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Original Article

The development of contingent reciprocity in children

Bailey House [a,*], Joseph Henrich [b], Barbara Sarnecka [c], Joan B. Silk [a]

[a] Department of Anthropology, University of California-Los Angeles, 90024, USA
[b] Departments of Psychology and Economics, University of British Columbia, Vancouver, V6T 1Z4, Canada
[c] Department of Psychology, University of California-Irvine, 30302, USA

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ABSTRACT

Cooperation between nonrelatives is common in humans. Reciprocal altruism is a plausible evolutionary mechanism for cooperation within unrelated pairs, as selection may favor individuals who selectively cooperate with those who have cooperated with them in the past. Reciprocity is often observed in humans, but there is only limited evidence of reciprocal altruism in other primate species, raising questions about the origins of human reciprocity. Here, we explore how reciprocity develops in a sample of American children ranging from 3 to 7.5 years of age, and also compare children's behavior to that of chimpanzees in prior studies to gain insight into the phylogeny of human reciprocity. Children show a marked tendency to respond contingently to both prosocial and selfish acts, patterns that have not been seen among chimpanzees in prior studies. Our results show that reciprocity increases markedly with age in this population of children, and by about 5.5 years of age children consistently match the previous behavior of their partners.

1. Introduction

Cooperation among kin is widespread in nature, but humans differ from most other species because we regularly cooperate with both relatives and non-relatives (Henrich & Henrich, 2007). Kin selection can lead to the evolution of prosocial behaviors that confer benefits on others that are related through descent from a common ancestor (Hamilton, 1964), but cannot account for cooperation between nonkin. Reciprocal altruism provides a mechanism for cooperation to evolve among pairs of nonrelatives (Axelrod & Hamilton, 1981; Trivers, 1971). Selection is expected to favor mechanisms that lead individuals to conditionally help others as long as the costs of helping are outweighed by the future benefits scaled by the likelihood of future interactions. For example, cooperation will be sustained if the benefits of cooperating are at least twice the costs, and if there is more than a 50% chance that interactions will be repeated. Reciprocal altruism requires individuals to keep track of past interactions in some way, assess the likelihood of future interactions, and condition their own behavior on the previous behavior of their partners (Axelrod & Hamilton, 1981; Trivers, 1971). Humans engage in contingent cooperation in at least some settings (Gurven, 2006), but we know very little about how the capacity for contingent reciprocity develops as children mature. The goal of this paper is to fill this gap by exploring the development of contingent prosocial behavior in children using an experimental task similar to one previously used with captive chimpanzees. This affords insight both into the developmental trajectory of human reciprocity, and also the phylogeny of this behavior.

There is considerable evidence that humans condition their own cooperation on the cooperation of others. In some small-scale societies, individuals and family units transfer greater quantities of goods to those that previously transferred greater quantities to them (Bliege Bird, Bird, Smith, & Kushnick, 2002, Gurven, 2004, 2006; Gurven, Hill, & Kaplan, 2002; Gurven, Hill, Kaplan, Hurtado, & Lyles, 2000). There is also evidence that these transfers are contingent on past behavior. Among the Ache, the quantity of food received by one family from another in one time period was positively related to the quantity of food given to the same family in a subsequent time period (Gurven, 2006).

Several studies have explored the development of reciprocal behavior in children (see Supplementary Materials, available on the journal's Web site at www.ehbonline.org, Table 1). Fujisawa, Kutsukake, and Hasegawa (2008) studied naturally occurring interactions among 3–4 year-old Japanese children, and found that children's tendency to provide help and give objects (e.g. toys) to peers correlated with the peers' tendency to act prosocial towards them. Children were not given explicit instructions about how they should behave during these observations, so this study provides a good source of naturalistic data on reciprocity in children, but correlational data do not provide clear evidence of contingency in behavior.

Experimental studies allow a more explicit analysis of contingency. Testing pairs of American fourth graders Staub and Sherk (1970) allocated a number of candies to one child in each pair, and allowed them to transfer some to the other child or keep them all. Later, the children were allowed to draw pictures, but only one crayon was

* Corresponding author. Department of Anthropology, University of California-Los Angeles, 375 Portola Plaza, 341 Haines Hall, Box 951553, Los Angeles, CA 90095-1553. Tel.: +1 413 883 6658.
E-mail address: bhouse80@ucla.edu (B. House).

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provided, and it was given to the child who was non-endowed previously. Children shared crayons more with children who had shared the most candy with them. Levitt, Weber, Clark, and McDonnell (1985) placed a barrier in the middle of a playroom to separate a pair of children aged 2.5–3 years, one of whom was provided with a toy and instructed by their parent to pass the toy to the child on the other side of the barrier. Later in the session, the second child was provided with a toy, and in 9 out of 10 dyads this child only shared if the first child had shared before. These data suggest a contingency in children's willingness to share, but it is possible that children were responding to the adult's instructions to share, not the behavior of their partners. In Fishbein and Kaminski (1985) pairs of 6–11 year old American children played a game in which each player had the opportunity to help the other advance toward a goal. Children helped their partner (actually a stooge who had been trained to always help) about 68% of the time after their partner had helped them. However, subjects were less likely to reciprocate help if their partners had been instructed to help by the experimenter, than if their partners helped them without explicit instructions. This suggests that children condition their prosocial behavior on the perceived intentions of their partners, and on the actions and desires of adults, and raises concerns about the interpretation of results from studies in which children are instructed to share by their parents or other adults.

Birch and Billman (1986) endowed pairs of 3–5 year-old children (from the same school) with asymmetrical quantities of food (10 pieces vs. 1 piece). They then observed whether the 'rich' child shared with the 'poor' child. Of 14 children who received food when they were 'poor', 13 subsequently shared when they were 'rich'. However, of 13 children who had not received food when they were 'poor', only 7 shared later when they were 'rich'. This finding suggests a contingency between sharing and being shared with, but because children are not re-paired with the same child who shared with them before, their responses may be evidence either for generalized reciprocity (Barta, McNamara, Huszár, & Taborsky, 2011) or for a norm psychology that is trying to learn relevant rules about sharing (Chudek & Henrich, 2011).

Dahlman, Ljungqvist, and Johannesson (2007) conducted a study in which children were paired with anonymous recipients, and played a series of three 'games'. In each game, one child (the actor) was allowed to choose between two outcomes that had different payoffs for themselves and another child. Then, the recipients were informed of their decisions and were allowed to choose from the same set of options. Three to five year old children's choices were not affected by the choices that their partners had made, but 6–8 year old children tended to match the previous behavior of their partners. However, the difference in the extent of reciprocity among the younger and older children was only significant in one of the three games, which has come to be known as the Prosocial Game (Fehr, Bernhard, & Rockenbach, 2008; House et al., 2012). In this game, actors chose between one option that provided a reward to themselves and a reward to the other child, and a second option that provided a reward to the actor, but nothing to the other child.

These studies do not provide a clear picture of the development of contingent reciprocity as children mature. Observational evidence suggests that 3–4 year old children are most helpful to those that are most helpful to them, but correlational data do not provide evidence that children are using contingent behavioral strategies. Similarly, evidence that toddlers shared more with those who have previously shared with them is confounded by the fact that the children had been instructed to share. Fishbein and Kaminski (1985) found no effects of age on the reciprocal behavior of the 6–11 year old children that they tested, but it is not clear when contingent strategies first emerge. Moreover, most experimental studies have been limited to a single round of exchanges, and do not tell us whether children's behavior changes as they gain experience with the task and the behavior of their partners.

The current study is designed to examine the development of contingent reciprocity as children mature, but also to provide a direct comparison between the behavior of human children and that of non-human primates. Reciprocity is a plausible foundation for cooperation in non-human primates, raising additional questions about the phylogeny of the human reciprocity that we are exploring in the present study. Questions about phylogeny are best answered by comparing experimental data across humans and closely related primates. Surprisingly, experimental evidence for contingent reciprocity among our closest primate relatives, chimpanzees, is limited. de Waal (1997) found that chimpanzees were 6% more likely to share food with individuals that had groomed them within the past two hours than with individuals who had not groomed them within this period. Melis, Hare, and Tomasello (2008) found a weak tendency towards reciprocity in a task in which chimpanzees could help a familiar group member gain access to a food reward by unlocking a door. However, in a task in which chimpanzees could insert tokens into a vending machine that delivered a food reward to a conspecific in an adjacent enclosure, individuals given free access to the apparatus didn't deliver many rewards to their partners or develop a contingent strategy (Yamamoto and Tanaka 2009). Similarly, Brosnan et al. (2009) presented pairs of familiar chimpanzees with a variant of the Prosocial Game in which one animal, the actor, could choose between two options: Option 1 delivered a food payoff to the actor and its partners, while Option 2 delivered a payoff only to the actor. Thus, Option 1 was prosocial (and equitable) and Option 2 was selfish (and inequitable). Prosocial choices were not costly to actors because they could not obtain higher payoffs by choosing the alternative outcome. Subjects alternated between playing the role of actor and recipient across trials. Actors' choices were not consistently affected by the choices of their partners in previous trials. Similar results were obtained in a subsequent study of chimpanzees using the same payoff distributions (Yamamoto and Tanaka 2010). These methods can be easily adapted for use with children.

Following the procedures of Brosnan et al. (2009), in the current study we paired familiar children aged 3–7.5 years in face-to-face interactions and allowed them to interact repeatedly across multiple rounds in the Prosocial Game. Our results suggest that the propensity to respond in a contingent manner does not develop until about 5.5 years of age, but by this age the performance of children clearly differs from the performance of captive adult chimpanzees in a similar experimental setting.

2. Methods

2.1. Participants

Children were recruited at preschools near the University of California, Irvine. Children received a toy when parents signed the consent form, but at the time of testing children did not receive compensation for their participation beyond the payoffs obtained during the experiment. N = 80 children (43 female) between the ages of 3 and 7.5 years (age 3–4: N = 33, mean age = 4.17, SD = .58; age 5–7.5: N = 47, mean age = 6.12, SD = .60). Pairs of children were about the same age, and usually drawn from the same class to emulate the methods of chimpanzee studies in which subjects are drawn from the same social groups. Pairs could be either same-sex or mixed-sex pairs, but were never composed of kin. Two participants were excluded from the analyses due to inattention or unwillingness to complete the experiment.

2.2. The experimental task

Children were seated across from one another on the floor, with the experimenter seated on one side. Two 8.5" × 14" cards were placed on the floor between the children (see Fig. 1), and each card had one red circle and one blue circle printed on it. The experimental materials were based on Fehr et al. (2008). For each trial, payoffs were placed in the circles and one of the two children was permitted to choose one of the two cards (binary, forced choice). Payoffs were metal washers (described as "coins"), and children were told that one washer would be exchanged for one sticker at the end of the experiment. Children were only allowed to take the payoffs from the circle that was closest to them on the selected card.

On each trial, one child was the actor and one child was the recipient. Actors were presented a choice between two options: (1) one washer for the actor and one for the recipient (the 1/1 option), or (2) one for the actor and nothing for the recipient (the 1/0 option). Actors and recipients alternated roles on successive trials. The children stored their payoffs in opaque paper bags that were provided to them, and later exchanged their payoffs for stickers.

2.3. Procedure

Experimenters first familiarized themselves with the children at the preschools by spending several hours at the school across multiple days. Children were approached and asked if they would like to play a game with the selected partner. Pairs were led to a quieter part of the school and seated across from each other. The full experimental session presented each child with two training trials and five test trials, for a total of 14 trials. Children alternated as actor and recipient during both training and test trials, and participants were told that they would alternate roles and have several turns in each role (see Supplementary Materials Section 2.1 for verbal instructions given to children, available on the journal's Web site at www.ehbonline.org). Children were not informed in advance of the exact length of the experiment, though a few inattentive pairs were informed when it was the last trial. After all testing in a particular classroom was completed, teachers were asked to complete a survey that rated the relationship quality of the pairs of children.

Training: Before each training trial, each child was given the full set of instructions, so each child heard the instructions four times. The first training trial presented the actor with a 1/1 vs. 2/2 choice, meaning that one card delivered only one payoff to each participant, while the second card delivered two payoffs to each participant. The second training trial presented actors with a 1/0 vs. 2/0 choice. These two trials were meant to introduce children to two facts about this game: payoffs obtained were influenced by the choices actors made, and recipients did not necessarily obtain payoffs. These two training trials were always presented in the same order, but the side of presentation for each payoff was counterbalanced across subjects.

Test: In each test trial, actors were presented with a choice between 1/1 and 1/0. Children were provided with no further instructions during test trials. Children were simply informed when it was their turn to play the actor role. Payoff options were counterbalanced so that half of the time 1/1 was presented on the left, and half of the time it was presented on the right.

2.4. Coding

Current Choice was the primary dependent variable, and indicated the choice that an actor made on a focal trial. A choice of 1/1 was coded as '1' and a choice of 1/0 was coded as '0'. *Partner's Previous Choice* indicated the choice that an actor's partner had made on the trial immediately prior to the focal trial (a 1/1 choice was coded as '1,' a 1/0 choice was coded as '0'). *Sex* indicates the sex of the actor (female was coded as '1', male was coded as '0'), *Trial Number* indicates the trial number of the focal trial, and *Age* was the absolute age of the actor.

The covariate *Relationship Quality* was created by asking teachers to rate the strength of the pair's friendship. Teachers were provided with a 7-point likert scale (1 = "not friends at all"; 4 = "on average, as good friends as are most children"; 7 = "best friends"; ? = "don't know"). We were able to collect ratings of relationship quality from 68 of our 80 subjects; 10 of the missing ratings were from the oldest children in our sample. As our sample of relationship quality is skewed toward younger children, we performed separate analyses on the subset of children for which relationship quality data were available.

2.5. Analyses

Each actor made binary choices between 1/1 and 1/0 payoff outcomes on four different trials. We used multi-level logistic regressions with 'actor identity' as a random effect, controlling for each subject contributing multiple data points. Models for *Current Choice* explore whether actors' choices on focal trials are predicted by their partners' previous choices (*Partner's Previous Choice*), actors' experience within the experiment (*Trial Number*), demographic information (*Age* and *Sex*), and dyadic relationship quality (*Relationship Quality*). Results are presented as Odds Ratios (ORs).

We hypothesized that *Partner's Previous Choice* would predict *Current Choice*, a result consistent with reciprocal altruism. An OR greater than 1.00 would indicate reciprocity by showing that a prior choice (either 1/1 or 1/0) predicts a greater likelihood of the same choice on the subsequent trial. Effects of age and sex have been reported in other studies of prosocial behavior in children (Eisenberg & Fabes, 1998; Silk & House, 2012), with females and older children being more prosocial than males and younger children, so we explored whether *Age* or *Sex* would predict *Current Choice.* An OR greater than 1.00 would indicate that females are more likely to choose 1/1 than are males, or that older children are more likely to choose 1/1 than are younger children (while an OR below 1.00 indicates the opposite). Game theory predicts an "endgame effect" for the last round of an iterated game, because as the game comes to an end individuals should be indifferent to the past behavior of others and act in their own self-interest because there are no future benefits to be obtained by cooperating (Normann & Wallace, 2004; Selten & Stoecker, 1986). We provided no explicit information about when the interaction would end, but children might expect that each subsequent trial had a greater probability of being the last, and might therefore have chosen 1/1 less often as the experiment progresses. An OR below 1.00 for the variable *Trial Number* would suggest an endgame effect by showing that children were less likely to choose 1/1 as the experiment progressed.

We also explored interactions between *Partner's Previous Choice* and *Age*, *Sex*, and *Trial Number* using the interaction terms: *Age* × *Partner's Previous Choice, Sex* × *Partner's Previous Choice*, and *Trial Number* × *Partner's Previous Choice*. We predicted that *Partner's Previous Choice* would interact positively with *Age* (i.e. older children would be more reciprocal than younger children), with an OR greater than 1.00. Endgame effects should also lead to a negative interaction between *Partner's Previous Choice* and *Trial Number* (i.e. an OR less than 1.00), again because children might expect that each subsequent trial has a greater probability of being the last, and thus become more indifferent to the prior behavior of their partners. We had no strong predictions about whether *Partner's Previous Choice* would interact with *Sex*.

To determine how well these factors (*Partner's Previous Choice, Age, Sex, Trial Number, Age* × *Partner's Previous Choice, Sex* × *Partner's Previous Choice,* and *Trial Number* × *Partner's Previous Choice)* fit the data, using Akaike weights (Burnham & Anderson, 2002; McElreath et al., 2008) we calculated the probability that each of these factors would be present in the model that best fits the data (for more details see Supplementary Materials Section 2.2, available on the journal's Web site at www.ehbonline.org). This is an independent measure of how important a particular factor is across different model structures.

Relationship Quality: We had no clear hypotheses about how *Relationship Quality* would predict *Current Choice*, though children

Table 1
Models for Current Choice, for the full sample.

DV: Current Choice	Probability that variable appears in the best model	Models						
		1	2	3	4	5	6	7
		Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)
Partner's Previous Choice	.44	2.58 (.69)				.15 (.20)	.58 (.72)	3.35 (1.35)
Age	.38		.99 (.15)			.73 (.14)		
Trial Number	.54			.91 (.05)			.86 (.07)	
Sex	.77				1.83 (.60)			2.42 (1.05)
Age × Partner's Previous Choice	.73					1.71 (.41)		
Trial Number × Partner's Previous Choice	.41						1.15 (.13)	
Sex × Partner's Previous Choice	.34							.66 (.36)
Random effect parameter (child ID)		.88 (.24)	1.00 (.23)	1.03 (.23)	.96 (.23)	.81 (.24)	.88 (.24)	.80 (.24)

The probability that each factor appears in the best model (out of all 127 models considered) is calculated by summing the Akaike weights for all models that include that factor. Factors with probabilities closest to 1 are the factors most likely to explain the data well, irrespective of exact model structure. Each model provides odds ratios and standard errors for each factor that has been included in the model. Odds ratios larger than 1.00 indicate that the parameter predicts a higher probability of choosing 1/1, while odds ratios less than 1.00 indicate that the parameter predicts a lower probability of choosing 1/1. The last row provides the estimates for the random effect (child id), which are presented as coefficients instead of odds ratios. For each model this parameter's coefficient is substantially larger than the standard error, indicating substantial differences across individual subjects in how they behave in this task.

were expected to be more prosocial (i.e. more likely to choose 1/1) when paired with closer friends. We also had no predictions about whether *Relationship Quality* would interact with *Partner's Previous Choice* (i.e. whether relationship quality predicted reciprocity), because closer friends might be more likely to interact in the future and thus more reciprocal, but prior studies also suggest that friends may be less likely to immediately reciprocate than non-friends (Silk, 2003). Analyses for *Relationship Quality* were performed separately from the other analyses because the sample from which we received relationship ratings was smaller, and skewed towards younger ages. The procedures for these analyses are identical to those used above, except that we used a reduced number of factors and thus consider fewer models in our analyses (31 models, instead of 127; see Supplementary Materials Section 2.2, available on the journal's Web site at www.ehbonline.org).

3. Results

Across all ages, children chose the 1/1 outcome on 63% of trials in which their partner had previously chosen 1/1, and on 45% of the trials in which their partner had previously chosen 1/0 (Fig. 2). Older children are primarily responsible for this pattern. A partner's previous choice had little impact on the behavior of 3–4 year-olds. However, 5–7.5 year-olds chose 1/1 on 70% of trials in which their partners had chosen 1/1, but on only 40% of trials in which their partner had chosen 1/0 (Fig. 2). These aggregate data do not control for the non-independence in the data, and we use multi-level logistic regressions to confirm and extend these results.

First we present the results for regression models of our main effects as odds ratios (*Partner's Previous Choice, Age, Sex,* and *Trial Number*), followed by the results of models including interaction terms (*Age × Partner's Previous Choice, Sex × Partner's Previous Choice*, and *Trial Number × Partner's Previous Choice*). We also present the results of our Akaike weight analyses for each factor in turn, which gives an indication of how important each factor is for interpreting these data.

Model 1 reveals an odds ratio larger than 1.00 for *Partner's Previous Choice* (Table 1), indicating that across all subjects actor's choices of 1/1 are positively predicted by their partner's choices of 1/1 on the previous trial. However, the probability that *Partner's Previous Choice* appears in the best model is relatively low, suggesting that other factors have an important impact on children's behavior in this task.

Fig. 1. Experimental Setup. Payoffs are individual washers (visible inside each circle below), each of which was exchanged for one sticker after the experiment was completed. In the example trial below the child on the left is the actor, and the child on the right is the recipient.

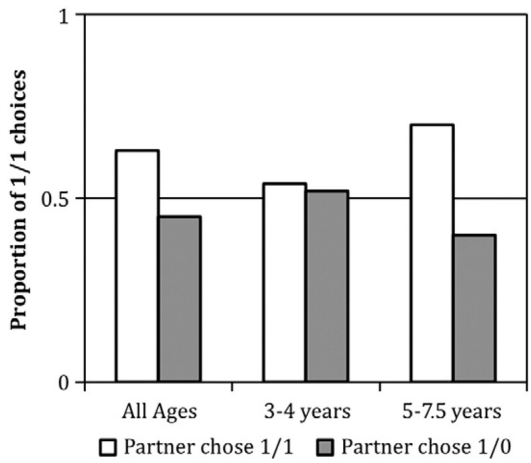

Fig. 2. Data across all trials: for all ages combined, children aged 3–4, and children aged 5–7.5. White bars denote the proportion of 1/1 choices that children made when their partner chose 1/1 on the previous trial. Grey bars denote the proportion of 1/1 choices that children made when their partner chose 1/0 on the previous trial. These data do not control for the fact that individual children were observed multiple times, and for this reason we do not include confidence intervals. See Fig. 3 for appropriate confidence intervals.

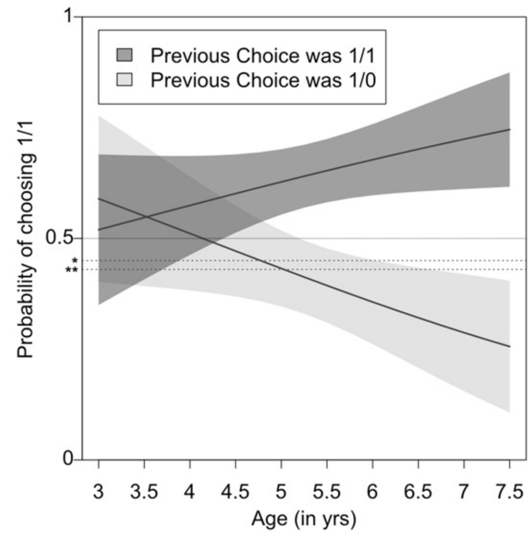

Fig. 3. Graphical representation of logistic function from Model 2 from Table 2, as independently applied to trials that were preceded by a partner's 1/1 choice (dark grey) and trials that were preceded by a partner's 1/0 choice (light grey). The x-axis represents children's age, and the y-axis represents the model's prediction about children's probability of choosing the 1/1 outcome. The dark and light grey regions denote estimated 95% confidence intervals for the logistic function. Children are estimated to reciprocate 1/1 choices by their partner more than 50% of the time by age 4.5 years, and to reciprocate 1/0 choices more than 50% of the time by 5.5 years. In contrast, chimpanzees never reciprocated their partner's choices more than 50% of the time (Brosnan et al., 2009). Differences between the behavior of children and chimpanzees can be estimated by determining where the confidence intervals no longer overlap with the dotted lines. * Probability that chimpanzees choose 1/1 when their partner chose 1/1. By 4 years of age children reciprocate 1/1 choices by their partner more than do chimpanzees. ** Probability that chimpanzees choose 1/1 when their partner chose 1/0. By 7 years of age children reciprocate 1/0 choices by their partner more than do chimpanzees.

In Model 2 *Age* displays an odds ratio slightly smaller than 1.00, suggesting that older children do not chose 1/1 more frequently than younger children. *Age* also has a relatively low probability of appearing in the best model. Similarly, in Model 3 *Trial Number* has an odds ratio slightly smaller than 1.00, indicating that children chose 1/1 less frequently as the experiment progressed. The probability of appearing in the best model is higher for *Trial Number* than it is for *Age*, but it is still relatively low. Thus, both age and progress through the experiment are factors that do not strongly predict children's choices of 1/1 on their own, and they are not the most important factors for understanding children's behavior in this task.

In Model 4, *Sex* has an odds ratio greater than 1.00, indicating that females are more likely to choose 1/1 than are males. *Sex* also has a high probability of being included in the best model.

Model 5 suggests that children become more reciprocal with age, as there is an odds ratio larger than 1.00 for the *Age* × *Partner's Previous Choice* interaction (Table 1). This indicates that with each one year increase in age, children are 1.71 times more likely to choose 1/1 if their partner had previously chosen 1/1. Additionally, the odds ratio for *Age* in Model 5 is smaller than 1.00, indicating that for each one year increase in age, children are 1.37 times more likely to choose 1/0 if their partner had previously chosen 1/0. The probability that *Age* × *Partner's Previous Choice* is included in the best model is relatively large, suggesting that this interaction is much more important for understanding children's behavior in this task than is *Partner's Previous Choice* on its own. These results are illustrated in Fig. 3, which displays two logistic functions obtained from applying Model 2 independently to the trials in which the actor's partner previously chose 1/1 and 1/0 (Fig. 3 is also a representation of the interaction between *Partner's Previous Choice* and *Age* in Model 5). These two samples of data are best modeled by two different functions: one indicating that the probability of actor's choices of 1/1 increase with age (when their partner's previous choice was also 1/1), and one indicating that the probability of actors' choices of 1/1 decrease with age (when their partner's previous choice was 1/0). For comparative purposes, Fig. 3 also plots the mean rates of chimpanzees' 1/1 choices after their partner previously chose 1/1 and 1/0, as reported by Brosnan et al. (2009).

In Model 6, the odds ratio for the interaction between *Trial Number* and *Partner's Previous Choice* indicates that as actors progressed through the experiment they became more likely to match their partner's previous choices (Table 1). However, the magnitude of the coefficient and the probability that this factor appears in the best model are both relatively small, suggesting that it is not very important for explaining children's behavior. The odds ratio for the interaction between *Sex* and *Partner's Previous Choice* in Model 7 is smaller than 1.00, indicating that males are more likely to reciprocate their partner's choices than are females, but the relatively large standard error for this coefficient implies that this effect is not very consistent. Supporting this interpretation, the probability that *Sex* × *Partner's Previous Choice* appears in the best model is relatively low.

Relationship Quality: We obtained ratings of *Relationship Quality* for 85% of the dyads, and the majority of these ratings were for younger children. However, the patterns in this sample (Table 2) generally resemble those in the full sample (Table 1). The odds ratios for *Partner's Previous Choice* (Model 8) and *Age* × *Partner's Previous Choice* (Model 12) are again greater than 1.00, indicating that actors tend to reciprocate the previous choices of their partners, and that this tendency increases as a function of age. However, the odds ratio for *Age* × *Partner's Previous Choice* in Model 12 is reduced (relative to the odds ratio in Model 5), as is the probability that this factor is included in the best model. In Model 10, the odds ratio for *Relationship Quality* is greater than 1.00 and indicates that actors were more likely to choose 1/1 when they were paired with closer friends. The high probability that this factor is included in the best model suggests that relationship quality has an important impact on prosocial behavior. Including both *Relationship Quality* and *Partner's Previous Choice* in Model 11 only moderately reduces both odds ratios, suggesting that these are largely independent effects. Interestingly, relationship quality also doesn't appear to be positively related to reciprocity in several experiments with captive chimpanzees (see Brosnan et al., 2009).

Model 13 then tests for an interaction between *Relationship Quality* and *Partner's Previous Choice*, which asks whether close friends are more influenced by a partner's previous choices than others. The odds ratio is larger than 1.00 but smaller than the standard error,

Table 2
Models for Current Choice, for the sample rated for relationship quality.

DV: Current Choice	Probability that variable appears in the best model	Models					
		8	9	10	11	12	13
		Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)	Odds Ratio (St Err)
Partner's Previous Choice	.40	1.88 (.55)			1.72 (.51)	.26 (.37)	1.17 (1.12)
Age	.28		1.09 (.18)			.87 (.19)	
Relationship Quality	.71			1.42 (.21)	1.36 (.19)		1.30 (.24)
Age × Partner's Previous Choice	.51					1.47 (.40)	
Relationship Quality × Partner's Previous Choice	.45						1.11 (.26)
Random effect parameter (child ID)		.93 (.25)	1.02 (.25)	.92 (.25)	.86 (.26)	.87 (.26)	.85 (.26)

The probability that each factor appears in the best model (out of all 31 models considered) is calculated by summing the Akaike weights for all models that include that factor. Factors with probabilities closest to 1 are the factors most likely to explain the data well, irrespective of exact model structure. Each model provides odds ratios and standard errors for each factor that has been included in the model. Odds ratios larger than 1.00 indicate that the parameter predicts a higher probability of choosing 1/1, while odds ratios less than 1.00 indicate that the parameter predicts a lower probability of choosing 1/1. The last row provides the estimates for the random effect (child id), which are presented as coefficients instead of odds ratios. For each model this parameter's coefficient is substantially larger than the standard error, indicating substantial differences across individual subjects in how they behave in this task.

suggesting a weak effect, and the low probability of being included in the best model suggests this factor is not nearly as important as is *Relationship Quality* on its own.

4. Discussion

These results demonstrate contingent prosocial behavior in our sample of American 3–7.5 year-olds, with older children being more likely to match the behavior of their partners than younger children. The models predict that in a similar sample by about 4.5 years children will choose 1/1 more than half the time when their partner chose 1/1 during the previous round, and by about 5.5 years children will choose 1/1 less than half of the time when their partner chose 1/0 previously (Fig. 3). This suggests that positive reciprocity develops slightly ahead of negative reciprocity, but it is also possible that children simply had a baseline bias towards the prosocial outcome making it appear as though positive reciprocity emerges earlier. Conclusions about the separate ontogenies of positive and negative reciprocity will require further study.

The behavior of human children differs substantially from the behavior of adult chimpanzees in this task. By age 5.5, children reciprocated both 1/1 and 1/0 choices by their partners significantly more than 50% of the time, while chimpanzees never did so. However, it would be premature to conclude that there are differences in the capacity for contingent reciprocity among chimpanzees and human children. There is correlational evidence for reciprocity in grooming and food sharing among wild chimpanzees (Mitani, 2006), and it is possible that reciprocity among chimpanzees is poorly captured by laboratory tasks like this one (see also Melis et al., 2008). Moreover, although we modeled our experiment after Brosnan et al. (2009), the procedures were not identical. For example, the children received verbal instructions, while the chimpanzees did not, receiving numerous training trials instead. It is also possible that developing in captivity has cognitive or behavioral consequences for chimpanzees that makes the behavior of captive animals a poor model for the behavior of wild animals (Boesch, 2007, 2008; but see: Tomasello & Call, 2008).

Regardless, our results clearly indicate that humans and chimpanzees differ in how reciprocity shapes their social interactions in a similar context, and this enhances our understanding of the constraints on the development of contingent reciprocity in humans and other animals. Understanding these constraints is necessary for understanding the mechanisms that underlie cooperation across species.

4.1. Developmental Effects on Contingent Reciprocity

Our results indicate that children begin to respond contingently when they are about between 4.5 and 5.5 years of age. Unfortunately, few other studies of the development of contingent cooperation span this age range within a single experimental context, making it hard to compare our results with the results from other studies. The correlational study showing that 3–4 year old Japanese children selectively share and help those that most often share and help them suggests that children may practice contingent strategies by this age (Fujisawa et al., 2008)—though contingency is not actually shown. In contrast, the 3–4 year-olds that we tested did not condition their behavior on the previous behavior of their partners. Differences in methodology make it difficult to compare these results directly, but raise a number of possibilities. First, as noted earlier, it is possible that the patterns observed among the Japanese preschoolers are not the product of contingent reciprocity. Second, it is possible that contingent behavioral strategies emerge earlier in naturalistic, everyday settings than in more artificial experimental settings. Third, cultural differences may produce different developmental trajectories among children in the US and Japan.

Birch and Billman (1986) found that 3–5 year old children were more likely to share with others if they had previously been the recipients of others' generosity than if they had not been the recipients of generosity. However, it is not clear whether the youngest children were as likely to "pay it forward" as the oldest children that they tested. Our results are also consistent with Fishbein and Kaminski (1985) finding that 6–11 year olds respond contingently to the behavior of their partners.

Our results are also consistent with the results of Dahlman et al. (2007) who found that 6–8 year-olds were significantly more likely to respond contingently to the behavior of anonymous partners in the Prosocial Game than 3–5 year olds. It is not clear, however, how anonymity influences children's likelihood of reciprocating, so the parallels in the results must be viewed with some caution.

4.2. Effects of Sex

In this experiment, females were generally more likely to choose the prosocial option than males, but there was no effect of sex on the likelihood of reciprocation. In other words, females were more likely than males to choose 1/1 when their partner chose 1/1 but also when their partner chose 1/0. This pattern is largely consistent with findings from the literature. Many studies of the development of prosocial behavior have reported that females are more prosocial than males (Fabes & Eisenberg, 1998). In Dictator Games conducted with children, females are more likely than males to donate some amount, and more likely to donate larger amounts (Blake & Rand, 2010; Gummerum, Hanoch, Keller, Parsons, & Hummel, 2010, Gummerum, Keller, Takezawa, & Mata, 2008; Harbaugh, Krause, & Liday, 2003; Leman, Keller, Takezawa, & Gummerum, 2009). However, sex differences do not emerge in all experimental economic studies conducted with children (Benenson, Pascoe, & Radmore, 2007; Harbaugh & Krause, 2000; Lucas, Wagner, & Chow, 2008; Sally & Hill, 2006; Takezawa, Gummerum, & Keller, 2006). There is little evidence of sex differences in children's reciprocal behavior. Sutter and Kocher (2007) found no effects of sex in an anonymous trust game played with subjects aged 8 years to adult. Dreman and Greenbaum (1973) found that male subjects, but not female subjects, responded to anonymity by becoming less prosocial. This might suggest an effect of sex on sensitivity to anonymity, but only indirectly suggests a possible sex difference in contingent responses.

4.3. Effects of Trial Number

Endgame effects are commonly found in repeated games as rates of cooperation drop as the game progresses toward the last rounds (Normann & Wallace, 2004; Selten & Stoecker, 1986). However, we found little evidence for endgame effects among the children that we tested. Although trial number negatively predicted prosocial behavior (Model 3, Table 1) and positively predicted reciprocity (Model 6, Table 1), the effects of trial number are very weak, and the magnitude of these effects is very small. Moreover, if the weak negative effect of trial number on prosocial choices were evidence of an endgame effect, then we would predict that trial number would also have a negative effect on reciprocity as children become less sensitive to the previous behavior of their partners in the last rounds of the game. Instead, we found that reciprocity increases as the experiment progresses, and on the final trial children reciprocate 1/1 choices 81% of the time (SE = 10). This suggests that children are becoming more, not less, reciprocal as they gain experience with the task. Thus, trial number may negatively predict children's probability of choosing 1/1 because they are becoming more inclined to punish selfish behavior by others, not because they are becoming less prosocial due to an endgame effect. Regardless, effects of trial number are substantially weaker than effects of previous choices and actor sex, suggesting that children enter the task already endowed with reciprocal strategies and their responses change little over the course of the experiment.

4.4. Effects of Relationship Quality

One might assume that relationship quality is associated with the likelihood of future interactions, and thus stronger relationships should predict higher rates of reciprocity. However, empirical studies of friendship among adults (at least in the West) show that friends are less likely to immediately reciprocate a prosocial act than are non-friends, and immediate repayment by a friend can even be viewed negatively, perhaps explaining why friends also sometimes go to the trouble of concealing prosocial acts (Silk, 2003). Interestingly, studies with non-human primates also suggest that reciprocity might be stronger across longer timescales (Schino & Aureli, 2009; Jaeggi, de Groot, Stevens, & van Schaik, in press in EHB). The reasons for such behavior among humans aren't fully understood. It is possible that short-term bookkeeping within a relationship is avoided because it implies that future cooperative interactions are unlikely. Alternatively, a long history of reciprocity within a dyad may reduce the relative value of any particular cooperative action, thus reducing the relative costs of that act and the need to reciprocate small prosocial acts. Regardless of their cause, these patterns among adults fit with our finding that children paired with close friends are typically more prosocial, but not more reciprocal, than those paired with non-friends. Importantly, we also show that effects of relationship quality are distinct from the effects of partner's previous choices, meaning that our evidence for reciprocity in children's behavior is not simply due to friends being highly (but non-contingently) prosocial.

Our analyses suggest that at least some of the fundamental characteristics of (Western-style) friendship in adults also describe friendships among children, as measured by third-party adult raters. This points to a paradigm for exploring the development of the dynamics of friendships among children in a systematic way, a topic that has not been investigated in much detail.

5. Summary

Despite considerable evidence for reciprocity in human social behavior, we do not fully understand the ontogenetic development of contingent reciprocity in humans. Our results demonstrate the emergence of contingent prosocial behavior and are largely consistent with the limited developmental literature on reciprocity that suggests that reciprocity is predicted by child age but not by child sex (although sex does predict prosocial behavior more generally). The current study also adds to our understanding of the phylogeny of human reciprocity, by illustrating that within similar experimental contexts children engage in contingent prosocial behavior (as do human adults) but captive adult chimpanzees do not. This suggests differences in the reciprocal strategies of humans and our closest living relatives, but the source of these differences will require further systematic study of the conditions under which reciprocity is elicited in both species. Our findings suggest that reciprocity develops in American children by 5.5 years of age within this experimental context. These results provide a useful foundation for future work that explores the nature of this developmental process, and sets the stage for more focused tests of how cognitive changes and cultural acquisition influences contingent reciprocity. Both are necessary for fully understanding the developmental processes that underlie human cooperation, and for understanding how human cooperation differs from that of our close primate relatives.

Supplementary Materials

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.evolhumbehav.2012.10.001.

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