occur for resources in general. If, in contrast, hunger is factoring into a more general, person-based assessment, such as “hungry people are more motivated,” then hungry individuals will be expected to win even in contests over non-food resources.
- Larger individuals should be expected to win a conflict with smaller individuals. If size is treated as an intrinsically relevant cue for predicting conflict outcomes, it



should not be necessary to make the existence of size differences (or any lack thereof) explicit in order for participants to robustly cue in on and incorporate size into their judgments.

- Cues of value and RHP within a single conflict should be integrated according to the logic of the AWA, such that when pitted against each other, cues of value and RHP should attenuate the effect of the other. For example, cues of hunger (value) in Agent A should mitigate some of the effects of size (RHP) in Agent B.

## Methods for Study 1a

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 4 months;  $SD=8.5$  months, 18 females) were recruited from a database of families who had agreed to participate in developmental research or were tested in local schools or a local museum. Before each session the child's parent signed a written informed consent form describing the study. After this was signed children also gave verbal assent to participate before being asked any questions. All studies reported herein were approved by the Yale University IRB.

*Materials and Procedure* Children were seated at a table and were first asked some questions unrelated to the current experiment. Cardboard doll character stimuli (see [ESM](#)) were next placed in front of each child as the following instructions were given: "I am going to tell you some stories using these dolls. When the story is done, I just want you to point at one of the dolls to answer my question. Is that ok?" All children answered yes to this question. The following vignettes, counterbalanced for order (either 1,2,3 or 3,2,1), were then presented:

1. This is Eric and he's holding his toy. This is Dave; he likes Eric's toy. Eric accidentally drops his toy and then the two fight over the toy. Who do you think will win the fight over the toy? [Ownership]
2. This is Brandon and he's really full from lunch. This is Mark; he is really hungry because he did not eat lunch. Both of them reach for a candy bar and they fight over the candy bar. Who do you think will win the fight over the candy bar? [Hunger]
3. This is Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. One day they get into a fight. Who do you think will win the fight? [Size]

Whenever a character was mentioned by name, the experimenter pointed to the corresponding cardboard cutout. When size differences were present, characters differed in scale by 25% (see [ESM](#)). For each trial, children responded either by saying the character's name or by pointing at one of the two dolls (during questioning the experimenter did not gesture or point to either doll).

## Methods for Study 1b

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 3.5 months;  $SD=10$  months, 19 females) were recruited in the same manner as Study 1a.



*Materials and Procedure* The same procedure as Study 1a was used. The same three vignettes of Study 1a were also presented, plus one additional vignette:

4. This is Brian and he's holding his sandwich and is really hungry. This is Paul [larger doll], he is full from lunch but really likes Brian's sandwich. Brian accidentally drops his sandwich and then they fight over the sandwich. Who do you think will win the fight over the sandwich? [Size vs. Hunger & Ownership]

This appeared between the [Hunger] and [Size] vignettes. As before, order was counterbalanced (1,2,3,4, or 4,3,2,1).

#### Methods for Study 1c

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 6.5 months;  $SD=11$  months, 20 females) were recruited in the same manner.

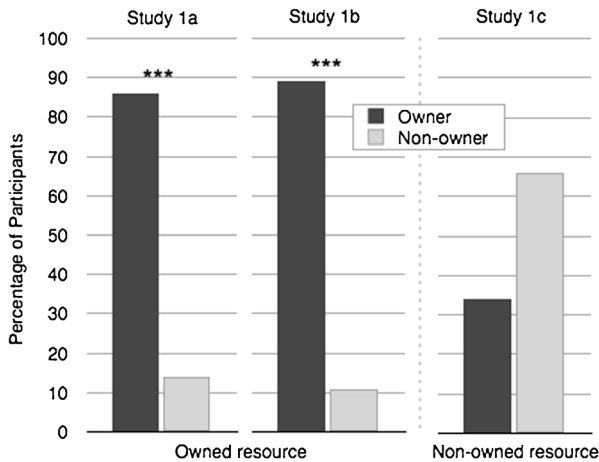
*Materials and Procedure* The same procedure as Study 1a was used. A new set of vignettes was presented, counter-balanced for order (either 1,2,3,4 or 4,3,2,1):

1. This is Eric and he's holding his toy. This is Dave; he likes Eric's toy. Eric puts his toy down. Eric and Dave see a candy bar that they want to eat. Both reach for it and fight over the candy bar. Who do you think will win the fight over the candy bar? [Ownership Control]
2. This is Brandon and he's really full from lunch. This is Mark; he is really hungry because he did not eat lunch. Both of them reach for a toy to play with and they fight over the toy. Who do you think will win the fight over the toy? [Hunger Control]
3. This is Brian and he's holding his toy car. This is Paul [larger doll]; he likes Brian's toy car. Brian accidentally drops his toy car and the two fight over the toy car. Who do you think will win the fight over the toy car? [Size vs. Ownership]
4. This is Steve [larger doll] and he's really full from lunch. This is Ned, he is really hungry because he did not eat lunch. Both of them reach for a sandwich and they get into a fight over the sandwich. Who do you think will win the fight over the sandwich? [Size vs. Hunger]

#### Results and Discussion, Study Set 1 (Studies 1a, 1b, & 1c)

The number of participants nominating each character was tabulated for each vignette and then analyzed.

*Is ownership expected to determine conflict outcomes?* Yes. Across two independent replications, owners were chosen as the expected winner over non-owners (Study 1a: owner  $n=30$  [86%], non-owner  $n=5$  [14%], binomial  $p<0.001$ ; Study 1b: owner  $n=31$  [89%], non-owner  $n=4$  [11%], binomial  $p<0.001$ ). However—and as predicted by the AWA model—this only occurred for contests involving the owned resource (Fig. 1).



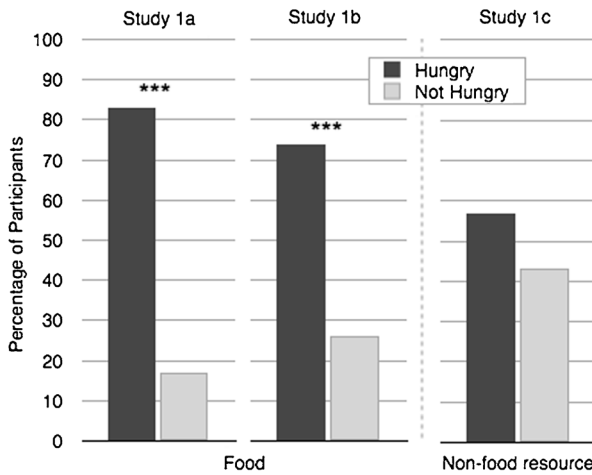
**Fig. 1** Effect of ownership on expected conflict outcome for the owned resource (left panel), and a non-owned resource (right panel). Y-axis indicates percentage of participants choosing the owner or non-owner. Two sets of bars in left panel are between-subjects replications. Significant effects are indicated with asterisks. \*\*\*  $p < 0.001$

When presented with a previously unowned resource, the expectation that an owner would win against a non-owner completely disappeared (Study 1c: owner  $n = 12$  [34%], non-owner  $n = 23$  [66%], binomial  $p = 0.09$ ). This expectation for the previously unowned resource was significantly different than the expectations for the owned resource (Fisher exact  $p < 0.001$  in both cases).

*Is hunger expected to determine conflict outcomes?* Yes. Across two independent replications, hungry individuals were chosen as the expected winner over non-hungry individuals (Study 1a: hungry  $n = 29$  [83%], non-hungry  $n = 6$  [17%], binomial  $p = 0.001$ ; Study 1b: hungry  $n = 26$  [74%], non-hungry  $n = 9$  [26%], binomial  $p = 0.006$ ). However—and as predicted by the AWA model—this only occurred for contests involving food. When the conflict involved a non-food-related resource, the expectation that the hungry individual would win completely disappeared (Study 1c: hungry  $n = 20$  [57%], non-hungry  $n = 15$  [43%], binomial  $p = 0.50$ ; Fig. 2). This expectation for the non-food resource was significantly different than the expectations for the food resource in one of the two comparisons (1a vs. 1c: Fisher exact  $p = 0.036$ ; 1b vs. 1c: Fisher exact  $p = 0.20$ ), and in both cases the difference occurred in the predicted direction. (Since neither food condition—1a and 1b—was significantly different from the other [Fisher exact  $p = 0.56$ ], and given that both food conditions are significantly different from the non-food condition when combined [Fisher exact  $p = 0.03$ ], the one non-significant comparison likely reflects noise.)

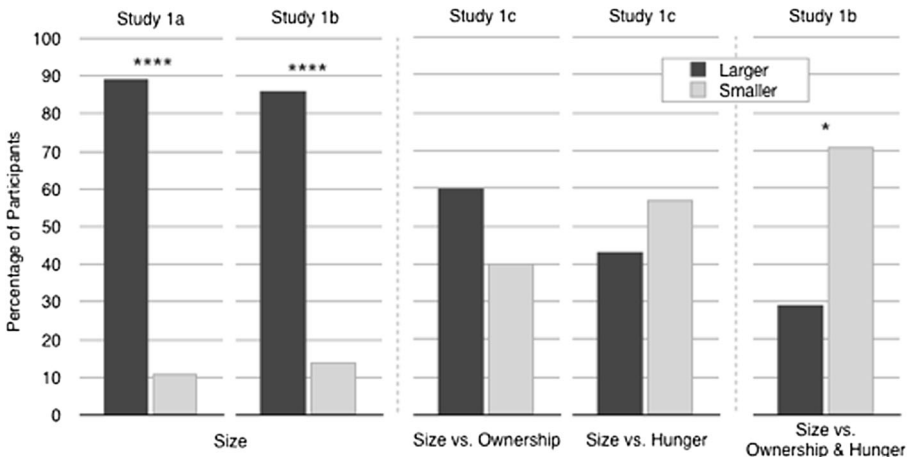
*Is size expected to determine conflict outcomes?* Yes. Across two independent replications, larger individuals were chosen as the expected winner over smaller individuals (Study 1a: larger  $n = 31$  [89%], smaller  $n = 4$  [11%], binomial  $p < 0.0001$ ; Study 1b: larger  $n = 30$  [86%], smaller  $n = 5$  [14%], binomial  $p < 0.0001$ ; see left panel of Fig. 3). This expectation occurred moreover without any explicit mention of the size difference between stimuli.

*Are ownership, size, and hunger integrated according to the logic of the AWA?* To answer this question we first examined the two vignettes that pitted one cue against



**Fig. 2** Effect of hunger on expected conflict outcome for a food resource (left panel), and a non-food resource (right panel). Y-axis indicates percentage of participants choosing the hungry or the not hungry individual. Two sets of bars in left panel are between-subjects replications. \*\*\*  $p \leq 0.006$

another: size vs. ownership and size vs. hunger. As predicted by the AWA, each determinant mitigated the effect of the other, such that no significant difference in either vignette was found. (Size vs. ownership: larger  $n=21$  [60%], smaller  $n=14$  [40%], binomial  $p=0.31$ . Size vs. hunger: larger  $n=15$  [43%], smaller  $n=20$  [57%], binomial  $p=0.50$ ; see central panel of Fig. 3). Ownership and hunger undermined the effect of size in conflict success, and vice versa. A third vignette pitted both ownership and hunger against size. These two cues overwhelmed the one RHP cue, such that a hungry owner was expected to win against a larger, sated, non-owner (small hungry owner  $n=25$  [71%], large sated non-owner  $n=10$  [29%], binomial  $p=0.02$ ; see right



**Fig. 3** Effect of physical size on expected conflict outcome. Y-axis indicates percentage of participants choosing the large or the small individual. Two sets of bars in left panel are between-subjects replications. Central panel depicts size pitted against ownership (a small owner against a large non-owner) and size pitted against hunger (a small hungry individual against a large sated individual). Right panel depicts the combined effects of pitting both hunger and ownership against size (a small hungry owner against a large sated non-owner). \*  $p < 0.05$ , \*\*\*\*  $p < 0.0001$

panel of Fig. 3). This reflected a different expectation than when the size cue was the only cue presented (within-subject McNemar test  $\chi^2_{1,35}=16.4, p<0.001$ ).

### Summary

Ownership, hunger, and size each guided expectations of who would win in a conflict. The effects of ownership and hunger were resource-specific. Owners and hungry individuals were not expected to win contests over other resources, ruling out more general expectations about owners and hungry individuals. When presented simultaneously, each cue was integrated according to the logic of the AWA.

## Study Set 2: Alliance and Foraging

Study Set 2 incorporated an additional cue: alliance strength, which, based on previous research, should also be a determinant of conflict outcome. Additionally, and as a way to examine the specificity of these expectations to outcomes involving direct conflict, a new question about non-conflict resource acquisition differences was asked: Who would spend more time looking for a resource? This search time expectation reflects calculations of foraging effort, which, based on previous work, should be sensitive to cues of value, but not to RHP.

### Alliance Strength as a Determinant of RHP

Numerical imbalances—the number of agents taking one side or another in a conflict—are strong determinants of the ability to impose costs and thus conflict outcomes, in both human and other animals (Byrne and Whiten 1988; Harcourt and de Waal 1992; Wrangham 1999). Proximity and number of allies has been shown to determine approach/withdrawal behaviors during pre-conflict assessments (McComb et al. 1994; Wilson and Wrangham 2003), acquisition of contested resources (Kawai 1958a, b), and dominance ranking in a number of non-human animals (Chapais 1992; Silk 2007). In humans, self-regarding behaviors in experimental economic decisions are affected by psychophysical cues of alliance strength, particularly in men (Charness et al. 2006; Ermer 2007). Outside of laboratory contexts, relative numerical advantage has been shown to determine the success of raiding in tribal societies (Chagnon 1988; Keeley 1996) and in conflicts of interest among preschoolers (Ross and Conant 1992).

### Rules Governing Foraging Behavior

The rules governing foraging—searching for and extracting benefits from the environment—follow the same underlying logic as those governing conflict: minimizing cost, maximizing benefit, and ensuring that costs do not generally exceed benefits (Charnov 1976; MacArthur and Pianka 1966). Generalized optimal foraging rules state that expected benefits should exceed expected search and handling costs, such that search effort should be terminated when the expected costs of continued search or additional processing and extraction of the resource outweigh the likely benefit of the resource (Stephens and Krebs 1986). Although typically applied to food resources (MacArthur

and Pianka 1966; Pyke 1984), these rules can apply to other recurrent fitness benefits in an organism's environment (e.g., mates, allies, information; Mangel and Clark 1986; Stephens and Krebs 1986; Wilke et al. 2009).

Importantly, the determinants of search differ from those of conflict, as foraging outcomes are strongly determined by resource value but not RHP (Pyke 1984, and see below for a discussion of ownership). RHP does not directly factor into search costs because in search the mechanism of attainment does not involve direct physical cost imposition from others, unlike in conflict. Instead, costs come from the time, energy, and opportunity costs of searching (Stephens and Krebs 1986). For the purposes of the current studies, foraging therefore provides a theoretically informed way to test for the generality of the conflict findings. If participants' expectations are being driven by more general rules or expectations about owners, hungry people, and larger people gaining access to resources in general—regardless of the mechanism of resource attainment—then those same expectations will occur in a foraging context, such that foraging expectations will be same as conflict expectations. If RHP determinants do not affect foraging expectations, as predicted, then this will show that participants are not simply applying these more general rules.

### Predictions

- Individuals with more allies should be expected to win a conflict against individuals with fewer or no allies.
- If alliance strength factors into RHP assessments, then pitting alliance strength against size should have an attenuating effect on each.
- Determinants of RHP should not affect foraging expectations. For example, larger individuals should not be expected to search longer for a resource than smaller individuals.
- Determinants of value should be expected to affect foraging outcomes. For example, hungry individuals should be expected to search longer for a food resource than a less hungry individual. (Technically this is true when search costs do not exceed the value of the food. Otherwise, hungry individuals would use up more energy searching than they would gain. Given the nature of the vignettes and the Westernized foraging experiences of our subject population, we expected that participants would indeed assume that food value would outweigh any search costs.)
- Ownership may or may not affect foraging outcomes, such that owners should be expected to search longer for a resource than a non-owner. This is because foraging decisions are much more dependent on the replacement cost of the resource than in the case of direct conflict. (This is because attrition during direct conflict entails additional social costs above and beyond the replacement costs of the resource, such as the reputational cost of others knowing that you are the kind of person who can have their possessions taken; Daly and Wilson 1988; Gintis 2007). This means that if participants expect that the resource has a low replacement cost—because it was only temporarily owned, could be easily acquired elsewhere, and so on—they will be less likely to expect owners to search longer. Therefore, the prediction that ownership should affect foraging expectations is less clear-cut than the predictions for hunger (which should affect foraging) and for size (which should not affect foraging).

- Unlike in the AWA, cues of ownership, value, and RHP should not be integrated for foraging expectations because cues of RHP should not factor into foraging expectations in the first place. Thus, RHP cues should not attenuate the effect of value (or of ownership, if such an effect exists). For example, when size is pitted against hunger, hunger should still determine who is expected to search longer.

### Methods for Study 2a

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 5 months;  $SD=10.5$  months, 17 females) were recruited in the same manner as Study Set 1.

*Materials and Procedure* The same procedure as in Study Set 1 was used. A new set of vignettes were presented, counterbalanced for order (either 1,2,3,4 or 4,3,2,1):

1. This is Brian and he's holding his toy car. This is Paul; he likes Brian's toy car. Brian is walking down the street and accidentally drops his toy car and it gets lost. Who do you think will spend more time looking for the toy car? [Ownership Foraging]
2. This is Brandon and he's really full from lunch. This is Mark; he is really hungry because he did not eat lunch. They are in their classroom and realize that there is a candy bar in the classroom under one of the desks. Who do you think will spend more time looking for the candy bar? [Hunger Foraging]
3. James and Mike are friends. Bob is not their friend. One day Bob gets into a fight over a sandwich with James and Mike. Who do you think will win the fight over the sandwich? [Alliance Strength]
4. This Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. One day they get into a fight. Who do you think will win the fight? [Size]

### Methods for Study 2b

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 3 months;  $SD=10$  months, 15 females) were recruited in the same manner.

*Materials and Procedure* The same procedure as in Study Set 1 was used. A new set of vignettes were presented, counterbalanced for order (either 1,2,3,4 or 4,3,2,1):

1. This is Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. One day Steven and Ned are looking for a toy to play with. Who do you think will spend more time looking for the toy? [Size Foraging]
2. This is Brian and he's holding his toy car. This is Paul [larger doll]; he likes Brian's toy car. Brian is walking down the street and accidentally drops his toy car and it gets lost. Who do you think will spend more time looking for the toy car? [Size vs. Ownership Foraging]
3. This is Brandon [larger doll] and he's really full from lunch. This is Mark; he is really hungry because he did not eat lunch. They are in their classroom and realize

- that there is a candy bar in the classroom under one of the desks. Who do you think will spend more time looking for the candy bar? [Size vs. Hunger Foraging]
4. James and Mike are friends. Bob [larger doll] is not their friend. One day Bob gets into a fight over a sandwich with James and Mike. Who do you think will win the fight over the sandwich? [Size vs. Alliance Strength]

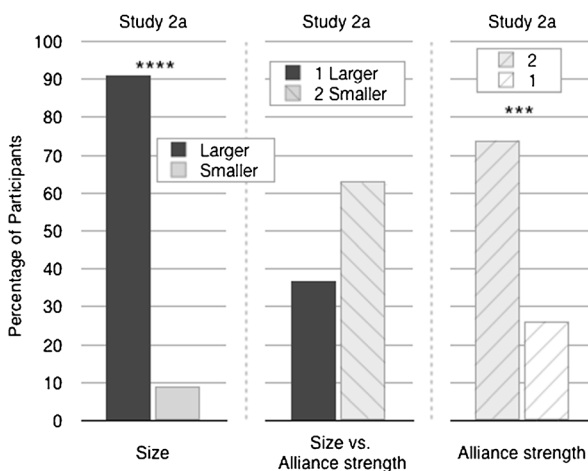
## Results and Discussion, Study Set 2 (Studies 2a & 2b)

*Is alliance strength expected to determine conflict outcomes?* Yes. In a conflict involving one versus two individuals, two were expected to win against one (two  $n=26$  [74%], one  $n=9$  [26%], binomial  $p=0.006$ ; see right panel of Fig. 4).

*Is size expected to determine conflict outcomes?* Yes. In a third independent replication, larger individuals were chosen as the expected winner over smaller individuals (larger  $n=32$  [91%], smaller  $n=3$  [9%], binomial  $p<0.0001$ ), even without explicit mention of the size difference between stimuli (see left panel of Fig. 4).

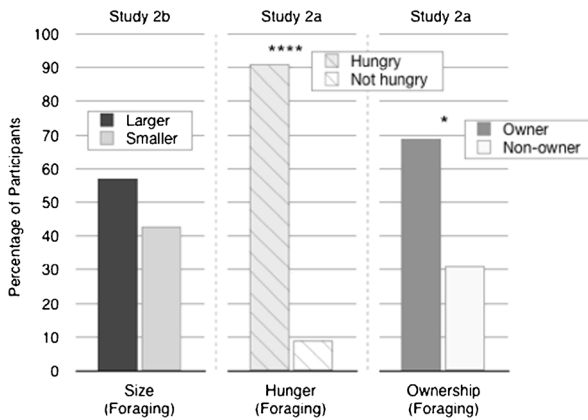
*Do alliance strength and size attenuate one another?* Yes. In a resource conflict where alliance strength and size were pitted against one another, such that two smaller individuals were pitted against one larger individual, no systematic expectation of who would win occurred (two small  $n=22$  [63%], one large  $n=13$  [37%], binomial  $p=0.17$ ; see central panel of Fig. 4). This expectation was significantly different from the conflict expectations for one large versus one small individual (Fisher exact  $p<0.0001$ ).

*Is size expected to determine foraging outcomes?* No. As predicted, larger individuals were not expected to search longer for a resource than smaller individuals (larger  $n=20$  [57%], smaller  $n=15$  [43%], binomial  $p=0.50$ ; see left panel of Fig. 5). This



**Fig. 4** Effect of physical size and alliance strength on expected conflict outcome. Left panel depicts the effect of size (a third between-subjects replication). Right panel depicts the effect of alliance strength (two individuals against one). Central panel depicts size pitted against alliance strength (one large individual against two small). \*\*\*  $p\leq 0.006$ , \*\*\*\*  $p<0.0001$





**Fig. 5** Effect of physical size, hunger, and ownership on expected foraging outcomes (who would look longer for the resource and thus acquire it). \*  $p < 0.05$ , \*\*\*\*  $p < 0.0001$

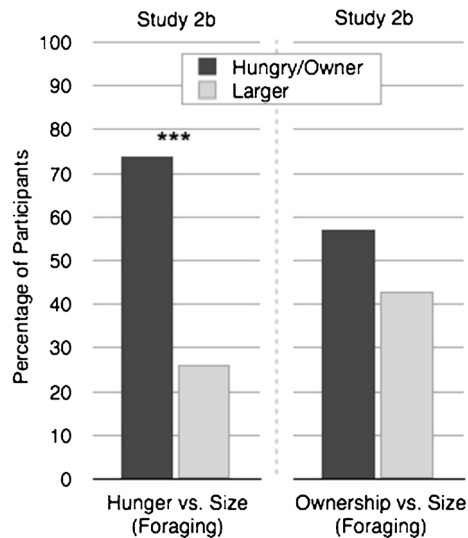
foraging expectation was significantly different from size conflict expectations (size conflict vs. size foraging: Fisher exact  $p = 0.002$ ).

*Is hunger expected to determine foraging outcomes?* Yes. Hungry individuals were expected to look longer for food than non-hungry individuals (hungry  $n = 32$  [91%], non-hungry  $n = 3$  [9%],  $p < 0.000$ ), matching the results found for conflict outcomes (see central panel of Fig. 5). Hunger strongly affected both conflict and foraging expectations.

*Is ownership expected to determine foraging outcomes?* Yes. Owners were expected to search longer than non-owners (owner  $n = 24$  [69%], non-owner  $n = 11$  [31%], binomial  $p = 0.041$ ; see right panel of Fig. 5). However, this effect was significantly weaker than the effect of hunger (Fisher exact  $p = 0.03$ ).

*Are ownership, size, and hunger integrated for foraging expectations?* For hunger, no. As predicted, when size was pitted against hunger in a foraging context, size did not mitigate the effect of hunger. Participants expected that hungry individuals would search longer than non-hungry individuals (small hungry  $n = 26$ , 74%; large sated  $n = 9$ , 26%;  $p = 0.006$ ; see left panel of Fig. 6). Moreover, the effect of hunger on foraging expectations did not differ when presented on its own than when pitted against size (Fisher  $p = 0.11$ ). Thus in a foraging context RHP did not mitigate value—a different pattern than what was found for resource conflict. For ownership, however, and contrary to predictions, size did mitigate the effects of ownership for foraging, such that owners were not expected to search longer than non-owners (owner  $n = 20$ , 57%; non-owner  $n = 15$ , 43%;  $p = 0.500$ ; see right panel of Fig. 6). However, a comparison between ownership pitted against size and ownership on its own revealed no significant difference (Fisher  $p = 0.458$ ), meaning that size did not significantly reduce the effect of ownership on foraging. There are two possible reasons for these contradictory ownership results. One is that size does mitigate the effect of ownership, contrary to predictions. The other is that size does not mitigate ownership, but instead the effect of ownership on foraging is so weak—it was by the far the weakest positive result of all factors; a 69/31 split—that the non-significant effect of ownership in the size vs. ownership

**Fig. 6** Effect of pitting hunger and ownership against size on expected foraging outcomes. Left panel depicts size pitted against hunger (a small hungry individual and a large full individual). Right panel depicts size pitted against ownership (a small owner and a large non-owner). \*\*\*  $p \leq 0.006$



vignette simply reflected statistical noise around the actual (low) mean for ownership. The next set of studies addressed these two possibilities.

### Summary

Alliance strength guided expectations of who would win in a conflict. Pitting alliance strength against size also had an attenuating effect on each, suggesting that alliance strength factors into RHP assessments. As predicted, the RHP cue of size had no effect on foraging expectations, whereas the value cue of hunger did guide expectations, with hunger individuals being expected to search longer. This effect of hunger was furthermore unaffected when pitted against size cues, as predicted. Unlike the AWA rule governing resource conflict, cues of RHP and value were not integrated in foraging expectations. Results for ownership were less clear. There was a smaller but still significant effect of ownership on foraging expectations. However, when pitted against size, this ownership effect went away, suggesting either that size mitigates the effects of ownership, but not hunger, in foraging contexts, or that the effect of ownership for foraging is relatively weak and inconsistent (at least for these stimuli).

### Study Set 3: Ownership and Hunger in Foraging, and Size versus Strength and Skills

Study Set 3 replicated and extended the tests of ownership and hunger on foraging expectations, in order to verify the robust and selective effect of hunger on foraging and establish whether ownership has any effect on foraging expectations, given the inconsistent results found in Study Set 2. The mechanism of the size effect on resource conflicts was also examined in more detail. Size was pitted against a more precise RHP cue (strength), and also against RHP-irrelevant cues (skill in math and dance).

## Size versus Strength as a Determinant of RHP

Although size is used as an initial and low-cost proxy for RHP, strength and fighting ability are typically better and more precise indices of RHP because they track individual differences in the ability to impose costs with more fidelity than overall body size (Archer 1988; Enquist and Leimar 1983; Sell et al. 2009a). Recent cross-cultural empirical work demonstrates humans are able to accurately assess men's strength from the face, body, and voice, and do so largely independent of overall body size (Sell et al. 2009a, 2010). Evidence also suggests that people can assess their own relative standing on RHP-relevant dimensions (including strength in men; Sell et al. 2009b). In accordance with the logic of the AWA, stronger men (with strength measured either directly or indirectly) feel more entitled, anger more easily, condone the use of force, both in interpersonal and international conflict, and report more success in conflict (Sell et al. 2009a).

### Predictions

- The effect of hunger on foraging should replicate. Hungry individuals should be expected to search longer for a food resource than a less hungry individual. Moreover—and as was true for resource conflict—the effect of hunger on foraging should be resource-specific, such that hungry individuals should not be expected to search longer for non-food items.
- If ownership cues affect foraging expectations, then owners should be expected to search longer for their object than non-owners. This effect should be object-specific, such that owners should not be expected to search longer for other objects in general. If, in contrast, ownership cues do not affect foraging expectations, then owners should not be expected to search longer for their object than non-owners, and there will be no difference between expectations of owners searching for their objects and owners searching for other objects in general.
- Because strength is a better RHP determinant than size, cues of strength should overwhelm any effects of size when strength and size are pitted against one another in a resource conflict.
- Non-RHP-relevant traits, such as skills in math or dance, should not impact expectations of conflict outcomes. Therefore, neither should attenuate the effect of size when pitted against size in a resource conflict.

### Methods for Study 3a

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 2.5 months;  $SD=11$  months, 17 females) were recruited in the same manner as Study Sets 1 and 2.

*Materials and Procedure* The same procedure as Study Sets 1 and 2 was used. A new set of vignettes was presented, counterbalanced for order (either 1,2,3 or 3,2,1):

1. This is Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. Look, Steve is trying to solve this math problem, but he can't. But look,

- Ned can. One day Steve and Ned get into a fight. Who do you think will win the fist fight? [Size vs. Math]
2. This is Brandon and he's really full from lunch. This is Mark; he is really hungry because he did not eat lunch. They are in their classroom and realize that there is a toy in the classroom under one of the desks. Who do you think will spend more time looking for the toy? [Hunger Foraging Control]
  3. This is Brian and he's holding his toy car. This is Paul; he likes Brian's toy car. Brian puts his toy down. They are in their classroom and realize there is a candy bar under one of the desks. Who do you think will spend more time looking for the candy bar? [Ownership Foraging Control]

### Methods for Study 3b

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 6 months;  $SD=8$  months, 16 females) were recruited in the same manner.

*Materials and Procedure* The same procedure as in Study Sets 1 and 2 was used. The Hunger Foraging and Ownership Foraging vignettes of the preceding study set were presented, plus one additional vignette (counterbalanced for order; 2,3,4 or 4,3,2):

4. This Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. Look, Steve is trying to lift this weight, but he can't. But look, Ned can lift it. One day they get into a fight. Who do you think will win the fist fight? [Size vs. Strength]

### Methods for Study 3c

*Participants* Thirty-five 6- to 8-year-olds ( $M=7$  years, 3.5 months;  $SD=9$  months, 16 females) were recruited in the same manner.

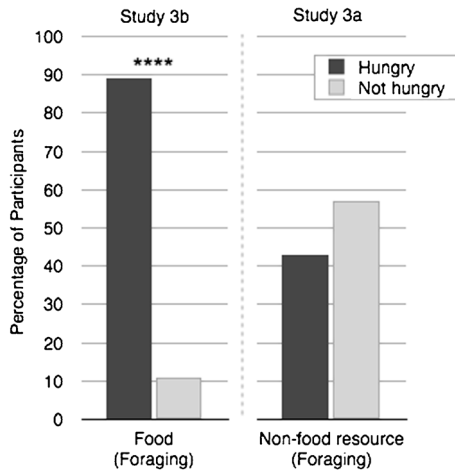
*Materials and Procedure* The same procedure as in Study Sets 1 and 2 was used. Only one vignette was presented:

1. This is Steve [larger doll]; his favorite color is red. This is Ned; his favorite color is orange. Look, Steve is trying to dance, but he can't. But look, Ned can dance. One day Steve and Ned get into a fight. Who do you think will win the fist fight? [Size vs. Dance]

### Results and Discussion, Study Set 3 (Studies 3a, 3b, 3c)

*Is hunger expected to determine foraging outcomes?* Yes. In a second independent replication, hungry individuals were expected to look longer for food than non-hungry individuals (hungry  $n=31$  [89%], non-hungry  $n=4$  [11%],  $p<0.0001$ ; see left panel of Fig. 7). This effect was specific to food. For a non-food-related resource, expectations

**Fig. 7** Effect of hunger on expected foraging outcomes. Left panel depicts the effect of hunger on search for a food resource. Right panel depicts the effect for a non-food resource. \*\*\*\*  $p < 0.0001$

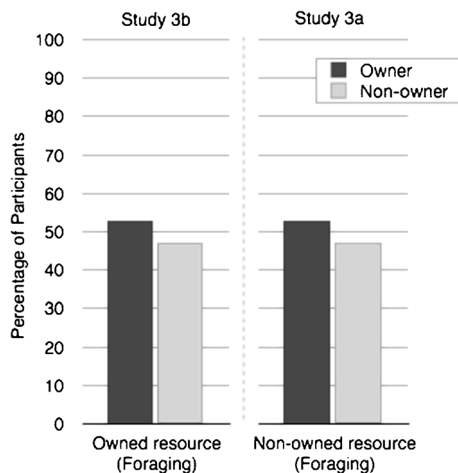


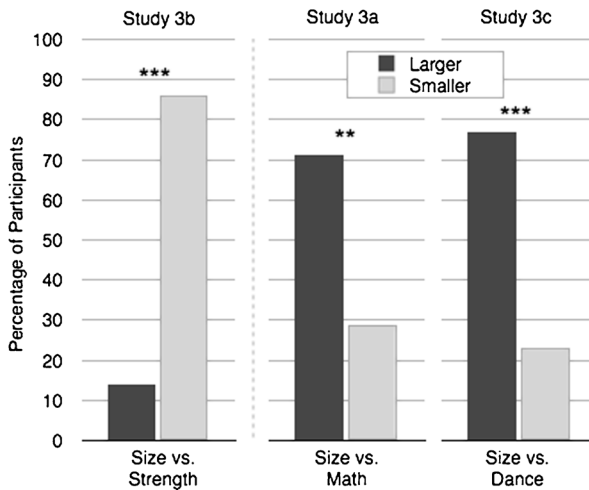
of hungry and non-hungry individuals did not differ (hungry  $n = 15$  [43%], non-hungry  $n = 20$  [57%], binomial  $p = 0.50$ ; see right panel of Fig. 7).

*Is ownership expected to determine foraging outcomes?* No. Owners were not expected to search longer than non-owners for their object (owner  $n = 18$  [53%], non-owner  $n = 17$  [47%], binomial  $p = 1$ ; see left panel of Fig. 8). This was no different from expectations of owners searching for other objects in general (Fisher exact  $p = 1$ ; owner  $n = 18$  [53%], non-owner  $n = 17$  [47%], binomial  $p = 1$ ; see right panel of Fig. 8). Ownership did not affect foraging expectations.

*Is strength expected to overwhelm size in conflict outcomes?* Yes. When cues of strength and size were pitted against one another in the context of a conflict, cues of strength overwhelmed cues of size. Small, strong individuals were chosen as the expected winner over larger, weaker individuals (strong small  $n = 30$  [86%], large weak  $n = 5$  [14%],  $p < 0.001$ ; see left panel of Fig. 9).

**Fig. 8** Effect of ownership on expected foraging outcomes. Left panel depicts the effect of ownership on search for an owned resource. Right panel depicts effects for a non-owned resource





**Fig. 9** Effect of size pitted against strength (left panel) and non-RHP relevant traits (central and right panels) on expected conflict outcome. \*\*\*  $p \leq 0.002$ , \*\*  $p = 0.017$

*Are non-RHP-relevant traits expected to overwhelm size in conflict outcomes?* No. Neither math nor dance capabilities had any mitigating effect on size. The larger individual was chosen as the expected winner in each case (size vs. math: larger  $n = 25$  [71%], smaller  $n = 10$  [29%], binomial  $p = 0.017$ ; size vs. dance: larger  $n = 27$  [77%], smaller  $n = 8$  [23%],  $p = 0.002$ ; see central and right panels of Fig. 9).

## Summary

Hunger guided foraging expectations. This effect was resource-specific. When a non-food resource was searched for, no systematic expectation occurred. In contrast, ownership had no effect on foraging expectations. This suggests that the ownership foraging results of Study Set 2 resulted from a weak or nonexistent effect of ownership on foraging, rather than size mitigating the effects of ownership in a foraging context. For expectations of who would win in a conflict, the RHP-relevant cue of strength (lifting ability) overwhelmed the effect of size, whereas non-RHP-relevant cues (math and dance ability) had no effect.

## Discussion

In all 17 conflict vignettes, participants' responses matched the predictions made by the model. Participants attended to ownership, RHP, and value determinants, and integrated them according to the logic of the AWA (Table 1).

Across three independent replications, and even in the absence of explicit mention, size was expected to determine conflict outcome. Participants were not, however, simply always choosing the larger individual: (a) when asked about search effort, size had no effect; (b) when pitted against a more RHP-diagnostic cue (strength), the smaller individual was chosen; (c) when pitted against one value determinant (hunger), or

**Table 1** Response percentages across all conditions and for all comparisons

	Conflict	Foraging
Hunger	83*; 74*	91*; 89*
Non-Food Resource	57	43
Ownership	86*; 89*	69*; 53
Unowned Resource	34	53
Size	89*; 86*; 91*	57
Size vs. Hunger	43	26*
Size vs. Ownership	60	43
Size vs. Hunger & Ownership	29*	–
Size vs. Strength	14*	–
Size vs. Math	71*	–
Size vs. Dance	77*	–
Alliance Strength	74*	–
Size vs. Alliance Strength	37	–

Each number indicates the percentage of participants choosing the individual with the characteristic on the left (i.e., Hunger = percentage of participants choosing the hungry individual, Ownership = percentage choosing owner, Size = percentage choosing larger, Alliance Strength = percentage choosing larger alliance). When size is pitted against other characteristics (e.g., Size vs. Hunger, Size vs. Strength), the number indicates the percentage of participants choosing the larger individual at the expense of the other characteristic(s). Multiple numbers within the same cell indicate between-subjects replications. \*=binomial  $p < 0.05$ ; otherwise non-significant. [–] indicates comparisons not conducted

against ownership, there were no systematic size expectations; and (d) when pitted against two conflict determinants simultaneously (ownership and hunger), the smaller individual was chosen. The attenuation of size was selective and specific: when non-RHP-relevant abilities were pitted against size (math and dance ability), no attenuation occurred. Likewise, when value determinants were pitted against size in the context of search effort, no attenuation occurred. Thus, pitting size against competing dimensions does not inevitably lead to an attenuation effect, and the effect of value on size varies according to whether resource acquisition is occurring through conflict or through search. In sum, participants only used size cues when relevant, and they abandoned size only when it was appropriate to do so.

Alliance strength was also expected to determine conflict outcome. When presented on its own, two individuals were expected to win in a conflict against a single individual. When pitted against size, featuring two small individuals against one larger, size and alliance strength attenuated each other, leading to no systematic expectation. These results show that alliance strength, like size, is treated as an RHP determinant.

Non-RHP determinants in the present studies included ownership and hunger. Each factored into conflict outcome expectations as predicted by the AWA. In two independent replications, ownership was expected to determine conflict outcome. This effect was selective, however; it was restricted to the owned object. Owners were not expected to win access to any and all objects, ruling out the counterhypothesis that these expectations are driven by a broader expectation that the owner of one resource



would be more likely to win resources in general. Hunger was also expected to determine conflict outcomes, and this effect was also selective. Hungry individuals were only expected to win in contests over food-related resources, not other resources. This rules out another broader expectation: that hungry individuals are more motivated to gain access to resources in general. As with the results for size reported above, this pattern shows that participants only used ownership and value when relevant and in accordance with the logic of the AWA.

When presented simultaneously, RHP, ownership, and value were integrated according to the logic of the AWA. Size pitted against ownership and size pitted against hunger each lead to no systematic expectation, demonstrating that each determinant mitigated the effect of the other. This cancellation effect demonstrates that children were not just saying who they thought should get the reward in line with morality or prosociality; if children were simply answering who should get the resource, then they should have picked the owner or hungry person at above chance levels even when this conflicted with size.

Results further show that this cancellation effect could not have been due to participants simply ignoring the task or being overwhelmed or confused when more than one determinant was included. In particular, when three determinants were included (ownership, hunger, and RHP), ownership and hunger overwhelmed the effect of the one RHP cue. This could only have happened if participants were keeping track of and summing determinants, not ignoring them or choosing at random. Likewise, no cancellation effect occurred when two determinants were pitted against one another in a foraging context, demonstrating that determinants were only integrated when appropriate.

Foraging (or search effort) expectations were included to serve as a comparison with conflict outcomes. As predicted, RHP—size in particular—had no effect on foraging outcomes, whereas value cues did. In particular, across two independent replications, hunger was expected to determine who would search longer for a food-related resource. As was true of conflict expectations, this expectation was resource-specific; there was no systematic expectation for non-food resources. The effect of ownership on foraging were expected to be weaker and more sensitive to resource parameters not directly tested in the present studies, such as the item's expected replacement cost. Indeed, in the present studies, ownership effects on foraging were weak to nonexistent: a weak effect in one condition and no effect in two subsequent conditions. This lack of an effect on foraging demonstrates that ownership expectations differ across conflict versus foraging contexts, and that ownership is not expected to have uniform effects across different types of resource acquisition (conflict vs. search). Future research directly manipulating cues of resource replacement cost, prior investment, and so on, will be better able to determine the extent to which ownership is expected to determine foraging outcomes, if it does at all.

### **Implications, Limitations, and Future Directions**

The present studies are the first in humans to combine RHP, ownership, and value within a single series of controlled experiments and to show that these are integrated according to the systematic and rule-governed logic of the AWA (for the most closely

related work see DeScioli and Wilson 2011; Sell 2005; Sell et al. 2009a, 2010). Whereas previous work has examined some subset of the model (for instance observational work on the relationship between RHP variables and success in conflict: Pellegrini et al. 2007; Raine et al. 1997; Tremblay et al. 1998; Felson 1996), the current studies were able to assess the entirety of the model. Moreover, because the current studies were experimental, the selective effects of each determinant could be assessed through control and comparison conditions (e.g., conflict versus search; the effects of hunger on non-food items; the effect of ownership on an unowned item).

This research extends ongoing research into how the logic of the AWA model of animal conflict applies to humans (e.g., Archer and Browne 1989; DeScioli and Wilson 2011; Sell 2005, 2011; Sell et al. 2009a, 2010; Sell et al. 2009b). Although size and physical strength (and RHP in general) are often viewed as important in determining conflict of interest outcomes, the current work highlights the importance of ownership and value.<sup>6</sup> A difference in value—because of a difference in need—can rival the effect of brute strength and force in determining outcomes during conflicts of interest, as the present results show. This somewhat un-Hobbesian worldview—that distribution of resources is not, or need not be, just a function of overall dominance, but can be also due to differences in value—appears to be a fundamental insight built into our evolved cognitive architecture.

This has broad implications, given that the psychology of resource conflict extends beyond mere schoolyard scuffles over candy bars and toys. For instance, recent evidence suggests that the evolved psychology of resource conflict in part governs intuitions about both financial distribution and international conflict; Petersen et al. 2013; Sell et al. 2009b). One of the broad lessons from the AWA literature is that because determinants of value are often hidden and abstract, they are less easy to assess than determinants of RHP (Arnott and Elwood 2008; Enquist and Leimar 1987). This may be especially true for humans in modern Westernized environments, as evolutionarily recurrent indices of need and value (such as obvious signs of injury, hunger, or social isolation) are often obscured either by abstract and evolutionarily novel currencies (such as money), or by the extent to which modern circumstances suppress the direct interactions between people required to signal and receive sufficient information about value and need. Although the feeling that the world is insensitive to our needs may be a universal part of the human condition, it may be exacerbated by such circumstances. Moreover, because the ability to impose costs (RHP) can substitute for need and value, when attempts to signal need and value are perceived to go unheeded, individuals (or groups) may feel compelled to ratchet-up signals of their formidability or directly demonstrate their ability to impose costs on others through violence and aggression. As such, a complete understanding of violence and aggression will require understanding need and value (e.g., Sell 2005).

The fluid relationship between RHP, ownership, and value also creates a problem of induction for representation and learning processes, and how the mind solves this

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<sup>6</sup> “Value” here refers to expected fitness benefits (an ultimate description), not the motivational settings or phenomenology of a psychological system (a proximate description). It is important to distinguish between proximate and ultimate here because it is likely that RHP and ownership—even in the absence of ultimate value differences (or fitness payoffs)—create the proximate phenomenological experience of valuation (i.e., having more of an attachment to, caring about, and wanting to retain a resource).

problem will need be addressed in future research. Because RHP is fungible with other variables in determining outcome conflict, this can lead to a problem when trying to infer which variables contributed to any one conflict outcome (Did size not predict conflict outcome in instance X because the smaller agent wanted the resource more, or because size doesn't predict conflict outcomes in general?). One recent finding from infancy research suggests the early emergence of at least one element of RHP sensitivity: that of differential attrition based on cues of size (in 9-month-old human infants; Thomsen et al. 2010). We expect that one reason for this early emergence is to collapse degrees of freedom: If obvious RHP differences can first be calculated and controlled for, learning adaptations designed to infer RHP, ownership, and value magnitudes from conflict outcomes will be much more accurate. Collapsing degrees of freedom for inducing RHP, ownership, and value is an important computational and developmental problem that has not yet been fully addressed in either the human or non-human literature, and it will be an important area for future research.

These results are only a starting point for more detailed investigations, and there are important limitations of the present work. For instance, because of the ethical considerations of experimental studies of conflict, the current studies measured expectations of third-party expectations, and not first-person decisions during real conflict (though of course third-party expectations are important in their own right; Pietraszewski and German 2013). Although the present experimental results closely map the predictions of selection models, and the results of the human observational studies that have thus far been done (Ross 2012; Weigel 1984), additional non-experimental observational studies will be needed to fully corroborate the integration of RHP, value, and ownership during real conflict decisions.

The current studies also do not yet provide us with enough detailed information about how each determinant—size, strength, alliance strength, hunger, ownership, and so on—is assessed by proximate psychological systems. Recent work by Sell and colleagues also motivated by the logic of the AWA model of conflict (Sell 2005, 2011; Sell et al. 2009a, 2009b, 2010; 2014) has explicitly examined the question of how RHP (particularly strength) is assessed by psychological mechanisms in humans, and this work has already lead to a number of important discoveries. We expect similar progress can be made investigating the cue structure of other AWA determinants, including alliance strength, ownership, hunger, and other value indices. Recent work by Friedman and colleagues (Friedman and Neary 2008; Friedman et al. 2011; Nancekivell et al. 2013; Neary and Friedman 2013), for instance, has examined the cue structure of ownership, and the psychology of ownership in general is becoming more prominent in experimental and developmental psychology (see also Blake and Harris 2009). The work reviewed in this paper on modeling the selection dynamics of ownership (see “Ownership as a Determinant of Conflict Outcome”) suggests additional and as-yet-untested hypotheses for this area of research (e.g., Arnott and Elwood 2008; Kokko 2013; Parker 1974; Parker and Rubenstein 1981; Williams et al. 2006; Yee 2003). The current studies only scratch the surface of the predictions made by these models. They suggest, for instance, that decisions about withdrawal, the cues of who is considered an owner, and even what is considered an ownable resource in the first place, will depend on local averages of information asymmetry, RHP asymmetry, and the distribution, variance, and replacement cost of the resource within the local ecology, and so on. This means understanding the proximate psychology of ownership will require

understanding the dynamics of conflicts of interest between agents and how they interact with the properties of the resource being contested.

Finally, and most broadly, we do not yet know enough about the proximate systems that underlie conflict-related decisions and expectations. In the current studies, we have used previous work on selection dynamics as a source of hypotheses for how proximate phenotypes should behave (i.e., what inputs they should be sensitive to, and what outputs they should generate), and we demonstrate that they produce outcomes consistent with evolutionary models of conflict. We have not described the adaptations that underlie these responses, aside from grossly oversimplified input/output relationships. (Selection dynamic models are not in themselves models of cognitive function, though they do inform us about what problems psychological mechanisms are designed to solve and also often specify—at a very broad level—the inputs these mechanisms should be sensitive to, and what kinds of outputs they should generate: Arnott and Elwood 2008; Sell 2005; Stephens and Krebs 1986; Tooby and Cosmides 1990, 2005.) To a first approximation, almost nothing is yet known about the human psychology of conflict-related decisions at the level of input-process-output contingency rules. For instance, the design of the proximate systems that exist to set persistence thresholds during conflict—including how they react contingently to predicted parameters in the environment over ontogenetic time—is still uncharted territory in humans (but see Lukaszewski 2013; Lukaszewski and Roney 2011; von Rueden et al. 2008; Sell 2005, 2011; Sell et al. 2009b). Withdrawing from conflict seems as simple and self-evident as seeing and breathing. But, just like seeing and breathing, this simplicity is a consequence of precise and elegantly engineering evolved systems designed around environmental regularities over evolutionary time. Selection dynamic models are a useful tool for making headway into their design.

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**David Pietraszewski** received his PhD from the Department of Psychology at UC Santa Barbara and was a postdoc in the Department of Psychology at Yale University. He is currently at the Center for Adaptive Rationality at the Max Planck Institute for Human Development in Berlin, Germany. He applies an adaptationist approach to social cognition, with a focus on coalitions and conflict.

**Alex Shaw** received his PhD from the Department of Psychology at Yale University and was a postdoc at the University of Chicago Booth School of Business. He is currently an assistant professor of developmental psychology at the University of Chicago. He applies evolutionary principles to study social phenomena and is specifically interested in reputation and signaling.