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1                    **Schoolchildren cooperate more successfully with non-kin than with siblings**

2

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11 **Abstract**

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

27

28 **Keywords**

29 Kin selection, Kinship, Evolution of cooperation, Children development, Human Evolution

## 30 **Introduction**

31            Cooperation is thought to have played a key role in the evolution of advanced  
32 societies, especially in humans [1–7]. Both kin-based interactions and reciprocity can  
33 promote cooperation while protecting against cheating [2–6]. Cooperation among kin can  
34 mean that benefits to the recipient of help can lead to indirect genetic benefits to the donor, an  
35 evolutionary process called “kin-selection” [8], as described in social insects [9,10] and a  
36 number of vertebrates [11,12]. Alternatively (or additionally), unrelated individuals who  
37 interact repeatedly can *reciprocate* leading to benefits to each individual in the partnership  
38 across time [13,14] such as egg trading in fish [15,16] and allogrooming in primates [17].  
39 More recently, a few studies have shown that both mechanisms can operate in tandem with  
40 one mechanism playing a more important role in cooperation for a given system. For  
41 example, food sharing in vampire bats is clearly maintained by reciprocity even if such  
42 sharing can occur among kin adding further indirect benefits [18–20]. Likewise, cooperation  
43 in humans occurs both among kin [21,22] as well as through reciprocal interactions [6,23–  
44 27], although human adults clearly favor cooperation with kin over strangers [28–31].

45            In many organisms, the form of cooperation can change with age. For example, young  
46 individuals act as helpers in cooperative breeding birds but adults do not [32,33] whereas the  
47 opposite is true in many cooperative breeding mammals [34]. Whether similar shifts occur  
48 with age in systems where both kin and non-kin cooperation occur either in absolute terms or  
49 in the relative importance of each form of cooperation, is unknown. Studying the  
50 development of kin and non-kin cooperation is critical to our understanding of the evolution  
51 and function of cooperation in longer-lived organisms and their role in the development and  
52 evolution of advanced societies [7,35]. Surprisingly, appropriate experimental tests in  
53 humans are still lacking. Among the limited number of experimental studies comparing kin  
54 and non-kin cooperation or prosociality in children, reciprocation seems to be important [36–

55 39] but children tend to favor sharing with their relatives compared to strangers [40,41] like  
56 adults. However, previous experimental studies of kin-sharing in children use third party  
57 tasks, where participants are asked about abstract scenarios, and these tests often give  
58 different results from direct participation in a task [42,43] since it reflects what the participant  
59 thinks another person *should* do but not necessarily how they would *actually* behave in a real  
60 cooperative situation (see however Crittenden et al. [31]). In addition, third party tasks are  
61 thought to be “removed from the evolutionary mechanisms that [...] likely shape these  
62 phenomena in early ontogeny” and do not “reflect the effects of the collaborative foraging  
63 context of early humans, in which one shares the spoils [...] among those who took part in  
64 the *collaborative effort*” [43]. Because no experimental study in children has directly  
65 compared kin and non-kin cooperation in situations in which individuals are asked to actively  
66 collaborate in a realistic setting, little is known about the development of kin and non-kin  
67 cooperation in humans with age.

68         Here, we used a direct-action cooperation task to evaluate if children cooperate more  
69 with kin, friends, or non-friends when actively engaged in a game that requires children to  
70 cooperate and coordinate actions with other children. We measured cooperation using a rope  
71 pulling task (Fig. 1A) in which two children coordinate in pulling a single rope to reach a  
72 reward and succeed only if both rope ends are pulled at the same time and same speed [44–  
73 46]. This task is complex and needs the active engagement of children in the task since it  
74 requires paying attention to the partners’ actions to succeed. While a previous experiment  
75 using this design began by giving the children a demonstration, we decided to render the task  
76 more difficult by omitting the demonstration and merely telling the children that they would  
77 have to work together to complete the task [46]. To examine the roles of kinship and  
78 friendship on performance by children of a cooperative task, we assigned each child a partner  
79 who could be classified as kin (a sibling), a socially close non-kin (a “best friend”) or a

80 socially distant non-kin (a non-friend). Pairs were quasi-randomly assigned by the  
81 experimenter based on questionnaires administered to teachers and children before the task  
82 (see methods) and each pair was allowed to conduct the task until successful or up to three  
83 attempts if unsuccessful. In so doing, we investigated whether joint success in a cooperative  
84 task was linked to the degree of relatedness between partners in children. We found that  
85 children cooperate more efficiently with non-kin (friends and non-friends) than with kin (i.e.  
86 siblings) partners.

## 87 **Methods**

### 88 Participants

89 We recruited 290 children from ages 3 to 10 (92 3-to-5 year-olds, 139 6-7 year-olds  
90 and 59 8-to-10 year-olds; 135 females) from 15 kindergartens and elementary schools in  
91 southwestern France. While this age range is large, it reflects all children that potentially  
92 interact within schools where the study was conducted as many schools have mixed level  
93 classes and a common play area. All parents signed an informed consent form for their  
94 children and only children who gave their verbal assent were included. Parents also filled a  
95 demographic questionnaire including parents' income, living area (urban vs. rural), number  
96 of siblings and native language. Thirty percent of children were from middle-class  
97 backgrounds (20,000 to 30,000 euros/year) and 35 % lived in urban areas. Participants had  
98 2.5 siblings on average: 18% were an only child, 44% had only one sibling, 20% had two  
99 siblings and 18% had more than 2 siblings. Sixty-nine percent of the children were native  
100 French and all children (except 2 children from whom the test was performed in English)  
101 were French-speaking. The same female experimenter tested children during a single video-  
102 recorded session in an available room at their schools.

### 103 Experimental procedure

104 Participants performed a rope pulling task [44] that requires coordinated pulling to  
105 reach a reward (see Fig. 1 and Fig. S1). Two children are required to pull their end of the rope  
106 simultaneously, each holding the end of the same rope where the two ends are far enough  
107 apart that one person could not reach both ends at the same time. A single rope is threaded  
108 around an apparatus such that only if both rope ends are pulled at the same time can the  
109 containers be moved and the rewards be reached. Pulling on one end would only move the  
110 rope but not the two sliding containers which contain the rewards, making the other end of  
111 the rope unavailable to a partner. Only if both participants pulled the rope at the same time  
112 and at similar speeds, would they each obtain a reward (i.e. joint success, with no delayed  
113 reciprocity). Two cases lead to failure in the cooperative task: asymmetric pulling led to  
114 neither participant obtaining the reward (0/0) or if both participants pulled at the same time  
115 but one let go after gathering their reward but before their partner could take their own  
116 reward such that just one of the two obtained the reward (0/1 or 1/0). If only one child took  
117 his/her own sticker, the sticker was put back into the sliding container and children began a  
118 new trial together.

119 The Experimenter (E) explained to the children that they would play together to each  
120 win a reward (stickers) but provided no further instruction. By not providing more guidance,  
121 this cooperative task was rendered more difficult than in previous studies using the same  
122 game (63% success here vs. 94% success during first trials in a previous study [46]). E placed  
123 the two rewards (one for each child) in the apparatus (one in each container of the apparatus)  
124 under observation of the children and told them they could start to play.

125 Each time a pair attempted to pull the ropes is termed a “trial”. Our measure of  
126 cooperation and coordination was focused on a single trial, but upon request of teachers to  
127 not create inequalities in the classroom, dyads of children could perform a maximum of 3  
128 trials beyond which E stopped the testing and gave the stickers to the children. As such, we

129 focused our analyses on the first trials to avoid any impact of learning on joint success in  
130 subsequent trials. Overall, most children succeeded within those 3 trials as 63% (91/145) of  
131 the pairs succeeded in the first trial, 21% (31/145) in the second trial, 6% (9/145) during the  
132 third trial, and only 10 % (14/145) of dyads did not succeed by the 3 trial. In supplemental  
133 information, we provide additional analyses of these subsequent trials which reinforces  
134 results from the first trial only (see supplemental results, Table S1 and Fig. S2). Overall the  
135 sample included 39 pairs of siblings, 52 pairs of friends, and 54 pairs of non-friends who  
136 performed 77, 71 and 67 trials respectively, corresponding to a total of 215 trials among 145  
137 dyads.

138         The partners of a dyad could be either siblings, friends (someone they frequently play  
139 and interact with), or non-friends (someone they know but do not particularly interact with).  
140 The status of the dyad (i.e., siblings, friends, non-friends) was determined before conducting  
141 the experiment by asking the children's teachers to name the friends of the participants and  
142 specifying each participant's best friend through a questionnaire filled out before the  
143 experiment. We asked teachers to base their estimation of relationship closeness of a dyad on  
144 the amount of time children spent together, intensity of positive interactions, and time they  
145 play with each other at school [47,48]. Based on the responses of the questionnaires, dyads  
146 were formed by E. Following the definition of friendship in the literature [49], "friends" were  
147 formed by dyads where both children considered the other their best friend and "non-friends"  
148 were formed among two individuals where neither considered the other a friend.  
149 Furthermore, "non-friend" dyads specifically avoided matching individuals who have  
150 conflictual relationships. Finally, kin status was assigned to any siblings within the class or  
151 between two classes in the school. Because it was more rare to find siblings given logistical  
152 constraints at schools, possible sibling dyads were formed as a priority. Remaining  
153 individuals were then assigned to the other two categories at random. Given that kin dyads



154 naturally showed larger age and sex differences than friend dyads (often same age and same  
155 sex), the “non-friend” dyads were balanced by matching both pairs of the same age and same  
156 sex children and pairs with large age differences and different sex to be more similar to the  
157 kin category (see Fig. S3).

158 In order to confirm the assignment of the dyads based on teacher evaluation of friendship, a  
159 questionnaire for children was also performed. E asked children about their relationship with  
160 their partner (“Do you like to play with CHILD X?”) and about the quality of their  
161 relationship using an emoticon Likert scale (“How much do you like to play with CHILD X?:  
162 a lot, a little, not at all) [50]. The order of the emoticons was counterbalanced across  
163 participants to avoid bias. In order to investigate whether participation in the rope pulling task  
164 affected the relationship of the partners, the same questions were administered 24 h after the  
165 test. Finally, we gathered information about each child’s friend network before the  
166 experiment, by asking the child to name their friends (“Please, tell me the names of the  
167 children you like to play with the most?”). Due to logistical constraints, we were only able to  
168 gather complete friendship network data at 10 of the 15 schools in our sample.

### 169 Data coding

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

179 Statistical analysis

180 All analyses were performed in the R environment for statistical computing version  
181 3.3.6 (R Development Core Team, 2018).

182 We examined the effect of partner relationship within a dyad on joint success using a  
183 binomial GLM [51] including the first trial (0 vs. 1) performed by each dyad. We built a full  
184 model that included fixed effects of dyad relationship (kin, friend, non-friend), dyad sex  
185 (male-male (MM), female-female (FF), male-female (MF)), average age of partners and age  
186 difference between the partners. Since nearly all dyads eventually succeeded in performing  
187 the task by the third trial (see above), analyses of the change in relationship between a pair  
188 could not be compared between pairs that succeeded in the first trial relative to those who did  
189 not and so simply included all individuals.

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

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

203 For GLMs, visual inspection of residual plots using the DHARMA package [52] did  
204 not reveal deviations from homoscedasticity or normality. For each fixed effect, statistical  
205 significance was evaluated by likelihood ratio tests of the full model against the same model  
206 without the tested fixed effect. In supplemental tables, we report odd-ratios and their  
207 corresponding 95% confidence intervals, p-values as well as marginal, conditional or pseudo  
208 R2 of the Full Model when appropriate.

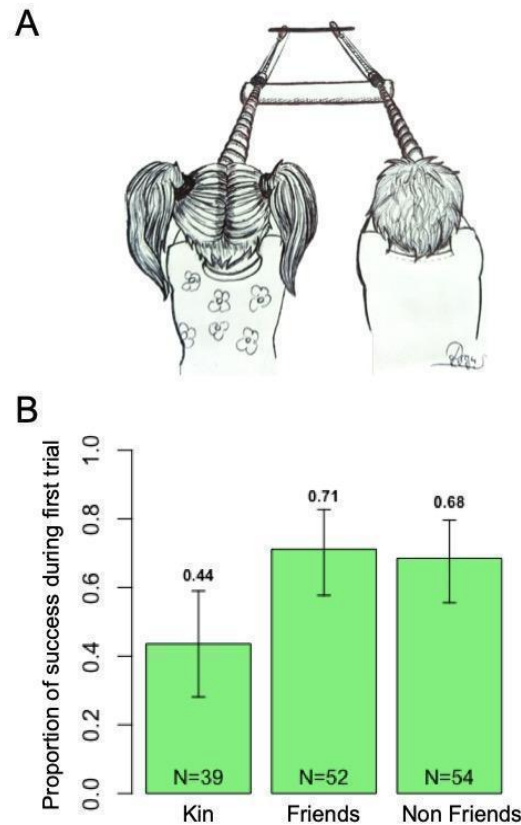
209 Finally, we tested the effect of the rope pulling task on the quality of the relationship  
210 between the two partners, we performed McNemar and Cochran Q test when appropriate on  
211 kin, friend and non-friend partners separately.

212

## 213 **Results and discussion**

214 During first trials, 63% (91 out of 145 trials) of the children jointly succeeded in the  
215 cooperative rope pulling task. We found that children cooperate less well with kin than with  
216 non-kin (Fig. 1B): the likelihood of cooperating during the first trial was significantly  
217 affected by dyad type while controlling for mean age, age difference and sex of dyads  
218 (binomial GLM, partner status:  $P=0.019$ , mean age:  $P=0.008$ ; age difference:  $P=0.084$ , sex:  
219  $P=0.81$ ; Fig. 1B and Table S2). Friends (52 dyads, 71% successful;  $z=2.62$ ;  $P=0.009$ ) and  
220 non-friends (54 dyads, 68 % successful,  $z=2.29$ ;  $P=0.022$ ) were more likely to succeed on  
221 their first cooperative trial than kin partners (39 dyads, 44%, Fig. 1B and Table S2) whereas  
222 performance of friends and non-friends did not differ from each other ( $z=-0.61$ ;  $P=0.54$ ; Fig.  
223 1B and Table S2). There was no effect of an interaction between the mean age of the dyad  
224 and partner status (mean age  $\times$  partner status: deviance= -0.056;  $P=0.97$ ) nor between age  
225 difference of the dyad and partner status (age difference  $\times$  partner status: deviance: 1.22  
226  $P=0.54$ ) suggesting that any shifts in cooperative preferences towards kin with age must

227 occur beyond 8-10 years-old (Fig. S4). These patterns were consistent when controlling for  
228 demographic information (Table S3) and restriction to subsets of the data (Figs. S4, S5).



229

230 *Fig. 1. Performance in the cooperative rope pulling task by partner status. A) Illustration of*  
231 *the cooperation apparatus. The "rope pulling game" was adapted from previous studies on*  
232 *chimpanzees and children [46,54]. Photograph of the apparatus is also provided in Fig. S1*  
233 *in supplemental information (SI). B) Proportion of successful first trials of kin (i.e. siblings)*  
234 *and non-kin friend and non-friend dyads in cooperative rope pulling. Error bars indicate*  
235 *95% bootstrapped confidence interval. N values indicate the number of dyads in each*  
236 *category (i.e. kin, friends, non-friends). Kin partners were less successful than non-kin in the*  
237 *rope-pulling task.*

238

239 The contrast in the propensity to cooperate with kin relative to non-kin between  
240 studies in adults [21,22,53] and our results in children suggest that there is a striking  
241 developmental shift in the value of different forms of interactions. We could not run the same  
242 exact study in adults since the task would be far too easy for them and so could not directly  
243 contrast preferences in adults and children using the same population. However, studies in

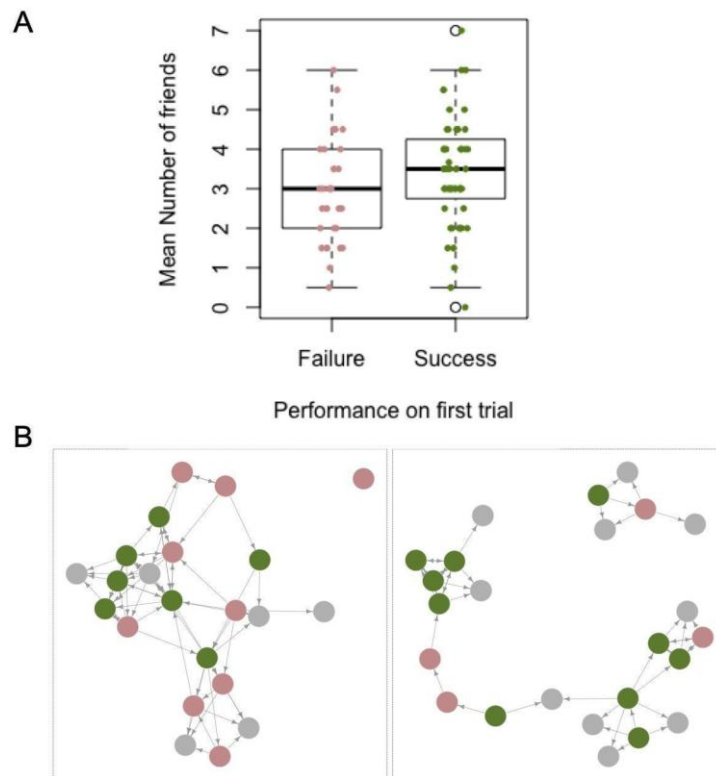
244 adults show a very consistent pattern of kin preferences over non-kin across a broad variety  
245 of experimental paradigms (e.g. public good game, prisoners' dilemma) and populations. For  
246 instance, adults from Western industrialized countries trust kin more [21], are more likely to  
247 cooperate with individuals who have similar facial features to their own [22], and minimize  
248 punishment after rule transgression for kin compared to strangers [55,56]. Furthermore, non-  
249 Western traditional societies show comparable preferences for cooperation with kin [57,58].  
250 While we did find an improvement in joint success in the cooperative task with age (Fig. S4  
251 and Tables S2 and S3), this improvement did not alter patterns of cooperation between kin  
252 versus non-kin (i.e. no significant interaction effect reported above; Fig. S4) while controlling  
253 for dyad age suggesting that contrasts between children and adults in their preference for  
254 cooperating with kin are not simply due to an improvement of solving a cooperative task.  
255 Well known cooperative systems shift from cooperation among kin to no cooperation or the  
256 reverse with age [32] [33] [34], but to our knowledge, such age related shifts in cooperative  
257 preferences have not yet been examined experimentally in systems where both kin and non-  
258 kin cooperation coexist. For example, it would be interesting to know if vampire bats which  
259 show reciprocal cooperation with non-kin more so than kin among adults show a strong  
260 preference for food sharing among kin rather than non-kin among juveniles. Knowing if such  
261 shifts are general will require both a concerted effort to document more cases of kin and non-  
262 kin cooperation in the same system as well as tests of cooperative preferences with age.

263         Shifts in preferences for cooperating with kin vs. non-kin may be a consequence of a  
264 shift in the value of cooperating with different classes of individuals with age. Kin  
265 cooperation among adults might provide the greatest direct and indirect benefits to success  
266 (e.g., fitness, wealth, etc. [60]) since they have reached reproductive maturity where gene  
267 transmission is likely more important than reciprocity thereby favoring kin interactions and  
268 indirect genetic benefits from cooperation. On the other hand, children are far from

269 reproductive age and therefore might invest primarily in resource acquisition and survival  
270 which can benefit from reciprocal cooperation with peers regardless of kinship. Furthermore,  
271 kin-competition might reduce the value of kin-cooperation among children (e.g. siblings)  
272 [61–63] especially if resources are primarily provided by parents [43]. The benefits of a given  
273 cooperative interaction to success in children are indeed modest given that children are still  
274 supported by their parents and instead may serve primarily to develop cooperative skills  
275 needed for the future such as building a social network [64].

276         Developing friendships and affiliations with peers in mid-childhood has indeed been  
277 linked to future success at adulthood [60,65,66]. Since the current network of young children  
278 is still fairly limited, reinforcing and increasing reputation through reciprocity and building a  
279 broader social network might thus be more important during childhood than adulthood.  
280 Indeed, social networks tend to expand in size among young adults, but shrink in older adults  
281 [67]. Here, we found that having a bigger social network before the experiment was related to  
282 subsequent performance during the first trial in the rope pulling task (Fig. 2) after controlling  
283 for the age difference between partners, mean age, sex and number of children in the  
284 classroom (binomial GLM, out degree centrality or number of friends named by participants:  
285 deviance=5.61; P=0.018, mean age: deviance=10.27; P=0.001; age difference:  
286 deviance=3.14; P=0.076, sex: deviance=2.12; P=0.35; number of children in the classroom:  
287 deviance=1.12; P=0.29; Fig. 3, Fig. 2, Table S4 and Fig. S6). This correlative relationship  
288 could exist either because social individuals cooperate more readily or because those who  
289 have built a bigger network develop cooperative skills. Regardless of directionality, our  
290 results show a cooperative benefit to a larger social network.

291



292

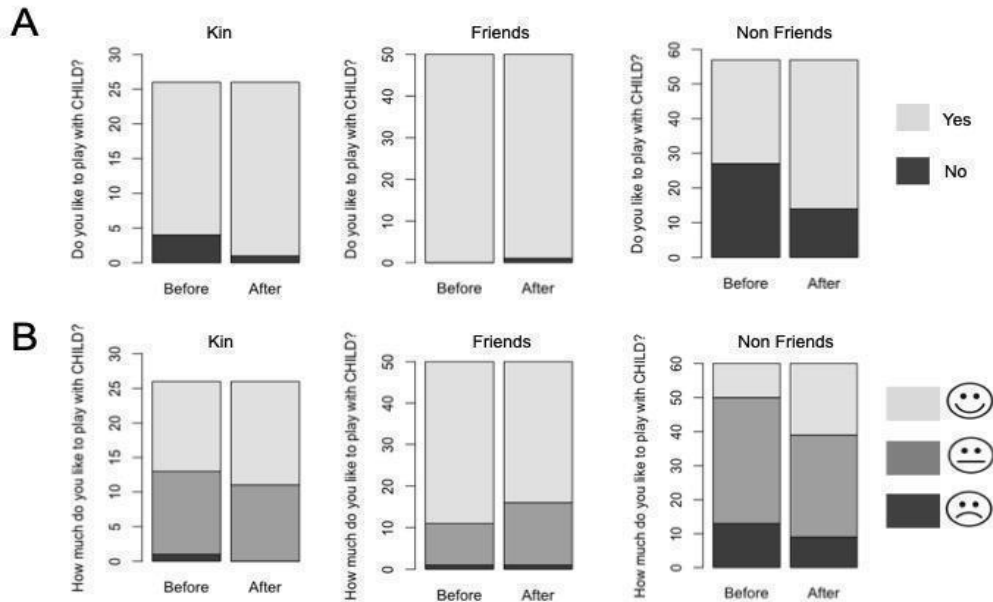
293 *Fig. 2. Relationship between the number of friends (out degree centrality) and performance*  
 294 *in the rope pulling task. The number of friends and social network were based on a*  
 295 *questionnaire before the experiment where children were asked to give the names of children*  
 296 *they prefer to play with in their classroom including children who did not participate in the*  
 297 *task. A) Boxplots contrasting the number of friends averaged between the two partners*  
 298 *according to their performance during the first trial. Failure in the first trial is shown in red*  
 299 *and joint success in green. Each dot represents a dyad of children. B) Examples of two*  
 300 *classroom networks in which individuals who succeeded in the first trial appear in green and*  
 301 *who failed in red. Children who did not participate and who participants named as friends*  
 302 *appear in grey. Arrows represent friendship between children such that bi-directional arrows*  
 303 *represent pairs of individuals who each listed the other as a friend whereas single headed*  
 304 *arrows represent cases where one individual considered the other a friend while the second*  
 305 *individual did not list the first as a friend. All networks are presented in Fig. S6. Having more*  
 306 *friends is linked to a higher success in the cooperative task.*

307

308 Building a large social network should be especially valuable in unpredictable environments,  
 309 since extending one's social network to cooperate with non-kin could provide benefits when  
 310 the social community is perturbed whereas limiting one's social network only to kin would be  
 311 risky [18,19]. For example, under unpredictable/risky situations [19,68] or when non-kin are  
 312 more numerous than kin [18], different species of mammals (e.g. bats [19], primates and  
 313 dolphins [68]), tend to favor cooperation with non-kin compared to kin partners. For children,

314 the school environment is constituted mostly of non-kin and has some risks (e.g.  
315 victimization by peers [69–71]), so expansion of the social network could indeed carry  
316 “social bet hedging” benefits. If cooperation serves to strengthen or build a social network,  
317 we would predict that participation in a cooperative action should alter future interactions. As  
318 such, we investigated whether performing the rope pulling task subsequently modified the  
319 relationship between the two partners. To do so, children were asked to rate their relationship  
320 with their partner before and again one day after the cooperative task (Fig. 3) using a Yes/No  
321 preference test (“Do you like to play with CHILD X?”; Fig. 3A) and an emoticon Likert scale  
322 (“How much do you like to play with CHILD X? A lot, a little, not at all”; Fig. 3B). We  
323 found that the relationship quality of non-friends improved after performing the rope pulling  
324 task together in both the Yes/No preference scale (McNemar  $\chi^2(1,56)=9.60$ ;  $P = 0.002$ ; Fig. 3A)  
325 and the Emoticon Likert scale (Cochran  $Q(1,55)=7.35$ ;  $P=0.007$ ; Fig. 3B). As expected, we  
326 did not detect a change in how much children liked kin partners (Yes/No preference test:  
327 McNemar  $\chi^2(1,25)=1.33$ ;  $P=0.25$ ; emoticon Likert scale: Cochran  $Q(1,25)=1.80$ ;  $P= 0.18$ ; Fig. 3)  
328 and friend partners (Yes/No preference test: McNemar  $\chi^2(1,49)=1$ ;  $P=1$ ; emoticon Likert scale:  
329 Cochran  $Q(1,49)=2.78$ ;  $P=0.10$ ; Fig. 3) after the task since kin and friends already liked their  
330 dyad partners in nearly all cases before performing the cooperative task (Fig. 3).





331

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

341

342 Overall, our results show that cooperation between non-kin partners plays a key role during  
 343 childhood which we argue serves to expand a child’s social network since non-friends had a  
 344 more positive view of their “unknown” partner after interacting during the cooperative task.  
 345 These results contrast with two studies in which children had to choose how to allocate  
 346 resources between dolls (i.e. third party tasks with fictional characters) which both showed  
 347 greater apparent cooperation with kin than friends or strangers [e.g. 40,72]. We believe that  
 348 differences in experimental methods lead to this contrast since the use of fictional characters  
 349 is more likely to elicit a response that reflects what children think they or others *should* do  
 350 [42,73] whereas direct interactions to cooperate in a face-to-face situation used in our  
 351 experiments should better reflect the actual outcome of natural cooperative situations.

352 Furthermore, direct tasks are more challenging than simple allocation tasks such that costs of  
353 cooperation could also alter decisions. A difference in the value of friendships vs. sibling  
354 relationships among children relative to adults might drive contrasts in how much effort each  
355 group put into the cooperative task. The rope pulling task used here requires continued, active  
356 attention and coordination with a partner to succeed. Indeed, we observed that most of the  
357 unsuccessful trials happened either when a child pulled the rope before the other could grab  
358 it, or when a child let go of the rope before his/her partner could grab their own reward. We  
359 hypothesized that one possible explanation of failure could be a lack of attention between the  
360 two partners. Consistent with this idea, the number of gazes during the first trials was indeed  
361 a strong predictor of joint success (Fig. S7 and Tables S5) and kin dyads displayed fewer  
362 gazes than other types of dyads (friends partners:  $P < 0.005$ ; non-friends:  $P=0.056$ ; Fig. S7).

363 Using this direct-action cooperation task, we found that children cooperate more with non-kin  
364 peers compared to siblings in direct contrast with results in adults. Given the difficulty of our  
365 cooperative task for children and considering the time children in western societies spend at  
366 school, we believe our results reflect an ecologically realistic measure [74] of cooperation in  
367 schoolchildren, at least in France. However, the value of cooperation with kin versus non-kin  
368 could vary by context or culture and it would be interesting to see if our results hold in other  
369 populations. Indeed, a more complete understanding of how decisions about cooperation shift  
370 through life will require both attention to the context of testing (e.g. [75]) and application of  
371 similar direct-interaction tests in individuals from a broad age range and across cultures.

372 Whether such developmental shifts in cooperation are common in other organisms also  
373 remains to be explored, but should exist in cases where the benefits of cooperating with  
374 different types of partners shifts through life [76]. This new hypothesis motivated by our  
375 findings challenges our understanding of cooperation and should stimulate new research into  
376 cooperation across life stages in both humans and other social organisms.

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#### 575 **Author Contributions**

576 G. B. -J., A. S. C, M.B and A.H. designed research; G. B. -J and A. R. performed research;  
577 M. C. and G. B. -J. analyzed data; G.B.-J, A.S.C and M.C. wrote the paper; M. B. and A.H.  
578 gave feedback on the paper.

#### 579 **Additional Information**

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

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