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# Schoolchildren cooperate more successfully with non-kin than with siblings

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Cooperation plays a key role in the development of advanced societies and can be stabilized through shared genes (kinship) or reciprocation. In humans, cooperation among kin occurs more readily than cooperation among non-kin. In many organisms, cooperation can shift with age (e.g. helpers at the nest); however, little is known about developmental shifts between kin and non-kin cooperation in humans. Using a cooperative game, we show that 3- to 10-year-old French schoolchildren cooperated less successfully with siblings than with non-kin children, whether or not non-kin partners were friends. Furthermore, children with larger social networks cooperated better and the perception of friendship among non-friends improved after cooperating. These results contrast with the well-established preference for kin cooperation among adults and indicate that non-kin cooperation in humans might serve to forge and extend non-kin social relationships during middle childhood and create opportunities for future collaboration beyond kin. Our results suggest that the current view of cooperation in humans may only apply to adults and that future studies should focus on how and why cooperation with different classes of partners might change during development in humans across cultures as well as other long-lived organisms.

## 1. Introduction

Cooperation is thought to have played a key role in the evolution of advanced societies, especially in humans [1–7]. Both kin-based interactions and reciprocity can promote cooperation while protecting against cheating [2–6]. Cooperation among kin can mean that benefits to the recipient of help can lead to indirect genetic benefits to the donor, an evolutionary process called 'kin-selection' [8], as described in social insects [9,10] and a number of vertebrates [11,12]. Alternatively (or additionally), unrelated individuals who interact repeatedly can *reciprocate* leading to benefits to each individual in the partnership across time [13,14] such as egg trading in fish [15,16] and allogrooming in primates [17]. More recently, a few studies have shown that both mechanisms can operate in tandem with one mechanism playing a more important role in cooperation for a given system. For example, food sharing in vampire bats is clearly maintained by reciprocity even if such sharing can occur among kin adding further indirect benefits [18–20]. Likewise, cooperation in humans occurs both among kin [21,22] as well as through reciprocal interactions [6,23–27], although human adults clearly favour cooperation with kin over strangers [28–31].

In many organisms, the form of cooperation can change with age. For example, young individuals act as helpers in cooperative breeding birds but adults do not [32,33] whereas the opposite is true in many cooperative breeding mammals [34]. Whether similar shifts occur with age in systems where both kin and non-kin cooperation occur either in absolute terms or in the relative

importance of each form of cooperation is unknown. Studying the development of kin and non-kin cooperation is critical to our understanding of the evolution and function of cooperation in longer-lived organisms and their role in the development and evolution of advanced societies [7,35]. Surprisingly, appropriate experimental tests in humans are still lacking. Among the limited number of experimental studies comparing kin and non-kin cooperation or prosociality in children, reciprocation seems to be important [36–39] but children tend to favour sharing with their relatives compared to strangers [40,41] like adults. However, previous experimental studies of kin-sharing in children use third-party tasks, where participants are asked about abstract scenarios, and these tests often give different results from direct participation in a task [42,43] since it reflects what the participant thinks another person *should* do but not necessarily how they would *actually* behave in a real cooperative situation (see however Crittenden *et al*. [31]). In addition, third-party tasks are thought to be 'removed from the evolutionary mechanisms that […] likely shape these phenomena in early ontogeny' and do not 'reflect the effects of the collaborative foraging context of early humans, in which one shares the spoils […] among those who took part in the *collaborative effort*' [43]. Because no experimental study in children has directly compared kin and non-kin cooperation in situations in which individuals are asked to actively collaborate in a realistic setting, little is known about the development of kin and non-kin cooperation in humans with age.

Here, we used a direct-action cooperation task to evaluate if children cooperate more with kin, friends, or non-friends when actively engaged in a game that requires children to cooperate and coordinate actions with other children. We measured cooperation using a rope-pulling task (figure 1*a*) in which two children coordinate in pulling a single rope to reach a reward and succeed only if both rope ends are pulled at the same time and same speed [44,46,47]. This task is complex and needs the active engagement of children in the task since it requires paying attention to the partners' actions to succeed. While a previous experiment using this design began by giving the children a demonstration, we decided to render the task more difficult by omitting the demonstration and merely telling the children that they would have to work together to complete the task [44]. To examine the roles of kinship and friendship on performance by children of a cooperative task, we assigned each child a partner who could be classified as kin (a sibling), a socially close non-kin (a 'best friend'), or a socially distant non-kin (a non-friend). Pairs were quasi-randomly assigned by the experimenter based on questionnaires administered to teachers and children before the task (see methods) and each pair was allowed to conduct the task until successful or up to three attempts if unsuccessful. In so doing, we investigated whether joint success in a cooperative task was linked to the degree of relatedness between partners in children. We found that children cooperate more efficiently with non-kin (friends and non-friends) than with kin (i.e. siblings) partners.

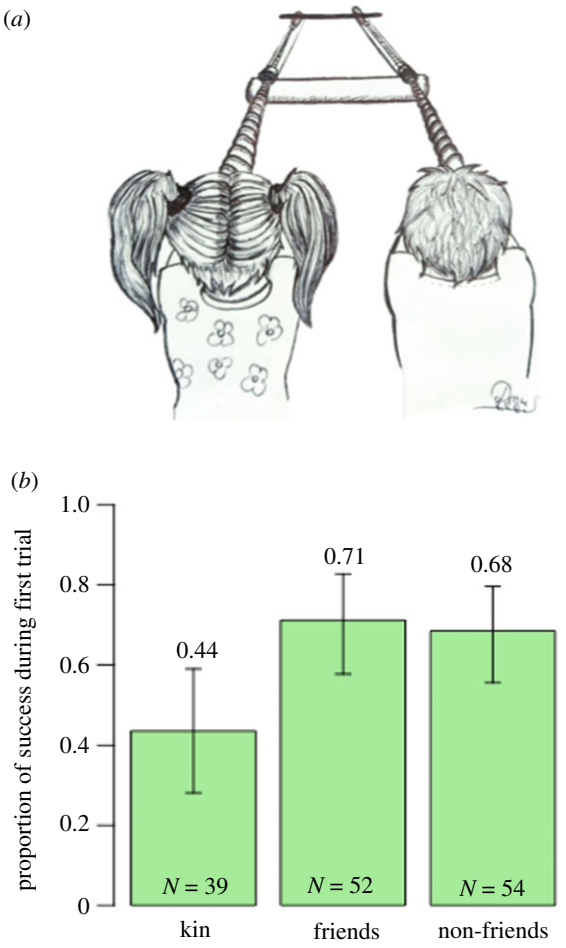


**Figure 1.** Performance in the cooperative rope-pulling task by partner status. (*a*) Illustration of the cooperation apparatus. The 'rope-pulling game' was adapted from previous studies on chimpanzees and children [44,45]. A photograph of the apparatus is also provided in electronic supplementary material figure S1 in the supplemental information (SI). (*b*) Proportion of successful first trials of kin (i.e. siblings) and non-kin friend and non-friend dyads in cooperative rope pulling. Error bars indicate 95% bootstrapped confidence intervals. *N* values indicate the number of dyads in each category (i.e. kin, friends, non-friends). Kin partners were less successful than non-kin in the rope-pulling task. (Online version in colour.)

## 2. Methods

### (a) Participants

We recruited 290 children from ages 3 to 10 (92 3- to 5-year olds, 139 6- to 7-year olds, and 59 8- to 10-year olds; 135 females) from 15 kindergartens and elementary schools in southwestern France. While this age range is large, it reflects all children that potentially interact within schools where the study was conducted as many schools have mixed level classes and a common play area. All parents signed an informed consent form for their children and only children who gave their verbal assent were included. Parents also completed a demographic questionnaire including parents' income, living area (urban versus rural), number of siblings, and native language. Thirty per cent of children were from middle-class backgrounds (20 000 to 30 000 euros/year) and 35% lived in urban areas. Participants had 2.5 siblings on average: 18% were an only child, 44% had only one sibling, 20% had two siblings, and 18% had more than two siblings. Sixty-nine per cent of the children were native French and all children (except two children for whom the test was performed in English) were French-speaking. The same female experimenter tested children during a single video-recorded session in an available room at their schools.

### (b) Experimental procedure

Participants performed a rope-pulling task [46] that requires coordinated pulling to reach a reward (figure 1 and electronic

supplementary material, figure S1). Two children are required to pull their end of the rope simultaneously, each holding the end of the same rope where the two ends are far enough apart that one person could not reach both ends at the same time. A single rope is threaded around an apparatus such that only if both rope ends are pulled at the same time can the containers be moved and the rewards be reached. Pulling on one end would only move the rope but not the two sliding containers which contain the rewards, making the other end of the rope unavailable to a partner. Only if both participants pulled the rope at the same time and at similar speeds, would they each obtain a reward (i.e. joint success, with no delayed reciprocity). Two cases led to failure in the cooperative task: asymmetric pulling led to neither participant obtaining the reward (0/0) or if both participants pulled at the same time but one let go after gathering their reward but before their partner could take their own reward such that just one of the two obtained the reward (0/1 or 1/0). If only one child took his/her own sticker, the sticker was put back into the sliding container and children began a new trial together.

The Experimenter (E) explained to the children that they would play together to each win a reward (stickers) but provided no further instruction. By not providing more guidance, this cooperative task was rendered more difficult than in previous studies using the same game (63% success here versus 94% success during first trials in a previous study [44]). E placed the two rewards (one for each child) in the apparatus (one in each container of the apparatus) under the observation of the children and told them they could start to play.

Each time a pair attempted to pull the ropes is termed a 'trial'. Our measure of cooperation and coordination was focused on a single trial, but upon request of teachers to not create inequalities in the classroom, dyads of children could perform a maximum of three trials beyond which E stopped the testing and gave the stickers to the children. As such, we focused our analyses on the first trials to avoid any impact of learning on joint success in subsequent trials. Overall, most children succeeded within those three trials as 63% (91/145) of the pairs succeeded in the first trial, 21% (31/145) in the second trial, 6% (9/145) during the third trial, and only 10% (14/145) of dyads did not succeed by the third trial. In the supplemental information, we provide additional analyses of these subsequent trials which reinforces results from the first trial only (see electronic supplementary material, results, table S1 and figure S2). Overall the sample included 39 pairs of siblings, 52 pairs of friends, and 54 pairs of non-friends who performed 77, 71, and 67 trials, respectively, corresponding to a total of 215 trials among 145 dyads.

The partners of a dyad could be either siblings, friends (someone they frequently play and interact with), or non-friends (someone they know but do not particularly interact with). The status of the dyad (i.e. siblings, friends, non-friends) was determined before conducting the experiment by asking the children's teachers to name the friends of the participants and specifying each participant's best friend through a questionnaire filled out before the experiment. We asked teachers to base their estimation of relationship closeness of a dyad on the amount of time children spent together, the intensity of positive interactions, and time they play with each other at school [48,49]. Based on the responses of the questionnaires, dyads were formed by E. Following the definition of friendship in the literature [50], 'friends' were formed by dyads where both children considered the other their best friend and 'non-friends' were formed among two individuals where neither considered the other a friend. Furthermore, 'non-friend' dyads specifically avoided matching individuals who have conflictual relationships. Finally, kin status was assigned to any siblings within the class or between two classes in the school. Because it was more rare to find siblings given logistical constraints at schools, possible sibling dyads were formed as a priority. Remaining individuals were then assigned to the other two categories at random. Given that kin dyads naturally showed larger age and sex differences than friend dyads (often same age and same sex), the 'non-friend' dyads were balanced by matching both pairs of the same-age and same-sex children and pairs with large age differences and a different sex to be more similar to the kin category (see electronic supplementary material, figure S3).

In order to confirm the assignation of the dyads based on teacher evaluation of friendship, a questionnaire for children was also performed. E asked children about their relationship with their partner (Do you like to play with CHILD X?) and about the quality of their relationship using an emoticon Likert scale ('How much do you like to play with CHILD X?: a lot, a little, not at all) [51]. The order of the emoticons was counterbalanced across participants to avoid bias. In order to investigate whether participation in the rope-pulling task affected the relationship of the partners, the same questions were administered 24 h after the test. Finally, we gathered information about each child's friend network before the experiment, by asking the child to name their friends (Please, tell me the names of the children you like to play with the most?). Due to logistical constraints, we were only able to gather complete friendship network data at 10 of the 15 schools in our sample.

## (c) Data coding

All trials were recorded using a video camera oriented so that both participants and the apparatus were visible allowing us to score the children's performances. Successful trials were scored when both partners pulled together and successfully reached the reward (i.e. joint success). Failed trials were scored when children failed to pull the rope together such that neither reached the reward or when only one child reached the reward. The same trained research assistant coded the number of gazes (each movement of the eyes accompanied by a movement of the head toward the partner) of each dyad blind to dyad category for the first trial only of each dyad. The number of gazes included situations when both partners look at each other and when a single individual looks at the other one.

## (d) Statistical analysis

All analyses were performed in the R environment for statistical computing version 3.3.6 (R Development Core Team, 2018).

We examined the effect of partner relationship within a dyad on joint success using a binomial generalized linear model (GLM) [52] including the first trial (0 versus 1) performed by each dyad. We built a full model that included fixed effects of dyad relationship (kin, friend, non-friend), dyad sex (male–male (MM), female–female (FF), male–female (MF)), average age of partners, and age difference between the partners. Since nearly all dyads eventually succeeded in performing the task by the third trial (see above), analyses of the change in the relationship between a pair could not be compared between pairs that succeeded in the first trial relative to those who did not and so simply included all individuals.

Coordinated rope pulling could be facilitated by looking at a partner, so we looked at the impact of gaze frequency (gazes per second) on joint success in the first trial (0 versus 1) performed by each dyad using a GLM. We built a full model that included fixed effects of dyad relationship (kin, friend, non-friend), dyad sex (MM, FF, MF), the average age of partners, and age difference between the partners. We also investigated the effect of partner status on the number of gazes using a linear model (LM) including gaze frequency (gaze per second) during the first trial. We included dyad relationship (kin, friend, non-friend), dyad sex (MM, FF, MF), average age of partners, and age difference between the partners as fixed effects.

We then assessed the relationship between performance in the task and the size of a child's social network. Using a binomial GLM, we asked whether performance (0 versus 1) during the first trial was affected by a child's number of friends (i.e. out-degree centrality in social network analysis) while controlling for dyad sex, mean age of the dyad, age difference of the dyad partners, and number of children in the classroom.

For GLMs, visual inspection of residual plots using the DHARMa package [53] did not reveal deviations from homoscedasticity or normality. For each fixed effect, statistical significance was evaluated by likelihood ratio tests of the full model against the same model without the tested fixed effect. In the electronic supplementary material, tables, we report odd-ratios and their corresponding 95% confidence intervals, *p*-values as well as marginal, conditional, or pseudo R2 of the Full Model when appropriate.

Finally, we tested the effect of the rope-pulling task on the quality of the relationship between the two partners, we performed McNemar and Cochran Q tests when appropriate on kin, friend, and non-friend partners separately.

## 3. Results and discussion

During the first trials, 63% (91 out of 145 trials) of the children jointly succeeded in the cooperative rope-pulling task. We found that children cooperate less well with kin than with non-kin (figure 1*b*): the likelihood of cooperating during the first trial was significantly affected by dyad type while controlling for mean age, age difference, and sex of dyads (binomial GLM, partner status: $p = 0.019$, mean age: $p = 0.008$; age difference: $p = 0.084$, sex: $p = 0.81$; figure 1*b* and electronic supplementary material, table S2). Friends (52 dyads, 71% successful; $z = 2.62$; $p = 0.009$) and non-friends (54 dyads, 68% successful, $z = 2.29$; $p = 0.022$) were more likely to succeed on their first cooperative trial than kin partners (39 dyads, 44%, figure 1*b* and electronic supplementary material, table S2), whereas performance of friends and non-friends did not differ from each other ($z = -0.61$; $p = 0.54$; figure 1*b* and electronic supplementary material, table S2). There was no effect of an interaction between the mean age of the dyad and partner status (mean age × partner status: deviance = −0.056; $p = 0.97$) nor between age difference of the dyad and partner status (age difference × partner status: deviance: 1.22; $p = 0.54$) suggesting that any shifts in cooperative preferences towards kin with age must occur beyond the age of 8 to 10 (electronic supplementary material, figure S4). These patterns were consistent when controlling for demographic information (electronic supplementary material, table S3) and restriction to subsets of the data (electronic supplementary material, figures S4, S5).

The contrast in the propensity to cooperate with kin relative to non-kin between studies in adults [21,22,54] and our results in children suggest that there is a striking developmental shift in the value of different forms of interactions. We could not run the same exact study in adults since the task would be far too easy for them and so could not directly contrast preferences in adults and children using the same population. However, studies in adults show a very consistent pattern of kin preferences over non-kin across a broad variety of experimental paradigms (e.g. public good game, prisoners' dilemma) and populations. For instance, adults from Western industrialized countries trust kin more [21], are more likely to cooperate with individuals who have similar facial features to their own [22], and minimize punishment after rule transgression for kin compared to strangers [55,56]. Furthermore, non-Western traditional societies show comparable preferences for cooperation with kin [57,58]. While we did find an improvement in joint success in the cooperative task with age (electronic supplementary material, figure S4 and tables S2 and S3), this improvement did not alter patterns of cooperation between kin versus non-kin (i.e. no significant interaction effect reported above; electronic supplementary material, figure S4) while controlling for dyad age suggesting that contrasts between children and adults in their preference for cooperating with kin are not simply due to an improvement of solving a cooperative task. Well-known cooperative systems shift from cooperation among kin to no cooperation or the reverse with age [32–34], but to our knowledge, such age-related shifts in cooperative preferences have not yet been examined experimentally in systems where both kin and non-kin cooperation coexist. For example, it would be interesting to know if vampire bats which show reciprocal cooperation with non-kin more so than kin among adults show a strong preference for food sharing among kin rather than non-kin among juveniles. Knowing if such shifts are general will require both a concerted effort to document more cases of kin and non-kin cooperation in the same system as well as tests of cooperative preferences with age.

Shifts in preferences for cooperating with kin versus non-kin may be a consequence of a shift in the value of cooperating with different classes of individuals with age. Kin cooperation among adults might provide the greatest direct and indirect benefits to success (e.g. fitness, wealth, etc. [59]) since they have reached reproductive maturity where gene transmission is likely more important than reciprocity thereby favouring kin interactions and indirect genetic benefits from cooperation. On the other hand, children are far from reproductive age and therefore might invest primarily in resource acquisition and survival which can benefit from reciprocal cooperation with peers regardless of kinship. Furthermore, kin-competition might reduce the value of kin cooperation among children (e.g. siblings) [60–62] especially if resources are primarily provided by parents [43]. The benefits of a given cooperative interaction to success in children are indeed modest given that children are still supported by their parents and instead may serve primarily to develop cooperative skills needed for the future such as building a social network [63].

Developing friendships and affiliations with peers in mid-childhood has indeed been linked to future success at adulthood [59,64,65]. Since the current network of young children is still fairly limited, reinforcing and increasing reputation through reciprocity and building a broader social network might thus be more important during childhood than adulthood. Indeed, social networks tend to expand in size among young adults, but shrink in older adults [66]. Here, we found that having a bigger social network before the experiment was related to subsequent performance during the first trial in the rope-pulling task (figure 2) after controlling for the age difference between partners, mean age, sex, and number of children in the classroom (binomial GLM, out degree centrality, or number of friends named by participants: deviance = 5.61; $p = 0.018$, mean age: deviance = 10.27; $p = 0.001$, age difference: deviance = 3.14; $p = 0.076$, sex: deviance = 2.12; $p = 0.35$, number of children in the classroom: deviance = 1.12; $p = 0.29$; figure 3, figure 2, electronic supplementary material, table S4 and figure S6). This correlative relationship could exist either because social individuals

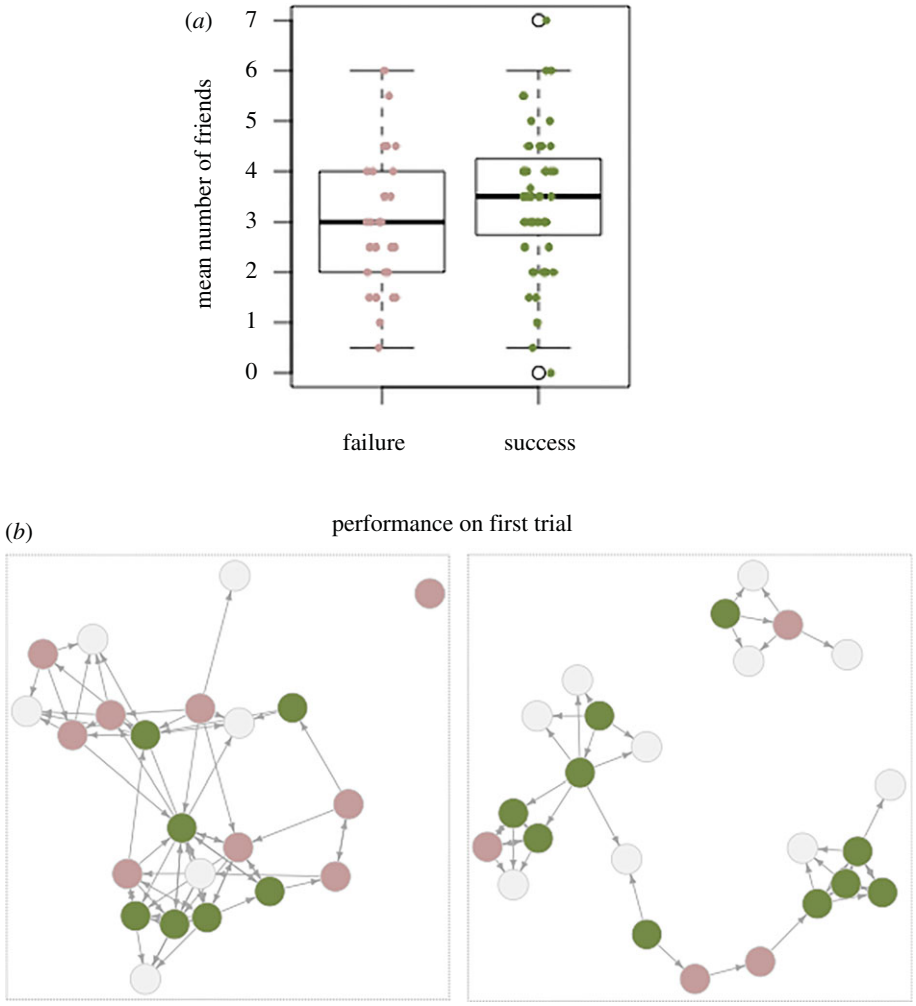


**Figure 2.** Relationship between the number of friends (out degree centrality) and performance in the rope-pulling task. The number of friends and social network were based on a questionnaire before the experiment where children were asked to give the names of children they prefer to play with in their classroom including children who did not participate in the task. (*a*) Boxplots contrasting the number of friends averaged between the two partners according to their performance during the first trial. Failure in the first trial is shown on the left (in red in online version) and joint success on the right (in green in online version). Each dot represents a dyad of children. (*b*) Examples of two classroom networks in which individuals who succeeded in the first trial appear in light grey (green in online version) and who failed in dark grey (red in online version). Children who did not participate and who participants named as friends appear in grey. Arrows represent friendship between children such that bi-directional arrows represent pairs of individuals who each listed the other as a friend whereas single-headed arrows represent cases where one individual considered the other a friend while the second individual did not list the first as a friend. All networks are presented in electronic supplementary material, figure S6. Having more friends is linked to a higher success in the cooperative task. (Online version in colour.)

cooperate more readily or because those who have built a bigger network develop cooperative skills. Regardless of directionality, our results show a cooperative benefit to a larger social network.

Building a large social network should be especially valuable in unpredictable environments, since extending one's social network to cooperate with non-kin could provide benefits when the social community is perturbed whereas limiting one's social network only to kin would be risky [18,19]. For example, under unpredictable/risky situations [19,67] or when non-kin are more numerous than kin [18], different species of mammals (e.g. bats [19], primates and dolphins [67]), tend to favour cooperation with non-kin compared to kin partners. For children, the school environment is constituted mostly of non-kin and has some risks (e.g. victimization by peers [68–70]), so expansion of the social network could indeed carry 'social bet hedging' benefits. If cooperation serves to strengthen or build a social network, we would predict that participation in a cooperative action should alter future interactions. As such, we investigated whether performing the rope-pulling task subsequently modified the relationship between the two partners. To do so, children were asked to rate their relationship with their partner before and again one day after the cooperative task (figure 3) using a Yes/No preference test ('Do you like to play with CHILD X?'; figure 3*a*) and an emoticon Likert scale ('How much do you like to play with CHILD X? A lot, a little, not at all'; figure 3*b*). We found that the relationship quality of non-friends improved after performing the rope-pulling task together in both the Yes/No preference scale (McNemar $\chi^2_{1,56} = 9.60$ ; $p = 0.002$; figure 3*a*) and the Emoticon Likert scale (Cochran $Q(1,55) = 7.35$; $p = 0.007$; figure 3*b*). As expected, we did not detect a change in how much children liked kin partners (Yes/No preference test: McNemar $\chi^2_{1,25} = 1.33$; $p = 0.25$; emoticon Likert scale: Cochran $Q^{(1,25)} = 1.80$; $p = 0.18$; figure 3) and friend partners (Yes/No preference test: McNemar $\chi^2_{1,49} = 1$; $p = 1$; emoticon Likert scale: Cochran $Q^{(1,49)} = 2.78$; $p = 0.10$; figure 3) after the task since kin and friends already liked their dyad partners in nearly all cases before performing the cooperative task (figure 3).

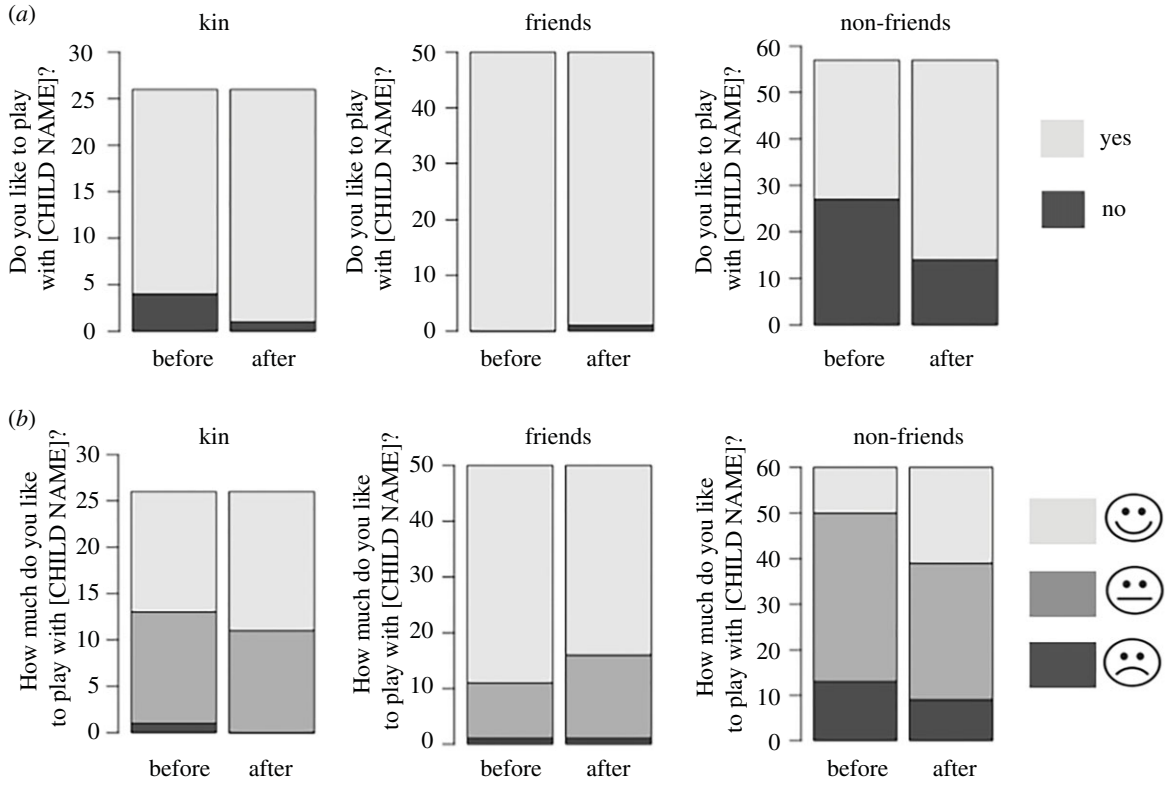


**Figure 3.** Effect of the cooperative task on the relationship quality between kin, friend, and non-friend partners. (*a*) Results from the Yes/No preference scale in which children were asked to answer the following question, before and after the rope-pulling task: 'Do you like to play with CHILD X?'. 'Yes' responses appear in light grey and 'No' responses in dark grey. (*b*) Responses from the Emoticon Likert scale during which children were asked to rate how much they like to play with their partner twice (before and after the rope-pulling task). They can either respond 'a lot' in light grey, 'a little' in medium grey, or 'not at all' in dark grey while pointing to a 'smiley scale' corresponding to each level. Perceived relationship quality of non-friends improved after cooperating.

Overall, our results show that cooperation between non-kin partners plays a key role during childhood which we argue serves to expand a child's social network since non-friends had a more positive view of their 'unknown' partner after interacting during the cooperative task. These results contrast with two studies in which children had to choose how to allocate resources between dolls (i.e. third-party tasks with fictional characters) which both showed greater apparent cooperation with kin than friends or strangers (e.g. [40,71]). We believe that differences in experimental methods led to this contrast since the use of fictional characters is more likely to elicit a response that reflects what children think they or others *should* do [42,72] whereas direct interactions to cooperate in a face-to-face situation used in our experiments should better reflect the actual outcome of natural cooperative situations. Furthermore, direct tasks are more challenging than simple allocation tasks such that costs of cooperation could also alter decisions. A difference in the value of friendships versus sibling relationships among children relative to adults might drive contrasts in how much effort each group put into the cooperative task. The rope-pulling task used here requires continued, active attention and coordination with a partner to succeed. Indeed, we observed that most of the unsuccessful trials happened either when a child pulled the rope before the other could grab it, or when a child let go of the rope before his/her partner could grab their own reward. We hypothesized that one possible explanation of failure could be a lack of attention between the two partners. Consistent with this idea, the number of gazes during the first trials was indeed a strong predictor of joint success (electronic supplementary material, figure S7 and table S5) and kin dyads displayed fewer gazes than other types of dyads (friends partners: $p < 0.005$; non-friends: $p = 0.056$; electronic supplementary material, figure S7).

Using this direct-action cooperation task, we found that children cooperate more with non-kin peers compared to siblings in direct contrast with results in adults. Given the difficulty of our cooperative task for children and considering the time children in Western societies spend at school, we believe our results reflect an ecologically realistic measure [73] of cooperation in schoolchildren, at least in France. However, the value of cooperation with kin versus non-kin could vary by context or culture and it would be interesting to see if our results hold in other populations. Indeed, a more complete understanding of how decisions about cooperation shift through life will require both attention to the context of testing (e.g. [74]) and application of similar direct-interaction tests in individuals from a broad age range and across cultures. Whether such developmental shifts in cooperation are common in other organisms also remains to be explored, but should exist in cases where the benefits of cooperating with different types of partners shifts through life [75]. This new hypothesis motivated by our findings challenges our understanding of cooperation and should stimulate new research into cooperation across life stages in both humans and other social organisms.

Supplementary Information is available for this paper. Correspondence and requests for materials should be addressed to Gladys Barragan-Jason.

Ethics. The treatment of participants in this study was in accordance with the ethical standards of the American Psychological Association. All participants signed an inform consent. This research has been approved by has the TSE-IAST review board for ethical standards in research, under the reference code 2017-01-001.

Data accessibility. Data and code are available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.vx0k6djps [76].

Authors' contributions. G.B.J., A.S.C, M.B., and A.H. designed research; G.B.J. and A.R. performed research; M.C. and G.B.J. analysed data; G.B.J., A.S.C., and M.C. wrote the paper; M.B. and A.H. gave feedback on the paper.

Competing interests. We declare we have no competing interests.

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