LETTER

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Collaboration encourages equal sharing in children but not in chimpanzees

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Humans actively share resources with one another to a much greater degree than do other great apes, and much human sharing is governed by social norms of fairness and equity[1–3]. When in receipt of a windfall of resources, human children begin showing tendencies towards equitable distribution with others at five to seven years of age[4–7]. Arguably, however, the primordial situation for human sharing of resources is that which follows cooperative activities such as collaborative foraging, when several individuals must share the spoils of their joint efforts[8–10]. Here we show that children of around three years of age share with others much more equitably in collaborative activities than they do in either windfall or parallel-work situations. By contrast, one of humans' two nearest primate relatives, chimpanzees (*Pan troglodytes*), 'share' (make food available to another individual) just as often whether they have collaborated with them or not. This species difference raises the possibility that humans' tendency to distribute resources equitably may have its evolutionary roots in the sharing of spoils after collaborative efforts.

Among great apes, only humans are true collaborative foragers[8,9,11]. Other apes forage in small parties, but they do not actively work together jointly to produce food—the only exception being chimpanzee group-hunting of monkeys[12,13]. In contrast, humans in all societies produce significant portions of their food through collaborative efforts, even bringing the results of their labour back to some central location to share with other group members[14,15]. After group-hunting, chimpanzees mostly share only under pressure of harassment by others[16] or else reciprocally with coalition partners[17].

Human children actively share valuable resources with others to some degree from early in ontogeny. A fairly well-established pattern across cultures is that three- to four-year-old children tend to divide a windfall of resources unequally, keeping the majority for themselves[4–6,18,19]. As they approach school age, they begin to share more equally[4,5,7,18,19]. But given that humans generate many or most of their resources collaboratively, a plausible hypothesis is that children would share a resource more equitably at an earlier age if it was not provided by adults as a windfall, but if instead they had to work together to produce it[20]. Furthermore, we might expect this positive effect of collaboration on sharing to be confined to humans, among great apes, as only they have an evolutionary history of obligate collaborative foraging[8,9,11].

In the current series of experiments, therefore, we presented pairs of human children and pairs of chimpanzees with resource distribution problems in which one individual had control of more than half of the resources and could choose whether or not to share them equally with their partner. The basic variable was whether the initial unequal distribution of resources resulted from a collaborative effort in which each contributed equally, or whether it came from some non-collaborative source (for example as a windfall or as a result of each individual working on their own).

In study 1, pairs of either two- or three-year-old children were in a room by themselves. In the 'collaboration' condition, they faced an enclosed board with a rope extruding from each end (Fig. 1a), and they knew from previous experience (from a demonstration phase) that they had to pull together to bring the board towards them. On each end of the board were two rewards (small toys) that could be accessed once the board had been pulled close enough. As the children pulled, one of the toys rolled to the other end of the board such that one child ended up with three toys and the other ended up with only one. In the control, 'no-work', condition, by contrast, as children entered the room the board with the toys was already at its end-state position, with three toys at one end and one at the other (Fig. 1b). The main result was that the 'lucky' child, who had gained three toys, made one of the toys available to the 'unlucky' partner, who had gained one, restoring equity, more often in the collaboration condition than in the no-work condition ($F(1, 22) = 21.85$ (analysis of variance), $P < 0.001$). The effect was similar for children of both ages (Fig. 2a).

In this experiment, it was possible that from the beginning of the collaboration children viewed the rewards on their end of the board as belonging to them, such that when one reward rolled to the other end it was as if one of their possessions had been taken away (which was not the case in the no-work condition). In study 2, therefore, we presented pairs of two- or three-year-old children initially with four toys bunched together, so that an initial sense of possession was not an issue. In addition, we added a second control condition—the parallel-work condition—with a very similar set-up, in which each child pulled on a separate board with their own separate rope, to account for the fact that the collaboration condition required work whereas the original control condition (no-work) did not (Fig. 1c–e). Thus, if children are attentive to work effort in general and not to collaborative effort in particular, they should share similarly in the parallel-work and collaboration conditions. However, in this study also, the three-year-old lucky child handed over one of the toys to the unlucky partner more often in the collaboration condition than in either of the two control conditions (no-work and parallel-work). By contrast, the two-year-olds did not differentiate among conditions (see Fig. 2b for data and statistics for both ages).

Because studies 1 and 2 consisted of multiple trials, they leave open the possibility that children shared in the collaboration condition out of a concern that if they did not share their partner might not pull their end of the rope in future trials (which was not an issue in the parallel-work and no-work conditions as children obtained rewards on their own.) In study 3, to ensure that children understood that they would play the game only once, in the demonstration phase we showed them the total number of toys available and made it clear that their number decreased over demonstrations. When there was only one set of four toys left, we pointed this out and specifically asked the children whether the game could be played after this last set was gone. Only children who answered that this would be the last time were then given the actual test trial (that is, only their data was used for analysis; see Supplementary Information for details). Replicating our results once more, three-year-old children equalized the distribution of toys more often in the collaboration trials (75%) than in the parallel-work trials (25%; $\chi^2_{(\mathrm{d.f.}=1, n=24)} = 6.0$, $P = 0.039$; Fig. 2c). Taken together, these studies show that collaborative work encourages equal sharing in

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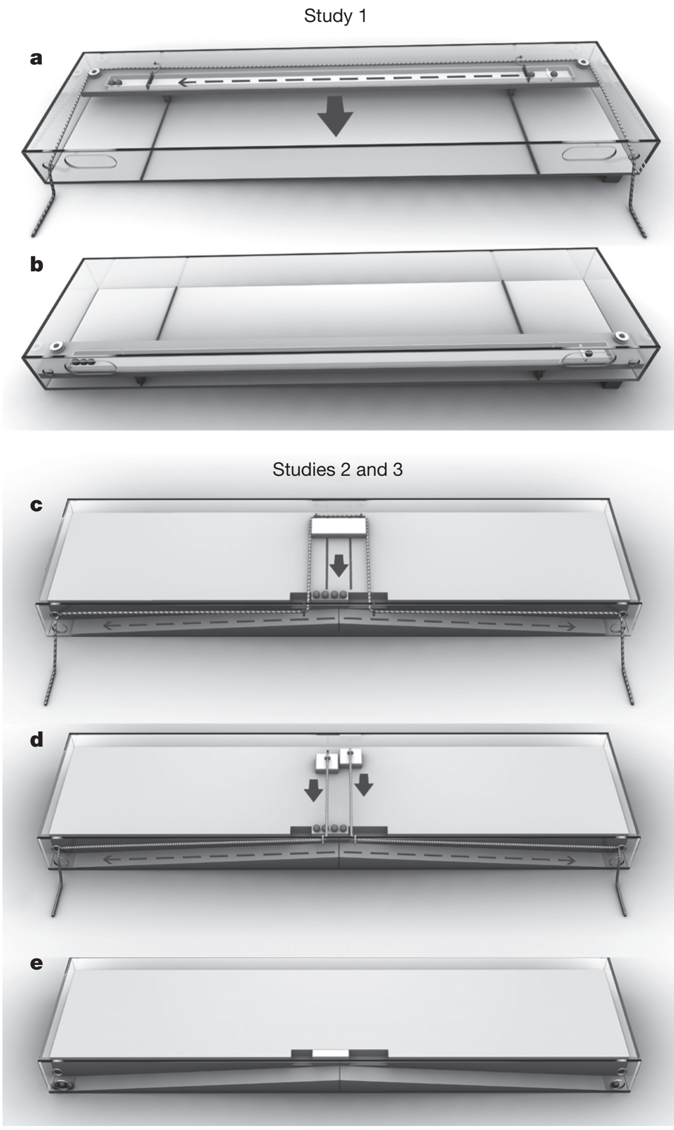

Figure 1 | Child study tasks. **a**, Apparatus from study 1 with reward relocation mechanism as used in the collaboration condition (180 cm × 60 cm × 15 cm; adapted from studies with chimpanzees[29,30]). In the collaboration condition, children had to pull both ends of the rope simultaneously to move the board towards the access holes in the front of the enclosure (solid arrow). Initially, two toys (marbles) were on each side (as shown), but as the children pulled the board closer, the black barriers slipped out such that one marble rolled to the other end, resulting in a 3:1 reward distribution (moving from right to left in this example; dashed arrow). **b**, In the no-work condition, the board was already in the front part of the apparatus, with no attached rope, when children approached it (same reward distribution, of 3:1). **c**, In studies 2 and 3, children had to move a block closer to move the marbles such that they would roll in front of the access holes. In the collaboration condition, children had to pull a single, long rope simultaneously to move a large block closer (solid arrow), moving four marbles at once, which then rolled towards the respective access holes (in this example, three marbles rolled to the left and one marble rolled to the right; dashed arrows). **d**, In the parallel-work condition, two smaller blocks (each with a rope attached) could be pulled individually, one by each child, causing the respective marbles to move and roll down the ramps. **e**, The no-work condition, without any work but with the same reward distribution, 3:1.

children much more than does working in parallel or acquiring resources in a windfall.

Chimpanzees do not regularly offer resources to others actively, so to test for the same effect of collaboration on sharing in chimpanzees we had to use a slightly more complex apparatus that enabled one individual to provide another with food that the second could not

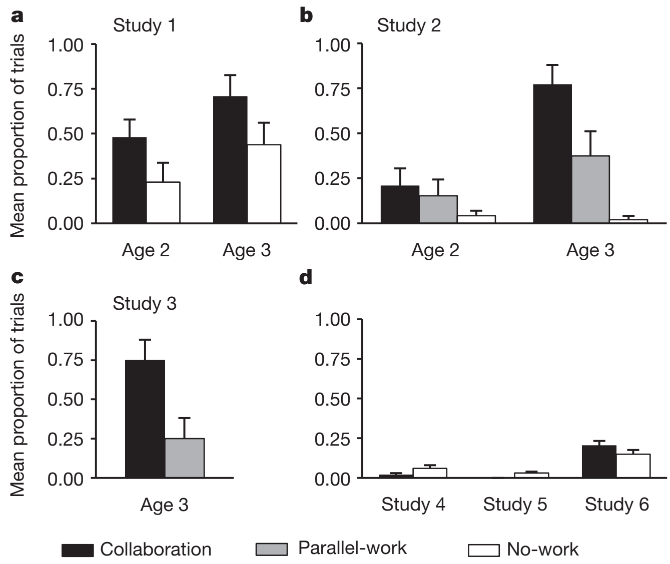

Figure 2 | Rates of equal shares. **a**, In study 1, children in both age groups shared more often in the collaboration condition than in the no-work condition ($F(1, 22) = 21.85$, $P < 0.001$). This was true even if only the results of the first trial in both conditions were used for the analysis (McNemar test, $n_{1,0} = 0$ (number of dyads sharing in the no-work condition but not in the collaboration condition), $n_{0,1} = 6$ (number of dyads sharing in the collaboration condition but not in the no-work condition), $P = 0.03$). **b**, In study 2, three-year-olds, but not two-year-olds, shared differently in the three conditions (significant age × condition interaction, $F(2, 66) = 5.26$, $P = 0.008$; main effect of condition, $F(2, 66) = 12.87$, $P < 0.001$). Three-year-olds shared significantly more often in the collaboration condition than in either of the other two conditions (*post hoc* Scheffé tests, both $P < 0.05$). The difference between the parallel-work and no-work conditions approached significance ($P = 0.06$). **c**, In study 3, children shared significantly more often in the collaboration condition as compared with the parallel-work condition ($\chi^2_{(\text{d.f.}=1, n=24)} = 6.0$, $P = 0.039$). **d**, Across studies 4–6, chimpanzees did not share differently in the collaboration and control (no-work) conditions. See main text and Supplementary Information for details and additional analyses. Error bars, s.e.m.

obtain. Although some researchers have proposed that chimpanzees use work effort during group hunts as a criterion for dividing up the spoils[21], our hypothesis was that because chimpanzees are not true collaborative foragers (at least not to the degree of humans[8,9,13]), they would not share differently in windfall and collaboration situations.

The two chimpanzees operated a single apparatus but from adjacent rooms (after enough practice with the apparatus for both to know how it worked; Supplementary Information). The upper level of the apparatus (Fig. 3) was similar to the apparatus used in the experiment with children, in that it contained a long board holding rewards (in this case food) and attached to a rope that each chimpanzee could access. In all conditions, at some point there was one piece of food on a lower level on a see-saw device, such that the lucky chimpanzee could tip the see-saw only either towards itself or away from itself and towards its partner. In a series of three experiments, we made it increasingly easy for one chimpanzee to make the fallen piece of food available to its partner. In all three experiments, there was a collaboration condition, in which the pair worked together to pull on the board, and a control (windfall) condition, in which the food got into position without the chimpanzees' joint effort.

The first chimpanzee study (study 4) was very similar to the first child study (as this procedure was most facilitative of sharing for the children). In this study, the lucky chimpanzee (who got two pieces of food and had a chance to get the fallen piece) could take the fallen piece for itself or could restore the 2:2 balance by actively providing the fallen piece to the unlucky partner (who got one piece of food and had a chance to get the fallen piece) or by doing nothing and letting the unlucky partner tip it to itself. What happened most often was that

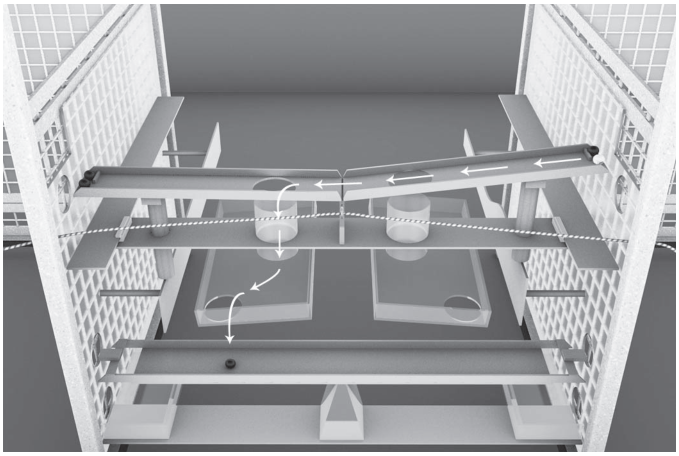

Figure 3 | Chimpanzee study task. The apparatus was mounted in a booth between testing rooms. Two chimpanzees located in adjacent rooms (partition mesh not shown) had to pull the two ends of the rope simultaneously to move the upper-level platform in front of the access holes. During the movement, one of the unlucky individual's rewards (grapes) fell onto the lower, see-saw, level and rolled to the lucky chimpanzee's side. In the picture, the sliding platform (upper level) has been pulled almost to the front. This movement has caused one side of the platform to tilt, causing one grape from the right (initial location represented by the grape drawn in white) to roll to the left, falling through a hole and landing on the see-saw mechanism below. The see-saw could then be tilted by the chimpanzees (manner dependent on study and condition).

the unlucky partner almost immediately tipped the see-saw and took the fallen reward for itself (63% of trials); in no cases did the lucky chimpanzee actively tip the reward to the unlucky partner (even though in pre-training they often tipped the food away from themselves into the other room, if they themselves could then go through an open door and get it). In the remaining trials, the lucky chimpanzee took the reward for itself. Importantly, the fate of the fallen reward did not differ between conditions (Wilcoxon signed-rank test, $T+ = 31.5$, $n = 12$ (no ties), $P = 0.60$). Additional analyses showed that in only 4% of cases did the lucky chimpanzee in fact give up the food voluntarily by tolerating the unlucky partner's taking of it (again with no difference between conditions: $T+ = 18$, $n = 11$ (one tie), $P = 0.19$, Fig. 2d).

In the second chimpanzee study (study 5), we tried to encourage the lucky partner by making it impossible for the unlucky partner to operate the see-saw. The result was that the lucky chimpanzee almost always tipped the food to itself (98% of trials), thus creating a 3:1 reward imbalance. There was again no difference in the rate of equitable sharing between the collaboration and control conditions (Wilcoxon signed-rank test, $T+ = 0$, $n = 4$ (eight ties), $P = 0.13$). In the third chimpanzee study (study 6), we made it impossible for the lucky partner to get the fallen piece of food for itself: if it tipped the see-saw towards itself, the food was lost. This new set-up resulted in a higher sharing rate than before (mean, 0.17 of trials; s.d. = 0.17), with subjects tipping the reward to the unlucky partner more often than in both chimpanzee study 1 ($T+ = 69$, $n = 12$ (no ties), $P = 0.016$) and chimpanzee study 2 ($T+ = 64$, $n = 11$ (one tie), $P = 0.003$). However, as in the previous two chimpanzee experiments, the results did not differ between the collaboration and control conditions ($T+ = 40$, $n = 10$ (two ties), $P = 0.22$; Fig. 2d).

Previous research with older school-age children (seven to ten years of age) has shown that they take into account work effort in so-called distributive justice problems in which one individual must say how the fruits of a collaborative effort should be doled out to participants[22–26]. Younger children typically are not able to factor work effort into their decisions in this way. Nevertheless, the current study shows that although they may be unable to balance work and rewards sensitively, children as young as two or three years of age do take note of whether or not rewards were produced from collaborative efforts with others, and that this affects how they think the rewards should be distributed. Thus, the ontogenetically first sense of distributive justice may be that participation in a collaborative effort demands an equal division of spoils. Because chimpanzees rely very little on collaboration for subsistence, they have not evolved the tendency to distribute resources more equally when those resources result from a collaboration.

Collaborative foraging, by definition, requires partners. Any individual with a tendency to take more than their share of the fruits of a collaboration would not be chosen as a partner very often[27,28]. A possible evolutionary picture is thus that this 'social selection' of a tendency to share the fruits of collaboration equally among participants became ever stronger as the need to work together jointly in subsistence activities became ever more obligate. The current results, according to which young children, but not chimpanzees, share more equally after collaboration than in other situations, provide at least indirect support for this picture.

METHODS SUMMARY

Children. We tested children at 2 and 3 years of age (study 1, $n = 48$; study 2, $n = 144$; study 3, $n = 48$) who were paired with a same-sex peer from the same kindergarten. In the demonstration phase of each study, we first familiarized children with the apparatus requiring them to pull ropes to retrieve rewards (marbles to play an individual game). In all studies, the test event was that the lucky child ended up with three marbles and the unlucky child ended up with only one.

In study 1, during the demonstration phase both individuals learned how to pull together to bring an enclosed board holding rewards within reach of access holes in the enclosure (Fig. 1a). In the test phase, we presented two conditions, collaboration and no-work, in counterbalanced order within dyads.

In study 2, different pairs of children worked on a slightly modified version of the original apparatus (Fig. 1c). Children were tested either in a collaboration condition (preceded by a collaborative demonstration as in study 1), a parallel-work condition (preceded by an individual work demonstration; Fig. 1d) or a no-work condition (preceded by a joint no-work demonstration; Fig. 1e).

In study 3, pairs of three-year-old children participated either in a single collaboration test trial or in a single parallel-work test trial (preceded by demonstrations similar to those in study 2.)

Chimpanzees. We tested 12 chimpanzees separately with two partners from their social group, for a total of 12 test pairs. We conducted three studies with increasing levels of encouragement of the lucky individual to share. We achieved this by blocking the holes the chimpanzees could use to tip the see-saw or retrieve the food (Fig. 3). In all three experiments, we presented the collaboration and no-work conditions in a within-subject design administered in counterbalanced order (for details, see Supplementary Information).

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Supplementary Information is linked to the online version of the paper at www.nature.com/nature.

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