Altruism and strategic giving in children and adolescents [*]

Isabelle Brocas
University of Southern California
and CEPR

Juan D. Carrillo
University of Southern California
and CEPR

Niree Kodaverdian
University of Southern California

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Abstract

We conduct a laboratory experiment to investigate the evolution of altruism and strategic giving from childhood to adulthood. 334 school-age children and adolescents (from K to 12th grade) and 48 college students participated in a one-shot dictator game and a repeated alternating version of the same dictator game. Each dictator game featured the choice between a fair split $(4, 4)$ and a selfish split $(6, 1)$ between oneself and an anonymous partner. We find that altruism (fair split in the one-shot game) increases with age in children and drops after adolescence, and cannot alone account for the development of cooperation in the repeated game. Older subjects reciprocate more and also better anticipate the potential gains of initiating a cooperative play. Overall, children younger than 7 years of age are neither altruistic nor strategic while college students strategically cooperate despite a relatively low level of altruism. Participants in the intermediate age range gradually learn to anticipate the long term benefits of cooperation and to adapt their behavior to that of their partner. A turning point after which cooperation can be sustained occurs at about 11-12 years of age.

Keywords: developmental decision-making, altruism, strategic giving, repeated games.

JEL Classification: C72, C91, C92.

1 Introduction

Social interactions are a crucial component of our daily lives. In many instances, the best long term course of action requires a short term sacrifice. Social interactions are known to be shaped by other-regarding preferences and strategic motives but it is unclear how and when we acquire the ability to coordinate on mutually beneficial cooperative actions. It is also well-known that social preferences (Fabes and Eisenberg, 1998; Engel, 2011) and strategic thinking (Sher et al., 2014; Czermak et al., 2016) gradually evolve from childhood to adulthood. However, their relative importance for social decision-making at a given age is not well-understood. If a child shares a toy with his sibling, does it display altruism or is it a strategic decision with reciprocal expectations? Conversely, if he keeps it for himself, is it a myopic choice or is it due to the belief that the sibling will not realize the implicit expectation? Does the behavior of this child change as he grows as a consequence of a socialization process that makes him more empathic? Or does it change because his reasoning becomes more sophisticated? Answering these questions (and more generally, studying developmental decision-making) is critical not only to understand how school-age subjects behave in groups, a topic of practical relevance for children advocates, but also to realize how development shapes the motivations of adults and their ability to select mutually beneficial decisions.

The objective of this paper is to study the evolution from childhood to adulthood of the behavior, motivation and payoff consequences of efficient but costly sharing in dynamic relationships. Our primary goal is to disentangle between altruism –which we define as the willingness to sacrifice own payoff to benefit others– and strategic giving –which we define as the willingness to forego a current payoff as a means to encourage a mutually profitable long term relationship.[1] A major challenge for such a study is to design tasks that are short, simple and engaging, so that children as young as 5 years of age are able to understand and be engaged with them, but also challenging and subtle enough to maintain the attention of adults. In our experiment, we consider two tasks. First, a standard one-shot, anonymous dictator game with two options of "tokens for me" and "tokens for the other", where sharing is privately costly but socially efficient. The options we present are (6,1) and (4,4). Second, the same dictator game played multiple times with a fixed and anonymous partner and with alternating roles, which we call a supergame. We consider school-age subjects (5 to 17 years old) and a control group of USC students (on average,

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[1]We realize that the literature has provided slightly different definitions of "generosity", "altruism" and "prosociality" (see e.g., Blake and Rand (2010); Fehr et al. (2008, 2013); Dreber et al. (2014)). We do not take a strong stance on semantics. Instead, we ask the reader to think of our definition of altruism in terms of a costly transfer or a payoff sacrifice for the benefit of others. Also, we do not explore the motivations for such behavior (pure altruism, warm glow, etc.).

21.3 years old).

We observe the following. Using the likelihood that the subject chooses (4,4) in the one-shot game as a proxy for *altruism*, we find that altruism is hump-shaped: it monotonically increases with age for school-age subjects (from 0.14 to 0.59) and decreases for our control group (0.40) (Result 1). To study *strategic giving*, we consider two sets of measures. First, we study how subjects react to the choices of their partners, which we call "strategic adaptation." We find a significant increase with age in the probability of reciprocating (choosing (4,4) as a response to (4,4) by the partner), from 0.20 to 0.95. By contrast, the probability of choosing (4,4) as a response to (6,1) by the partner is low and relatively constant across age groups (between 0.12 and 0.28) (Result 2). Second, we look for evidence of the ability to anticipate future choices, which we call "strategic anticipation." A simple (and, arguably, pure) way to assess that ability is to look at whether a subject chooses (4,4) in the first round of the first supergame after choosing (6,1) in the one-shot game. Subjects who do so are unambiguously sacrificing some payoff in the first round to promote mutual goodwill in the hope of increasing their long run payoff, and not as a display of altruism. We find a sustained increase across age groups in the probability of choosing (4,4) in the first round among non-altruistic subjects, starting at 0.06 in the youngest population and ending at 0.80 in the control group (Result 3). Finally, despite the differences in behavior across age groups, we find that open-handed tit-for-tat maximizes payoffs in all age groups given the empirical behavior of the group. However, the same (optimal) strategy implies very different actions and payoffs for different age groups. Indeed, it results in subjects playing (4,4) around 35% of the time in our younger school-age subjects, around 75% in our older school-age subjects and around 85% in our control group, with the corresponding difference in expected payoffs (Result 4).

Overall, the increase in cooperation in the supergames results from the combination of three factors: the evolution of altruism, the evolution of strategic thinking, and the effect of the group subjects are in. Our younger subjects are typically selfish and myopic. As they grow, they steadily become more altruistic but, even more significantly, they learn to anticipate the strategic gains of cooperation. They also gradually realize the possibility of prompting their partner to a mutually advantageous implicit agreement. Finally, our control group is the most effective at efficient coordination despite their lack of altruism. That group's behavior suggests that strategic thinking is more important than altruism in order to reach sustained cooperation. Importantly, the differences in choices across ages are magnified by peer effects. Indeed, even if a subject is strategic, his behavior depends on the age group he belongs to. A subject in the youngest age group who plays (4,4) is exploited by his partner whereas the same behavior is rewarded in the older age groups with continued cooperation. Thus, the peer effect is a potent self-reinforcing factor that

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exacerbates differences in motivations across ages.

Our results are consistent with and expand on social and cognitive developmental paradigms. Acting strategically requires people to put themselves in the shoes of others, an ability referred to as Theory of Mind, and to think logically about their own as well others' courses of action. Very young children are self-centered and unable to take the perspective of others. Around 5 years of age, their Theory of Mind ability starts to develop (Premack and Woodruff, 1978). Children become less self-centered and start adapting their behavior to norms and rules in their environment. They move from a situation in which they neither infer nor care about what others think to a situation in which they attribute beliefs to others and empathize with them. This is consistent with the observed increase in altruism among school-age children in our study. The development of logical thinking occurs in stages (Piaget, 1972). Children develop the ability to think logically about what they observe (inductive logic) between the ages of 8 and 12 (Feeney and Heit, 2007). This ability is required for the development of strategic adaptation that we observe in our population. Children start developing the ability to reason abstractly (hypothetical and counterfactual thinking) around 12 years of age (Piaget, 1972; Rafetseder et al., 2013), an ability necessary for the strategic anticipation of the gains of cooperation. The age at which we notice an improvement of strategic anticipation corresponds closely to the time at which hypothetical thinking is known to start developing.

Before proceeding with the analysis, we briefly review the research most closely related to our paper, namely the experimental literatures on repeated prisoner's dilemma games and on decision making by children. There is a burgeoning experimental strand of research on repeated prisoner's dilemma games, revived by Dal Bó (2005) and surveyed in detail by Dal Bó and Fréchette (2014). The literature shows, among other things, that cooperation is enhanced when future interactions are more likely (discount factor closer to 1), subjects gain experience (number of supergames increases), cooperation is risk dominant and cooperation is robust to strategic uncertainty. Unlike this literature, our goal is not to study the determinants of cooperation. Instead, we are concerned about the evolution of altruism and strategic giving from childhood to adulthood (in other words, our main treatment variable is 'age').[2] Notice also that, instead of building on the standard prisoner's dilemma paradigm, we design a slightly different game that better captures the parameters of interest and that children can understand easily.

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[2]Some of this literature partly shares our focus, and correlates altruism with strategic cooperation by looking at behavior in dictator games and repeated prisoner's dilemma (Fudenberg et al., 2012; Dreber et al., 2014). Authors typically find weak or no correlation between the amount of giving in the dictator game and the level of initial cooperation in the repeated prisoner's dilemma, and they conclude that altruism is not a main driving force of cooperation and forgiveness. We also find that strategic considerations are more critical than intrinsic altruism in explaining the increase in cooperation across ages.

The literature in developmental psychology and economics has recently investigated changes in preferences and strategic thinking from childhood to adulthood. Studies have analyzed the evolution of prosociality (Blake and Rand, 2010; Fehr et al., 2008, 2013), reciprocity (House et al., 2013) and third-party punishment (Jordan et al., 2014; Lergetporer et al., 2014), emphasizing different developmental stages in other-regarding concerns and how these concerns are mediated by social interactions (Houser et al., 2012; Chen et al., 2016). Other works have explored the development of strategic thinking (Brosig-Koch et al., 2012; Sher et al., 2014; Czermak et al., 2016; Brocas and Carrillo, 2016), focusing on the gradual acquisition of different aspects of logical reasoning (inductive, deductive, hypothetical and recursive thinking). A third set of studies integrates both strands. They concurrently study age-related changes in altruism and strategic giving using public good games (Harbaugh and Krause, 2000), ultimatum games (Harbaugh et al., 2002) and trust games (Harbaugh et al., 2003; Sutter and Kocher, 2007). Our design has some advantages. First, it allows for a clean comparison between altruism and strategic giving by looking at the one-shot dictator game vs. the first round of the repeated alternating version of the same game. Second, our long repeated interaction provides a rich set of possible strategies, characterized by different degrees of sophistication, forward and backward looking behavior. To our knowledge, Blake et al. (2015) is the only work with a similar approach. The authors propose an innovative design to study cooperation in the prisoner's dilemma. The study looks at children in 5th and 6th grade, and children play either the one-shot or a 5-round version of the repeated prisoner's dilemma. The authors show that gender and conduct problems affect children's tendency to cooperate in those games. Compared to the present article, the limited age-range in Blake et al. (2015) impedes a study of the evolution of choices from childhood to adulthood. Also, the horizon of the repeated game is finite and short, precluding self-sustaining strategic cooperation. Finally, the between-subject design does not make it suitable to analyze the relative importance of altruism vs. strategic thinking in determining behavior at the individual level, nor the interaction between the two motives for giving.

2 Experimental design

Participants. We recruited 334 school-age subjects from grades K to 11th at the Lycée International of Los Angeles (LILA), a bilingual private school in Los Angeles, with campuses in Los Feliz (pre-K to 5th) and Burbank (6th to 12th). We ran 35 sessions that lasted between 60 and 90 minutes. Sessions were conducted in a classroom at the school using touchscreen PC tablets and the tasks were programmed in z-Tree. Sessions had 8 or 10 subjects. For each session, we tried to have male and female subjects from the same grade,

but for logistical reasons sometimes had to mix subjects of two consecutive grades. As a control, we ran 6 sessions with 48 USC students (U). These were conducted at the Los Angeles Behavioral Economics Laboratory (LABEL) in the department of Economics at the University of Southern California, using identical procedures. For the USC population, participants were recruited from the LABEL subject pool.[3] The number of subjects by grade is reported in Table 1.

| Location | \multicolumn{6}{c}{LILA Los Feliz} | \multicolumn{6}{c}{LILA Burbank} | USC |
Grade	K	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	U
# subjects	30	19	30	29	29	19	43	40	31	31	21	12	48

Table 1: Subjects by grade

Tasks. The experiment consists of three tasks always performed in the same order.

The first task is a series of one-shot binary-choice dictator games. Subjects in the session are randomly and anonymously matched in pairs. The dictator, decides between a split (x, y) and a split (x', y'), where the first element is the number of tokens for oneself and the second element is the number of tokens for the other subject, the recipient. After the decision, new pairs are randomly formed, with no information revealed between games. Each subject plays the four dictator games described in Table 2. Games are presented randomly. After subjects have made all four dictator choices, they learn their total accumulated payoffs (tokens kept as dictator in the four games and tokens received as recipient by four random and anonymous partners).[4]

(a)	(b)	(c)	(d)
(6,1) vs. (4,4)	(2,0) vs. (2,2)	(2,4) vs. (2,2)	(4,0) vs. (2,2)
sharing & efficiency	prosociality	envy	sharing

Table 2: One-shot anonymous dictator games

Game (a) has sharing and efficiency components. It constitutes a key benchmark for

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[3]The overwhelming majority of students at LILA go to well-ranked colleges in Europe and the US, so it is a reasonable match for USC college students, despite the obvious differences in backgrounds, size of school, etc. Also, since the distribution of behavior by young adults in dictator games (Engel, 2011) and repeated prisoners dilemma-type games (Dal Bó and Fréchette, 2014) is by now well-understood, the main role of the control population is to determine whether their behavior in our experiment falls on the lines of what is known to occur in similar contexts.

[4]We favored this design over choosing randomly one game to count for payoffs because it is easier to explain to small children. Since subjects only learn the total accumulated payoff and only at the end, we expect that the exact procedure will not significantly affect the choices.

comparison with the behavior in the repeated game. Games (b), (c), (d) are identical (up to scaling) to Fehr et al. (2008, 2013). The *sole purpose* of these games is to determine whether our subjects' attitude towards generosity, spitefulness and egalitarianism is similar to what has been emphasized in the literature.

The second task, which is the core of the paper, consists of two binary-choice alternating dictator supergames, with an *anonymous* partner *fixed* within each supergame. More precisely, subjects are anonymously paired and assigned a role as player 1 or player 2. In round 1, player 1 (the dictator) chooses a split between tokens for himself and tokens for player 2 (the recipient), where the options are $(6, 1)$ and $(4, 4)$, just like in game (a) of the first task. At the end of round 1, player 2 observes player 1's choice. In round 2, player 2 becomes the dictator and player 1 becomes the recipient. Player 2 decides between the same two options. Subjects keep alternating roles between dictator and recipient for the 16 rounds that comprise the first supergame. Subjects know that the supergame consists of "many alternating rounds" (literal words by the experimenter) with a fixed partner but are not told the exact number. At the end of the supergame, subjects are randomly and anonymously rematched with a different subject and play a second supergame, this time comprised of 12 rounds and again not knowing in advance the total length.

This alternating individual choice problem is considerably easier to explain to 5 year-old children than the simultaneous two-player, two-action prisoner's dilemma game. Yet, it captures a similar –though certainly not identical– trade-off between short term loss and long term gain of cooperation (one can easily notice that every pair of rounds is identical to a sequential symmetric prisoner's dilemma where the 'temptation', 'cooperation', 'defection' and 'sucker' payoffs are, respectively, 10, 8, 7 and 5).[5],[6]

Figure 1 provides screenshots of the supergame.

The left screenshot presents the information observed by the dictator. The left panel

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[5]There are two other important differences with the recent infinitely repeated prisoner's dilemma literature (Dal Bó and Fréchette, 2014). First, ending is unknown. This is obviously less rigorous than random ending and introduces the issue of length expectations, but it is much more natural and significantly easier to explain to young children. It precludes comparative statics on the horizon length (which we know is an important variable in adult cooperation) and presupposes a belief at every age that the horizon is long enough that cooperation can be mutually profitable. Overall, it is an imperfect but essential compromise for our study. Second, our subjects play only two supergames. This precludes studying the effect of experience but, again, we felt it was the right choice as the attention span of our population is limited. Notice also that we wanted to avoid a last period effect. For that reason, we reduced the length of the second supergame from 16 to 12 to mitigate last period effects in the (unlikely but conceivable) event that some of the older subjects recalled the length of the first supergame and expected the same number of rounds in the second one.

[6]Payoff-incentives are in the range of the prisoner's dilemma literature. Applying the payoff-normalization of Dal Bó and Fréchette (2014) to our modified prisoner's dilemma game, we get that, every two rounds, $g = l = 2$.
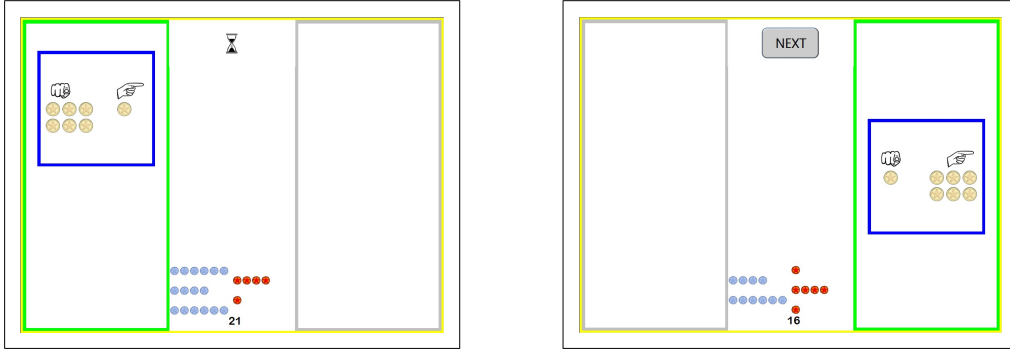
Figure 1: Screenshot of dictator (left) and recipient (right)

randomly displays the two options $(6, 1)$ and $(4, 4)$, one above the other. The dictator is instructed to tap on the preferred alternative and press "OK". In the screenshot of Figure 1, the dictator has selected $(6, 1)$ in the current (5th) round. The middle panel displays the history of the supergame, with the subject's own accumulated tokens in each round. The tokens obtained as a dictator (either 4 or 6) are displayed in blue (rounds 1, 3 and 5) whereas the tokens obtained as a recipient (either 4 or 1) are displayed in red (rounds 2 and 4). This panel fills up in real time as the game progresses. The total number of tokens accumulated is displayed at the bottom. Finally, the right panel of the dictator's screen is blank. The right screenshot presents the information observed by the recipient. The left panel is blank. The middle panel displays the same information as for the dictator (past history and accumulated tokens), except that this time it is presented from the recipient's own perspective. The right panel displays an hourglass picture while the recipient waits. When a choice has been made, it displays the split selected by the dictator from the recipient's own perspective, in this particular case $(1, 6)$, .

The third task is a learning exercise. Balls are sequentially drawn from an urn with green and yellow balls. Subjects are asked to guess the color of upcoming balls and are rewarded for correct guesses. Since this is a different task designed to study a different paradigm, we relegate analysis of this task to a different paper.

Payoffs. During the experiment, subjects accumulate tokens. We implemented two different conversions depending on the subjects' ages. USC students and subjects at LILA Burbank (grades 6th to 11th) had tokens converted into money, paid with an Amazon gift card at the end of the experiment.[7] For subjects at LILA Los Feliz (grades K to 5th) we

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[7]The conversion rate for USC subjects (\$0.15/token) is higher than for LILA Burbank subjects (\$0.07/token) to correct for differences in marginal value of money and opportunity cost of time. It implied large differences in average earnings (\$22.3 vs. \$10.0) despite similar average number of tokens obtained (149

set up a shop with 20 to 30 pre-screened, age and gender appropriate toys.[8] Different toys had different token prices. Before the experiment, children were taken to the shop and showed the toys they were playing for. They were also instructed about the token prices of each toy and, for the youngest subjects, we explicitly stated that more tokens would result in more toys. At the end of the experiment, subjects learned their token earnings and were accompanied to the shop to exchange tokens for toys. We made sure that every child earned enough tokens to obtain at least three toys. At the same time, no child had excess tokens after choosing all the toys they liked.[9] At the end of the experiment, we also collected demographic information consisting of "gender", "age", "grade", "number of younger siblings" and "number of older siblings". A transcript of the read aloud instructions is included in Appendix B.

For analysis, we cluster our subjects into five age groups: K-1st-2nd (G1), 3rd-4th-5th (G2), 6th-7th-8th (G3), 9th-10th-11th (G4) and the control population (G5). Although the cut is somewhat arbitrary, it allows us to reduce the number of groups while maintaining some age homogeneity and not mix subjects from different campuses.[10] Also and unless otherwise noted, when comparing aggregate choices we perform two-sided t-tests of mean differences. Standard errors are clustered at the individual level whenever appropriate. We use a p-value of 0.05 as the benchmark threshold for statistical significance.

3 Analysis of actions and strategies

3.1 One-shot (OS) dictator game: altruism

Our first step consists in analyzing the one-shot version of our main dictator game ((4,4) vs. (6,1) - Table 2 game (a)). Figure 2 presents the choices by age group.

Altruism, defined as the willingness to sacrifice own payoffs to benefit others, increases with age for school-age subjects (differences significant except for G3 vs. G4). It then drops significantly between G4 and our control population G5. While we do not find gender differences when we consider all ages together, we note that females in G1 are more altruistic than males (p-value = 0.041) whereas males in G5 are more altruistic than

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vs. 143). In compliance with LABEL policies, USC subjects were also paid a $5 show-up fee.

[8]These included gel pens, friendship bracelets and erasers for young girls, figurines, die-cast cars and trading cards for young boys, and apps, calculators and earbuds for older kids. However, children were free to choose any item they liked within their budget.

[9]In our experience, incentives are key to retain the attention of children. At the same time, it is important not to have an excessively high variance in payoffs, to avoid dramatic situations. Our payoff-calibration emphasized the value of earning tokens, ensured an enjoyable experience for everyone, and was still in line with the incentives in the literature (see footnote 6).

[10]We did a similar analysis grouping only two grades together and obtained similar results (but lower statistical power).
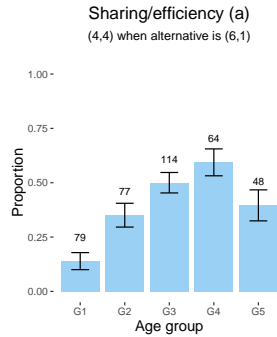
Sharing/efficiency (a)
(4,4) when alternative is (6,1)

(graphs show standard error bars and number of subjects per age group from which proportions are determined)

Figure 2: Aggregate choices in the one-shot dictator game (a) by age group

females (p-value = 0.023). This preliminary result constitutes the basis of comparison for the dynamic game.

Result 1 *Altruism monotonically increases from G1 to G4. Altruism drops between G4 and G5.*

The result is in line with developmental theories of other-regarding concerns (Fabes and Eisenberg, 1998; Hoffman, 2001; Carpendale and Lewis, 2004). Young children (G1) are typically self-centered. With age, they learn to adopt a more generous behavior, initially in response to norms and rules placed around them (elementary school children or G2), then in response to their own judgment and principles (middle and high-school students or G3 and G4, and adults or G5). It is therefore plausible that children in groups G2 to G4 aim at behaving in "stereotypically good" ways, while students in G5 solve a more complex trade-off between the material and moral costs and benefits of behaving nicely.

In Appendix A we study the choices of our subjects in the other one-shot dictator games, and compare them to the existing literature. We find that prosociality increases with age (game (b)) whereas envy decreases with age (game (c)). Sharing (game (d)) follows a very similar pattern to our baseline game (a), with the exception that G5 are marginally more willing to share when the sacrifice is collectively efficient ((a) rather than (d)). In general, the behavior of our subjects regarding generosity, egalitarianism and spitefulness are broadly in line with Fehr et al. (2008). The evolution with age emphasized in Fehr et al. (2013) extends to our older school-age population, and the choice of our college students conforms to standard dictator game theories(Engel, 2011).

Overall and with the caveat that the G5 population is not a perfect match for G1-G4, the evolution from childhood to adulthood in our one-shot dictator game (a) confirms

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known developmental theories and constitutes a valid template for the analysis of the repeated game.

3.2 Alternating dictator supergames: strategic adaptation

By analogy to the prisoner's dilemma and with a slight abuse of language, from now on we call "cooperate" (C) the strategy (4,4), which involves a short term loss in the hope of a long term gain. We call "defect" (D) the strategy (6,1), which involves the myopic maximization of current payoff. In Figure 3 we report $\Pr(C_t)$, the average proportion of cooperative play over all rounds t by age group in the first and second supergame.
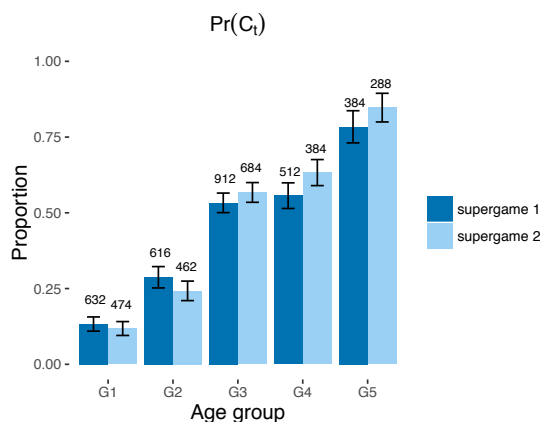
(graph shows standard error bars clustered at the individual level and number of observations per age group from which the proportions are determined)

Figure 3: Cooperation in first and second supergame by age group

In both supergames, we observe a strong and sustained increase in cooperation with age (p-value < 0.01), with the exception of age groups G3 and G4 which are not different from each other. Within a given age group, the level of cooperation is virtually identical in the first and second supergame. Therefore, from now on and unless otherwise noted, we will pool together observations from both supergames. Also, the proportion of cooperation is significantly above 0 for the youngest group and significantly below 1 for the control group. Table 3 presents the proportion of subjects within each age group who select C in every round of both supergames (all 14 choices) or D in every round.

Table 3 suggests that a significant fraction of subjects do not change their behavior during the experiment. Most notably, one-half of our youngest subjects never cooperate whereas two-thirds of our control subjects always cooperate. As we will see below, this is in part a reaction to the behavior of their partners.

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	G1	G2	G3	G4	G5
C every round	0.00	0.03	0.14	0.17	0.65
D every round	0.49	0.27	0.07	0.05	0.08

Table 3: Proportion of subjects with fixed actions by age group

Naturally, $\Pr(C_t)$ is a crude measure. Actions crucially depend on the past behavior of the partners. In Figure 4 we present the probability of cooperation in a given round t (≥ 2) of the supergame conditional on the action taken immediately before (round $t-1$) by the partner: C_{t-1} (left) or D_{t-1} (right).
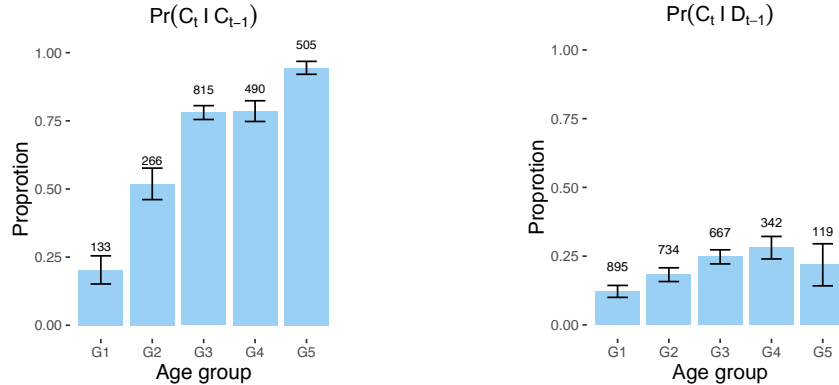
(graphs show standard error bars clustered at the individual level and number of observations per age group from which the proportions are determined)

Figure 4: Conditional cooperation by age group

All subjects respond to the behavior of their partners. In particular, differences between $\Pr(C_t \mid C_{t-1})$ and $\Pr(C_t \mid D_{t-1})$ are highly significant ($p < 0.001$) for all age groups except G1. This suggests that unconditional altruism is not a main driving force of behavior at any age. However, different groups respond differently. *Reciprocity*, defined as $\Pr(C_t \mid C_{t-1})$, follows the same sustained increase with age as the unconditional cooperation $\Pr(C_t)$ though, not surprisingly, levels are statistically higher ($\Pr(C_t \mid C_{t-1}) > \Pr(C_t)$) for all age groups except G1). *Forgiveness*, loosely defined as $\Pr(C_t \mid D_{t-1})$, is low and similar in all age groups (between 0.12 and 0.28), although differences across age groups are still statistically significant between the younger and older school-age subjects (G1 vs.

G3, G1 vs. G4, G2 vs. G4).[11],[12]

Overall, a Markov process seems to nicely capture some basic aspects of the similarities and differences in aggregate behavior across age groups. This would suggest that the main driving effect of age is a change in the willingness to maintain the cooperative agreement, once it is reached. If a subject deviates, reversion to C by the partner is uncommon in all age groups.

However, it would be simplistic to assume that our subjects do not take into consideration behaviors beyond their partner's last move. Indeed, if we consider an extended memory-2 process (the subject's choice as a function of their partner's last two choices), we notice that: $\Pr(C_t \,|\, C_{t-1}, C_{t-3}) > \Pr(C_t \,|\, C_{t-1}, D_{t-3})$ for age groups G2, G3, G4 and G5; $\Pr(C_t \,|\, C_{t-1}, D_{t-3}) > \Pr(C_t \,|\, D_{t-1}, C_{t-3})$ for age groups G3 and G4; and $\Pr(C_t \,|\, D_{t-1}, C_{t-3}) > \Pr(C_t \,|\, D_{t-1}, D_{t-3})$ for age groups G2, G3 and G4.[13] These differences suggest that while Markov strategies can help explain differences across ages, the history beyond the last move also matters. It will therefore be instructive to study the dynamic strategies of our participants. Such analysis is relegated to section 4.2.

Finally, one may wonder whether cooperation can be prompted, induced or taught. To address this question, we present $\Pr(C_t \,|\, C_{t-1}, D_{t-2})$ and $\Pr(C_t \,|\, D_{t-1}, D_{t-2})$ in Figure 5. These two probabilities capture the likelihood that a subject who did not cooperate in round $t-2$ reverts to cooperation in round t as a function of the partner's choice in $t-1$.

Subjects in G2, and even more significantly in G3 and G4, are willing to reverse their non-cooperative strategy if they realize that their partner wants to cooperate. By contrast, our youngest and control populations cannot be convinced to become cooperative if they have decided not to. This is expected in G1 where cooperation levels are pervasively low, but it is surprising in G5 where reciprocal cooperation is extremely high (0.94). It suggests a bi-modal behavior of our control population: sustained cooperation or sustained defection.[14] The conclusions of this section are summarized in the following result.

Result 2 *Strategic adaptation to the partner's choice evolves with age: (i) reciprocity strongly increases with age; (ii) forgiveness weakly increases with age; and (iii) subjects in G2 to G4 can be prompted to cooperate whereas subjects in G1 and G5 cannot.*

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[11]Figures 3 and 4 look very similar when we cluster age groups differently (two grades together) or when we compare the first 4 and last 4 rounds of each supergame (data available upon request).

[12]As in the one-shot games, gender differences are mostly concentrated on the youngest and oldest age groups and move in opposite directions: females in G1 reciprocate more (p-value = 0.001) and forgive more (p-value < 0.001) than males, while males in G5 forgive more (p-value = 0.002) than females. There are no statistically significant gender differences in the other age groups.

[13]Notice, however, that the number of observations in some categories is small and there is a selection effect in the way these variables are constructed.

[14]This last conclusion should be taken with a grain of salt given the small number of observations in G5.
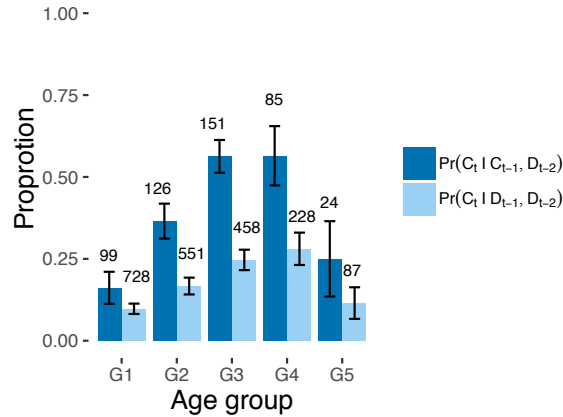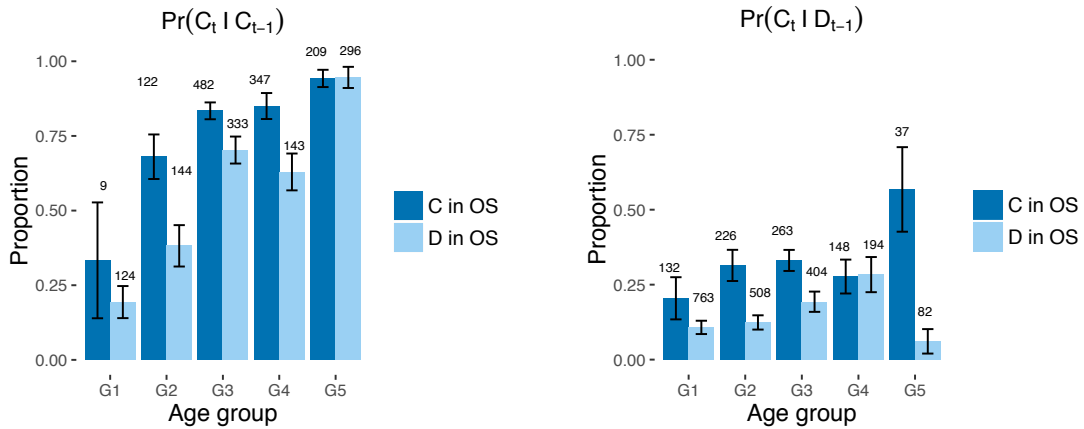
(graph shows standard error bars and number of observations per age group from which proportions are determined)

Figure 5: Learning to cooperate

3.3 The relationship between altruism and strategic adaptation

Motivated by the results in sections 3.1 and 3.2, we now study the relationship between altruism and strategic adaptation. Intuitively, altruistic subjects are likely to be more prone to cooperate. It is unclear, however, whether they will be more or less reactive to the choice of their partner. In Figure 6, we present the fraction of conditional cooperation by age group as a function of the subjects' behavior in the one-shot game.

(graphs show standard error bars clustered at the individual level and number of observations per age group from which the proportions are determined)

Figure 6: Conditional cooperation as a function of choice in OS

Consistent with the fact that behavior in OS game (a) partly reflects altruism, in

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age groups G1, G2 and G3 we observe a higher tendency to cooperate –in terms of both reciprocity and forgiveness–, by subjects who played C in OS than by those who played D in OS (the difference is not statistically significant for reciprocity in G1, a group with only 9 observations). However, even altruistic subjects react to their partner's choice: all age groups except G1 are significantly more likely to reciprocate than to forgive. Therefore, while subjects differ in their intrinsic preference for giving, they all respond to the behavior of others. Differences between our oldest school-age subjects and the control population are more subtle. All G5 subjects seem to realize the strategic gains of reciprocity but those who play C in OS are significantly more forgiving than those who play D in OS. By contrast, all G4 subjects are equally forgiving but those who play D in OS are significantly less likely to reciprocate than those who play C in OS, indicating a lower degree of strategic reasoning.

3.4   One-shot game vs. alternating supergame: strategic anticipation

We have shown that participants adapt to observed play. Our next step is to investigate whether they anticipate future possible beneficial outcomes. A simple test for strategic anticipation consists of analyzing the differences in behavior in OS game (a) and in the first round of the first supergame. The categories are [**CC**], [**CD**], [**DC**] and [**DD**]. So, for example, [**CD**] is an individual who played C in OS and then started the first supergame playing D. Figure 7 presents the results of this exercise. The left graph depicts each of the four probabilities by age group. The right table reports θ, the likelihood of playing C in the first round of the first supergame among the subjects who played D in OS.

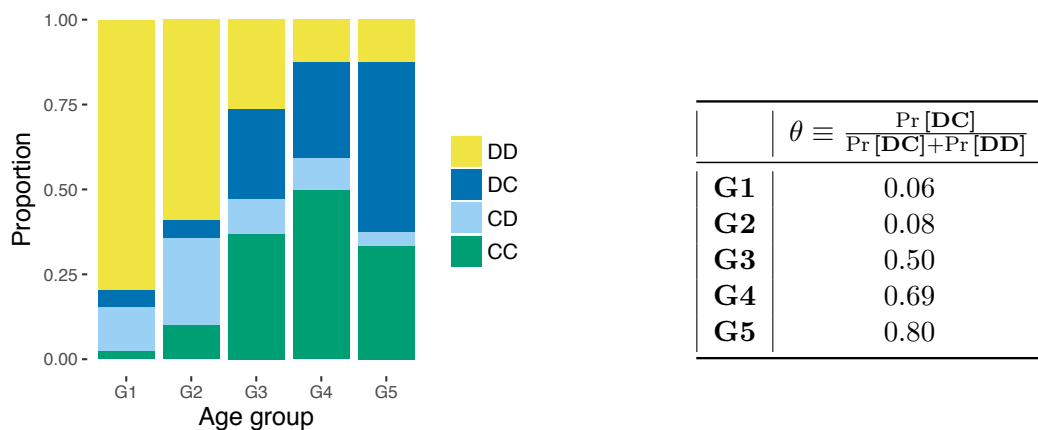|	$\theta \equiv \dfrac{\Pr[\mathbf{DC}]}{\Pr[\mathbf{DC}]+\Pr[\mathbf{DD}]}$
G1	0.06
G2	0.08
G3	0.50
G4	0.69
G5	0.80

Figure 7: Choice in OS game (a) and first round of first supergame by age group

There is a clear evolution in the "strategic anticipation" of the gains of initiating

cooperation, with a highly significant increase in [**DC**] between the younger school-age subjects (G1 and G2) and the older school-age subjects (G3 and G4). These are individuals who are not willing to sacrifice money to benefit their partner in OS game (a) but realize the potential of starting a cooperative agreement in the supergame. Evidence of this strategic giving behavior is still more noticeable in our control population, where [**DC**] is higher than in any other age group (the difference is statistically significant with all groups except G4).[15] The right table confirms those findings. Indeed, among the non-altruistic subjects (those who play D in OS), the percentage of strategic givers dramatically increases across age groups (all differences statistically significant except for G1 vs. G2, G3 vs. G4 and G4 vs. G5).

Result 3 *Strategic anticipation of the gains of initiating cooperation increases with age.*

3.5 The dual effect of altruism and first decisions

The previous sections have shown that altruism, strategic adaptation to past play and strategic anticipation of future play affect behavior in the supergames. Here we present a regression analysis to better assess the individual effects of these factors on cooperation across groups.

We first investigate how reciprocity relates to altruism and to the first decision in the supergame. For this, we run an Ordinary Least Squares (OLS) regression of a player's *Reciprocity* ($Pr(C_t|C_{t-1})$) on his choice in the one-shot game (a) (*Altruism* - coded 1 if the subject cooperated and 0 otherwise) and a dummy variable indicating if the first decision in the repeated game is C (*Choice C first trial*). We also control for age by including age dummies (*Dummy G2* to *Dummy G5*), and for any difference between the supergames, by adding a dummy taking value 1 for observations from the second supergame (*Dummy Supergame 2*). We later include demographic dummies (*Gender Female* and *Number of siblings*). The results are reported in the first 2 columns of Table 4.

Consistent with previous evidence, older and more altruistic subjects reciprocate more. Subjects also reciprocate more if the game starts with a cooperative move, suggesting a key role of the first choice in the pair. To check this prediction, we compute for each pair of players in each supergame the *Cooperation* rate within the pair ($Pr(C_t)$), and we regress it on the first decision in that pair controlling for the altruism of each player in

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[15]Confirming the previous results regarding our school-age subjects, the graph also shows that [**CC**] increases with age (all differences significant except for G1 vs. G2 and G3 vs. G4) and [**DD**] decreases with age (all differences significant except for G3 vs. G4). G5 behaves statistically like G3 and G4 in both cases. For subjects in G2, we also observe a significant fraction of subjects playing [**CD**]. Such puzzling behavior may be due to initial confusion or learning about one's preferences but, unfortunately, we do not have enough data to test this hypothesis.

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	Reciprocity	*Reciprocity*	*Cooperation*
Altruism	0.126***	0.126***	
	(0.030)	(0.030)	
Altruism First Mover			0.110***
			(0.028)
Altruism Second Mover			0.139***
			(0.028)
Choice C first trial	0.231***	0.232***	0.307***
	(0.036)	(0.036)	(0.033)
Dummy G2	0.119**	0.116**	0.036
	(0.056)	(0.056)	(0.040)
Dummy G3	0.293***	0.291***	0.141***
	(0.055)	(0.055)	(0.042)
Dummy G4	0.271***	0.269***	0.131***
	(0.060)	(0.061)	(0.049)
Dummy G5	0.452***	0.451***	0.365***
	(0.064)	(0.065)	(0.053)
Dummy Supergame 2	0.056**	0.056**	0.014
	(0.028)	(0.028)	(0.025)
Gender Female		-0.009	
		(0.029)	
Number of siblings		0.003	
		(0.012)	
Constant	0.143***	0.145***	0.073*
	(0.045)	(0.050)	(0.031)
Adj. R^2	0.340	0.340	0.551
# observations	553	553	382

(standard errors in parentheses)

*, **, *** = significant at 5%, 1% and 0.1% level

Table 4: OLS regression of reciprocity and group cooperation rates across supergames

the pair. The results are reported in the third column of Table 4. They indicate that, while altruism is important, the first choice is critical to establish cooperation. Overall, altruism and strategic anticipation (together with age) are the main drivers of cooperative behavior.

To better disentangle between the importance of altruism and strategic considerations, we consider the first supergame and restrict our attention to the first choice of each player in the pair. We then run Probit regressions, which we report in Table 5. The first set of regressions (columns 1 and 2) looks at the 1st *choice of* 1st *mover* as a function of his altruism and age group. The second set of regressions (columns 2 to 6) looks at the 1st *choice of* 2nd *mover* also as a function of his altruism and age group, as well as the

	1st choice of 1st mover		1st choice of 2nd mover			
Altruism	0.667**	0.693**	0.576**	0.518*	0.296	0.283
	(0.223)	(0.227)	(0.211)	(0.217)	(0.318)	(0.319)
1st *choice*				0.837***	0.661*	0.642*
				(0.241)	(0.303)	(0.306)
Altruism × 1st *choice*					0.417	0.422
					(0.434)	(0.437)
Dummy G2	0.252	0.322	0.398	0.317	0.361	0.395
	(0.397)	(0.410)	(0.360)	(0.365)	(0.366)	(0.370)
Dummy G3	1.612***	1.668***	1.308***	0.890*	0.935**	0.959**
	(0.350)	(0.360)	(0.327)	(0.349)	(0.354)	(0.358)
Dummy G4	1.987***	2.127***	1.525***	1.000*	1.014*	1.054**
	(0.398)	(0.413)	(0.367)	(0.398)	(0.402)	(0.408)
Dummy G5	2.329***	2.374***	1.798***	1.224**	1.265**	1.268**
	(0.432)	(0.436)	(0.390)	(0.429)	(0.433)	(0.434)
Female		-0.045				0.194
		(0.226)				(0.212)
Siblings		-0.181				-0.012
		(0.097)				(0.097)
Constant	-1.571***	-1.388***	-1.357***	-1.417***	-1.369***	-1.465***
	(0.307)	(0.354)	(0.271)	(0.272)	(0.275)	(0.317)
Pseudo R^2	0.335	0.349	0.226	0.272	0.276	0.279
# observations	191	191	191	191	191	191

*, **, *** = significant at 5%, 1% and 0.1% level; (standard errors in parentheses)

Table 5: Probit regression of first choice by First and Second mover

1st *choice of the 1st mover.* We can see from the table that while the initial decision of the first mover in a supergame depends significantly on his altruism (and age), the initial decision of the second mover is mostly driven by the choice of the first mover (and his age). Indeed, altruism loses significance in explaining the second mover's choice after controlling for the choice of the first mover. Besides, altruism does not interact significantly with cooperative first play, suggesting that altruistic second movers are not responding more positively to cooperative first play than non altruistic second movers.

The main conclusion of this analysis is that, even though altruism and strategic considerations are both driving mechanisms of cooperative behavior, the ability to anticipate the benefits of cooperation and to initiate cooperation is crucial in establishing and sustaining cooperation in a group. Second movers respond positively to cooperative first play independently of their level of altruism.

3.6 Summary

Behavioral differences across age groups are the result of (at least) three factors: altruism, strategic adaptation to the partner's choice (reciprocity, forgiveness and learning to co-operate), and strategic anticipation of the benefits of cooperation. Our youngest subjects (G1) are neither altruistic nor strategic. They rarely cooperate in the one-shot games or the supergames. G2 is a more positive version of G1: some of them are altruistic and some can be prompted to cooperate. G3 and G4 are similar to each other. Half of them are altruistic and many are strategic: they are reciprocal, learn to cooperate if prompted and anticipate the gains of cooperation in repeated interactions. Finally, G5 follows the homo economicus template: they are typically not altruistic but recognize and fully exploit the mutual benefits of cooperation.

The results in this section are consistent with theories of cognitive development. Children between 2 and 7 years of age tend to be egocentric (Piaget and Inhelder, 1956; Hughes, 1975; Perner, 1991) and are not yet able to perform logical reasoning. Gradually, they acquire Theory of Mind (Wellman et al., 2001; Wellman and Liu, 2004) and the ability to use logical reasoning (Sher et al., 2014). It is only after 12 years of age that children become able to reason hypothetically and in an abstract manner (Piaget, 1960, 1972; Rafetseder et al., 2013). In our framework, strategic thinking in the supergames requires the ability (i) to take the perspective of partners, (ii) to reason logically about their past moves and (iii) to use this information to reason abstractly about their future moves. Young children in G1, who are not yet thinking logically and are still not able to take a different perspective, are not equipped to think strategically. At the other extreme, students in G5 have acquired Theory of Mind and can think abstractly about the expected gains of cooperation. Children in groups G2 to G4 are gradually acquiring those skills and become progressively better at thinking logically about the past behavior of their partners (strategic adaptation) and at thinking hypothetically about their future behavior (strategic anticipation). Our findings suggest that cognitive abilities and social preferences have different developmental courses. Young children do not have the social or cognitive abilities to behave cooperatively. As they grow, children are motivated by prosociality to engage in cooperation, until they reach an age at which strategic reasoning becomes predominant and can alone support cooperation.

4 Empirical best response

Since choices are different at different ages, individuals who are sophisticated and anticipate the behavior of their peers are likely to make different (optimal) choices depending on their age group. In this section, we explore how to optimally behave against subjects of

different ages. In section 4.1 we assume a minimally strategic choice rule of other players (Markov strategy) and determine the best response. In section 4.2, we consider a more sophisticated contingent planning by subjects in the experiment and, again, determine the best response to such behavior.

4.1 Best response to Markov behavior

Our first approach consists of studying the best response strategy of an individual who plays against the empirical Markov strategy of his age group. Notwithstanding the limitations of Markov choices (we have shown that our subjects respond to decisions beyond the partner's last move) as well as the rationality and extensive knowledge requirements for such a best response behavior, the exercise is nevertheless instructive. Indeed, it explores the possibility that non-equilibrium behavior is a best response to other's choices rather than a non-strategic choice.

Assume that subjects in age group i ($\in \{G1, ..., G5\}$) play a Markov strategy given by $\Pr(C_t \,|\, C_{t-1}) \equiv p_i$ and $\Pr(C_t \,|\, D_{t-1}) \equiv q_i$. Facing a Markov partner, it is optimal to play 'always C' or 'always D.' Indeed, it is not in the subject's best interest to condition the choice in round τ on the partner's choice in $\tau - 1$ since, by the Markov assumption, the partner in $\tau + 1$ will decide between C and D only as a function of one's play in τ (independently of how the decision was reached). By playing always C and always D the expected payoff every two rounds for a subject in age group i is, respectively:

$$V_C^i = 4 + \left[4p_i + (1 - p_i)\right] \quad \text{and} \quad V_D^i = 6 + \left[4q_i + (1 - q_i)\right]$$

where the first term is the payoff when the subject chooses and the second and third terms are the expected payoff when the partner chooses given his Markov behavior.[16] It is then immediate that:

$$V_C^i \gtreqless V_D^i \quad \Leftrightarrow \quad p_i \gtreqless \frac{2}{3} + q_i \tag{1}$$

In Figure 8 we depict the empirical Markov behavior of each age group, pooling data from both supergames. The x-axis is $\Pr(C_t \,|\, C_{t-1}) \equiv p_i$ and the y-axis is $\Pr(C_t \,|\, D_{t-1}) \equiv q_i$. Each magnified dot represents the position of an age group in the (p_i, q_i) space, with the vertical and horizontal lines representing the error bars in the corresponding dimension (data taken from Figure 4). The diagonal line represents all the pairs where the subject is indifferent between C and D ($V_C^i = V_D^i$). The best response behavior is C in the lower right corner below the diagonal and D otherwise, see (1). Intuitively, C is optimal

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[16]For completeness, the payoff of playing the strategy $\Pr(C_t \,|\, C_{t-1}) = 1$ and $\Pr(C_t \,|\, D_{t-1}) = 0$ is $V_{CD}^i = \frac{q_i}{q_i + (1 - p_i)} V_C^i + \frac{(1 - p_i)}{q_i + (1 - p_i)} V_D^i$ and the payoff of $\Pr(C_t \,|\, C_{t-1}) = 0$ and $\Pr(C_t \,|\, D_{t-1}) = 1$ is $V_{DC}^i = \frac{(1 - q_i)}{(1 - q_i) + p_i} V_C^i + \frac{p_i}{(1 - q_i) + p_i} V_D^i$. V_{CD}^i and V_{DC}^i are always dominated by $\max\{V_C^i, V_D^i\}$.

only when the partner is likely to reciprocate ($\Pr(C_t \mid C_{t-1})$ high) and unlikely to forgive ($\Pr(C_t \mid D_{t-1})$ low). Finally, the table in the upper left corner of the graph presents the per-round difference in payoffs between playing 'always C' and playing 'always D' against a subject in age group i. This difference is positive when (p_i, q_i) is in the lower right corner below the diagonal (as for G5) and negative otherwise (as for G1 to G4). Its absolute value increases as we move away from the diagonal.
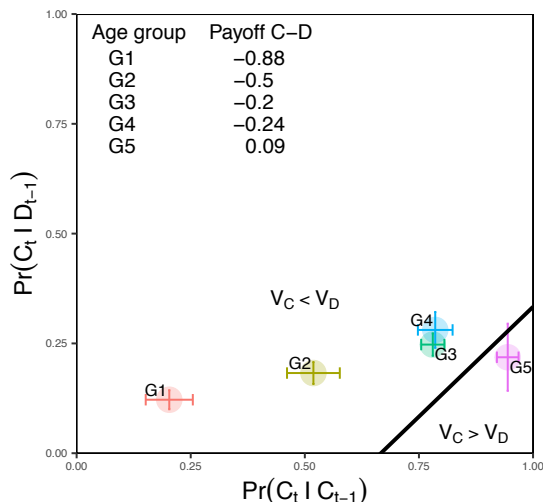

Figure 8: Best response to Markov strategy by age group

For our younger school-age subjects (G1 and G2) there is a significant per-round payoff loss of cooperation, whereas for our older school-age subjects (G3 and G4), the loss is more moderate. For our control population (G5), the best response involves cooperation.[17] The results suggest that while we know that the younger subjects are intrinsically less strategic and forward looking than their older peers, the observed differences in cooperation might be exacerbated due to group membership of the partner: the same self-interested, strategic, forward looking individual should optimally choose D when interacting with young children (G1 or G2) and C when interacting with adults (G5).

4.2 Best response to simple strategies

Since the observed actions strongly depend on past behavior, a natural step in the analysis is to determine the dynamic strategies employed by our subjects, and study the best response to such strategies. We consider up to nine possible simple strategies, many

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[17]Needless to say, this is not an equilibrium: if subjects in an age group i always cooperate ($p_i = 1$ and $q_i = 1$, upper right corner) the best response is to always defect.

of them frequently discussed in the recent repeated prisoner's dilemma literature: (1) closed-handed tit-for-tat (defect if first mover, then tit-for-tat); (2) open-handed tit-for-tat (cooperate if first mover, then tit-for-tat); (3) always defect; (4) always cooperate; (5) grim trigger (cooperate until partner defects, then defect forever); (6) alternating (alternate between defect and cooperate); (7) tit-for-two-consecutive-tats (cooperate unless opponent defects in each of the last two rounds, then defect once and revert to cooperation); (8) reverse tit-for-tat (choose opposite of the partner's preceding choice); and (9) reverse grim trigger (defect until partner cooperates, then cooperate forever).[18]

Only six subjects (1.6%) play one of the last five strategies (this does not include subjects who play strategies that are consistent with one of the last five and also with one of the first four). We will therefore restrict our attention to the first four strategies, which we label as cT, oT, aD and aC. These strategies (together with grim trigger) are also the most commonly observed in the repeated prisoner's dilemma literature (Dal Bó and Fréchette, 2014). With only two observations per subject (one string of actions in each supergame), the ensuing analysis is bound to be incomplete.[19] However, it can be instructive in determining whether subjects in different age groups behave according to simple strategies and, if so, which ones.[20]

The left graph of Figure 9 presents a Venn diagram that depicts the number of subjects who play according to each of the four strategies described above. To be classified as using a strategy, the subject must conform to it in both supergames. To allow small "mistakes", we include subjects who perfectly conform to a strategy and those who deviate once. Finally, we note that some sequences of actions are compatible with more than one strategy (for example, two subjects who always cooperate with each other may be playing aC or oT). The Venn diagram accounts for this possibility by locating the agent at the intersection of all the strategies compatible with the choices.[21,22] The table to the right of the diagram summarizes the percentage of subjects within each age group who conforms

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[18]Tit-for-tat has a slightly different interpretation in this game of perfect information than in the traditional (game of imperfect information) prisoner's dilemma. Naturally, (1) and (2) are indistinguishable for second movers.

[19]Insufficient data due to a low number of supergames may partly account for the absence of grim trigger behavior in our sample.

[20]For an informative and interesting (but substantially more complex) strategy elicitation method in repeated prisoner's dilemma, see Romero and Rosokha (2016).

[21]Subjects are classified based on the closest strategy. So, if a behavior is compatible with one strategy given no deviation and another strategy given one deviation, then it classifies the agent only in the strategy given no deviation.

[22]We use this simple method because we do not have enough supergames to conduct a more sophisticated econometric estimation of strategies like the ones proposed by Dal Bó and Fréchette (2011) or Camera et al. (2012) for example.

to these strategies, ordered from least to most cooperative, that is, aD to aC.[23]

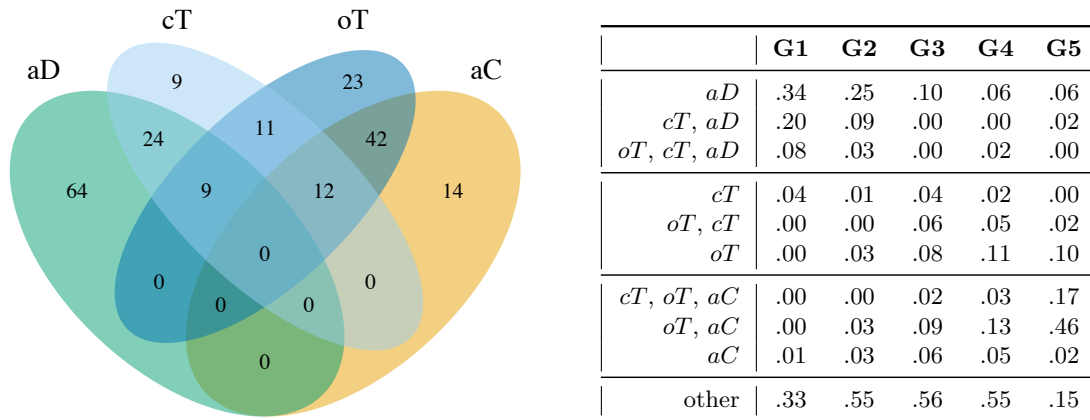|	G1	G2	G3	G4	G5
aD	.34	.25	.10	.06	.06
cT, aD	.20	.09	.00	.00	.02
oT, cT, aD	.08	.03	.00	.02	.00
cT	.04	.01	.04	.02	.00
oT, cT	.00	.00	.06	.05	.02
oT	.00	.03	.08	.11	.10
cT, oT, aC	.00	.00	.02	.03	.17
oT, aC	.00	.03	.09	.13	.46
aC	.01	.03	.06	.05	.02
other	.33	.55	.56	.55	.15

Figure 9: Strategies (1 deviation allowed)

Approximately 65% and 85% of subjects in G1 and G5 respectively conform to a precise strategy (often compatible with aD and aC respectively) whereas the percentage is significantly smaller (around 45%) for the other age groups. This is not surprising, since we already knew from Figure 5 that G2, G3 and G4 have the most malleable behavior, that is, they are most willing to change their action in response to a change in their partner's choice. Interestingly, among the children who do not conform to any strategy, those in age group G3 forgive significantly more (p-value = 0.007) and also prompt significantly more (p-value = 0.036) than those in G2. At that age, a developmental turning point occurs that makes cooperation become sustainable. More generally, there is a gradual transition during childhood from a selfish/myopic to a cooperative/forward looking strategy. Most subjects in G1 play a strategy compatible with aD, as mentioned above. G2 is a weaker version of G1, with a small fraction of subjects choosing a strategy compatible with aC. Neither of these age groups has a significant fraction of subjects whose behavior is consistent with oT and/or cT (but not aD or aC). We find the opposite tendency in G3, G4 and G5, where only a few subjects have strategies compatible with aD and the majority have strategies compatible with oT and/or cT.

Having determined the strategies of our subjects, we can now study the best response to these empirical choices. The analysis is trickier than it seems at first, and requires some judgment calls. For each age group i we compute the proportion of subjects α_s^i who use each of the four main strategies $s \in S = \{aD, cT, oT, aC\}$. Since we do not have a good theory on how to treat subjects who do not fall in any of these categories, we ignore

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[23]We performed the same analysis separately on each supergame and obtained similar results.

other strategies and assume that partners in age group i play strategy s with probability $\gamma_s^i \equiv \frac{\alpha_s^i}{\sum_{s \in S} \alpha_s^i}$.[24] Also, when a subject falls at the intersection of several strategies, we assign him to the one which is most responsive to the partner's choice. This means that oT and cT take precedence over aC and aD; in the case that both oT and cT are consistent with the subject's choice, we assume that each of them is played with equal probability.[25]

Table 6 presents for each age group the payoff of a subject who follows one of the strategies given that the partner plays each strategy with the empirically observed probabilities $\left(\gamma_{aD}^i, \gamma_{cT}^i, \gamma_{oT}^i, \gamma_{aC}^i\right)$. We report per-round payoffs assuming that the subject is the first or second mover with equal probability and that he uses the same strategy in both cases. We also report in brackets the proportion of times the subject plays C and the proportion of times the partner plays C.[26]

	G1	**G2**	**G3**	**G4**	**G5**
aD	3.53 [.00, .02]	3.60 [.00, .07]	3.75 [.00, .17]	3.71 [.00, .14]	3.61 [.00, .07]
cT	3.52 [.05, .05]	3.57 [.12, .13]	3.70 [.37, .38]	3.71 [.41, .41]	3.71 [.41, .41]
oT	**3.61 [.31, .28]**	**3.63 [.36, .33]**	**3.83 [.71, .70]**	**3.89 [.80, .79]**	**3.93 [.86, .86]**
aC	3.20 [1.0, .46]	3.16 [1.0, .44]	3.65 [1.0, .77]	3.78 [1.0, .85]	3.88 [1.0, .92]

Per-round payoff [prob. subject plays C, prob. partner plays C] (best response highlighted in bold)

Table 6: Best response to simple strategies by age group

There are several interesting conclusions from this table. The best response strategy is oT for all age groups. The result is in line with the seminal findings of Axelrod (2006), who highlights the desirable properties of tit-for-tat when confronted by a heterogeneous population: although it is not subgame perfect, it is a strategy that promotes cooperation, punishes deviation and forgives easily. Despite the fact that the optimal strategy is the same in all age groups, outcomes vary widely. Playing oT against our younger school-age subjects (G1 and G2) would result in the cooperative outcome only 28% to 36% percent of the time, and therefore to payoffs above but not far from those under sustained defection. By contrast, playing oT against our our older school-age and control groups (G3, G4 and G5) would result in the cooperative outcome 70% to 86% of the time, reaching payoffs below but reasonably close to those under full cooperation. It is also worth noting that

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[24]This is especially problematic in age-groups G2 to G4 where the aforementioned strategies only account for about one-half of our subjects.

[25]There are many other possibilities: equal likelihood of all strategies consistent with behavior, assign subjects to the least responsive strategy, etc. We opted for the most responsive as it magnifies the effect of the subject's action on the partner's choice.

[26]Naturally per-round payoffs can be computed from those proportions alone, since each time a subject plays C (D) he obtains 4 (6) and each time the partner plays C (D) he obtains 4 (1).

payoff differences between oT and cT are significant in all age groups, even though these strategies are only distinct one-half of the time (when the subject is a second mover). This payoff difference supports the finding in Table 5, which emphasized the key importance of the first decision in the supergame. Finally, we can see from the table in Figure 9 that the proportion of subjects who uses oT, the best response strategy to the empirical behavior of others, increases with age: 8% of participants in G1, 9% in G2, 25% in G3, 35% in G4 and 75% in G5 adopt a strategy compatible with oT. This suggests that participants develop correct beliefs about others over time and gradually learn to best respond to their behavior.

4.3 Summary

This section highlights the similarities and differences between age groups. While the best response strategy is identical in all cases (oT), the resulting behavior is widely different: *the same* selfish, rational forward-looking subject should (optimally) defect when paired with a younger partner and cooperate when paired with an older partner.[27] The observed differences in the levels of cooperation across age groups are therefore the consequence of two mutually reinforcing factors: (i) the differences in preferences and level of strategic reasoning and (ii) the anticipation of the differences in the partners' preferences and level of strategic reasoning. Stated differently, younger children are less strategic and forward than older children and adults, which explains their lower levels of cooperation. However, even the young children who are strategic and forward looking should optimally behave less cooperatively than their older peers. This conclusion is summarized below.

Result 4 *Differences in cooperation across ages are magnified by group effects, that is, by the anticipation that partners in different age groups have different tendencies to cooperate.*

5 Payoffs

We next study earnings. Figure 10 displays the average per-round payoff by age group both unconditional (left graph) and conditional on the subject's behavior in the one-shot game (right graph), pooling data from both supergames. We also report as benchmark horizontal lines the theoretical per-round payoffs that subjects would obtain under sustained mutual cooperation (4.0) and sustained mutual defection (3.5).

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[27]This result is based on indirect evidence. To obtain direct evidence, one should include a design that mixes subjects of different age groups. Although a fascinating possibility, implementing such design has its challenges. Indeed, our experience is that kids behave differently against partners of different ages for reasons that extend beyond strict game theoretic considerations (for example, they can be shy or impressed when they face an older kid). For this reason, we decided against a mixed-age treatment.
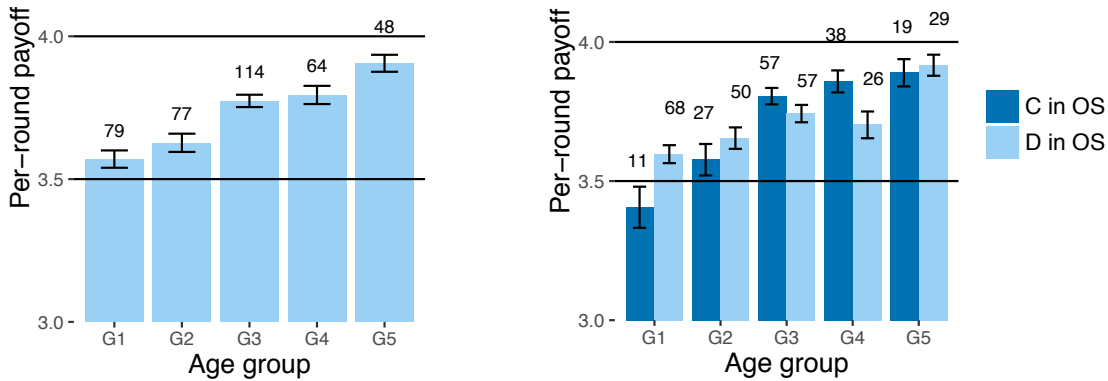
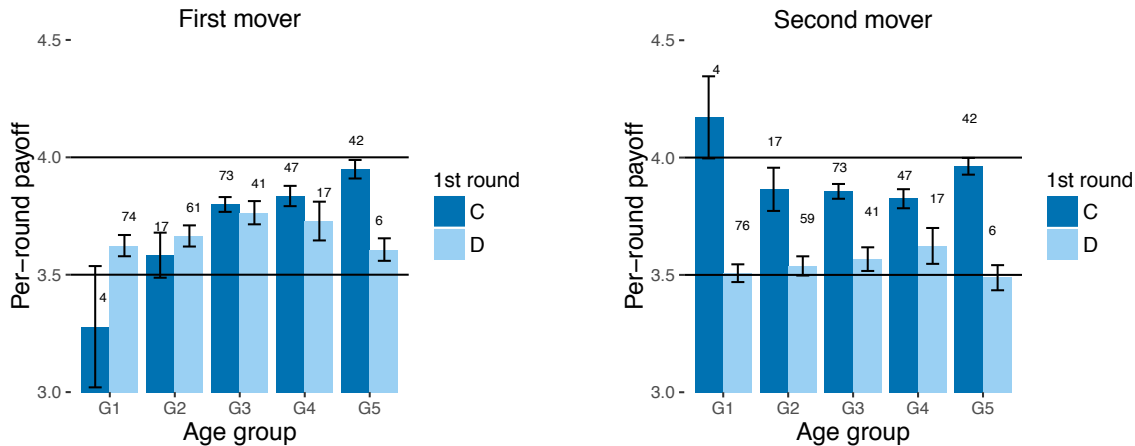(graphs show standard error bars and number of subjects per age group)

Figure 10: Per-round payoffs by age group: unconditional (left) and as a function of choice in OS (right)

Since cooperation increases with age (Figure 3), it is not surprising that payoffs also increase with age (differences significant except for G3 vs. G4). Payoffs within an age group depend on the subject's behavior in the one-shot game. Within our youngest school-age subjects (G1), those who play C in the one-shot game earn less than those who play D: altruism is exploited by their peers. Within our oldest school-age group (G4), the pattern is reversed: subjects who play C in the one-shot game are more likely to start a mutually advantageous agreement, earning more than those who play D. Finally, for our control adult group, behavior in the one-shot game has no predictive power on overall gains in the supergames: subjects who play C in the one-shot game earn as much as those who play D. This is similar to the findings in Dreber et al. (2014). In our case, the reason is that independently of altruism, the vast majority of the adults succeed in coordinating on the mutually advantageous strategy.

While the behavior in the one-shot game is an indicator of the subject's altruism, the behavior in the first round of the first supergame captures (to a certain extent) the willingness to initiate cooperation. To study how the choice in the first round affects the long run payoff of subjects, we perform the following analysis. We divide the sample into supergames where the first mover chose C in the first round and those where he chose D. We then compute the per-round payoff of the subjects from round 3 on (3 to 16 for the first supergame and 3 to 12 for the second) pooling both supergames together.[28] Figure

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[28]We remove round 1 to avoid an artificial difference in average payoffs due to the difference in behavior on the variable we are conditioning on (choice in round 1). We also remove round 2 to make sure that we count the same number of rounds as dictator and recipient for all subjects, otherwise the payoffs of first and second movers are not comparable.

11 presents these average per-round payoffs from the perspective of the first (left graph) and second (right graph) mover.

(graphs show standard error bars and number of subjects per age group)

Figure 11: Per-round payoffs of first (left) and second (right) mover from round 3 on, and as a function of choice in round 1

For school-age subjects who moved first, differences in per-round payoffs after round 3 are not statistically significant between those who played C and those who played D in round 1. However, it is interesting to see that subjects in G1 and G2, if anything, earn less when they start playing C, as they get exploited (though, the number of observations is small and the difference is not significant at the conventional 5% level). By contrast, the first action is crucial in G5: starting with C results almost invariably in sustained cooperation whereas starting with D results also almost invariably in sustained defection. This reinforces the results of section 3.2 where we found that subjects in our control population could not be prompted to cooperate (Figure 5). The result is also consistent with the developmental turning point around G3, as mentioned earlier: playing C in the first round pays off when children are capable of adapting their behavior to the behavior of others. Differences are starker for second movers, where subjects in all age groups significantly benefit from a partner who starts by playing C, either by taking advantage of them (younger school-age subjects) or efficiently coordinating in mutual cooperation (older school-age subjects and control group). More generally, the analysis of payoffs supports the findings of section 4, where we showed that identical actions have different consequences depending on the age of the partner. More specifically, subjects who are altruistic or strategic givers tend to obtain high rents against older partners but low rents against younger ones.

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	Per-round payoff		
Altruism	0.065*	-0.011	-0.010
	(0.025)	(0.025)	(0.025)
Choice C first trial		0.174***	0.174***
		(0.030)	(0.030)
Dummy G2		0.029	0.028
		(0.037)	(0.037)
Dummy G3		0.097**	0.098**
		(0.038)	(0.038)
Dummy G4		0.102**	0.105**
		(0.044)	(0.045)
Dummy G5		0.191***	0.194***
		(0.048)	(0.048)
Dummy Supergame 2	0.010	0.007	0.007
	(0.025)	(0.023)	(0.023)
Gender Female			-0.020
			(0.024)
Number of siblings			-0.005
			(0.010)
Constant	3.690***	3.562***	3.578***
	(0.020)	(0.028)	(0.032)
Adj. R^2	0.009	0.141	0.142
obs.	764	764	764

(standard errors in parentheses)

*, **, *** = significant at 5%, 1% and 0.1% level

Table 7: OLS regression of Per-round payoffs across supergames

To better disentangle the impact of altruism and strategic motives on rents, we conduct an OLS regression of the *Per-round payoff* of all subjects from round 3 on. Altruism is again measured by the choice in the one-shot game (a) and strategic motives are captured by the choice in the first round of the supergame. The results are reported in Table 7.

As we can see from the first column, altruism has a moderate positive impact on payoffs, through the likelihood of engaging in a long term cooperative agreement. However, when we include age and strategic considerations, we observe that being in an older age group and being in a pair that cooperates from the outset become the main determinants of payoffs. Once we control for these factors, the effect of altruism on rents disappears.

6 Concluding remarks

In this study, we have investigated developmental aspects of efficient but costly sharing in dynamic relationships. We have identified three main drivers: altruism, strategic adaptation to partner's decisions and strategic anticipation of cooperative gains.

It is interesting to note that only in the older age groups a significant fraction of subjects best respond to the empirical distribution of play in their group. These findings are reminiscent of recent studies showing that observed behavior differs as a function of the players' expertise (Palacios-Huerta and Volij, 2009) or IQ (Proto et al., 2016). As in this literature, subjects in different ability categories (in our case, age groups) play differently. Those in the highest ability category are the most strategic, both in adapting to the choices of others as well as in anticipating what the behavior of the partners will be. This in turn suggests that there might exist a cognitive link between the ability to think hypothetically about future consequences and the ability to form beliefs about others. Children who simply adapt to past play are not only unable to assess hypothetical future actions but also to assess the likelihood that others might choose those actions. We conjecture that, as hypothetical thinking develops, the abilities to foresee, best respond and form correct beliefs about others develop jointly.

While the connection between Theory of Mind and game theory is well established (Singer and Fehr, 2005), our understanding of the logic required to perform well in games is still imperfect. First, logical thinking is multi-facetted and social interactions require different types of reasoning (to make correct inferences and deductions, to anticipate future outcomes, and to logically best-respond to what is inferred and deduced). Second, logical thinking in strategic settings varies in complexity. As summarized for example in Camerer (2003), the body of experimental evidence indicates that decision-makers are able to play close to Nash easily in some games (e.g., coordination games), if they are given enough learning opportunities in some others (e.g., guessing games), and rarely in yet other cases (e.g., games of asymmetric information). This difference in the likelihood of reaching the equilibrium is likely due to differences in the logic required to solve those games and the complexity involved. It is, however, difficult to assess which type of logical ability is lacking in adults, because behavior reflects the interplay of all of one's abilities, some of them perhaps not fully acquired. By studying the development of strategic thinking, it becomes possible to assess the contributions of different logical abilities to strategic behavior. From our study, it seems that hypothetical thinking is key for sustaining cooperation and plays a bigger role than altruism. Further studies on strategic thinking in children should prove helpful to build behavioral models capable of both explaining and predicting the heterogeneity in behavior observed in experimental studies.

Last but not least, understanding how children and adolescents reason about choices and make strategic decisions is crucial for designing policies around school-age children and adolescents, and for enhancing a favorable educational environment. Perhaps the most important findings relate to the heterogeneity of behavior across ages due to the differences in perspectives, motivations and logical abilities to devise strategies. This means for instance that interventions aimed at regulating interactions between children (e.g., bullying) should control for age, as we cannot assign the same intentions to a young child than to an adolescent. In our study, non-cooperative behavior can be due to a lack of altruism or an inability to anticipate the gains of cooperation. Adults tend to associate anti-social behavior to an impaired capacity to relate emotionally to others, and they usually frame that behavior negatively. Our study suggests that young children may behave in an anti-social manner simply because they are not able to draw logical conclusions about what may happen under different scenarii. Understanding motivations behind the actions of children may be helpful for determining whether intervention in the regulation of a conflict should take the form of a stick (a punishment for not relating emotionally to others) or a carrot (an explanation for why thinking thoroughly would yield a superior outcome).

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Appendix A: analysis of one-shot games (b), (c) and (d)

Figure 12 presents the choices in the one- shot dictator games (b), (c) and (d) described in Table 2.
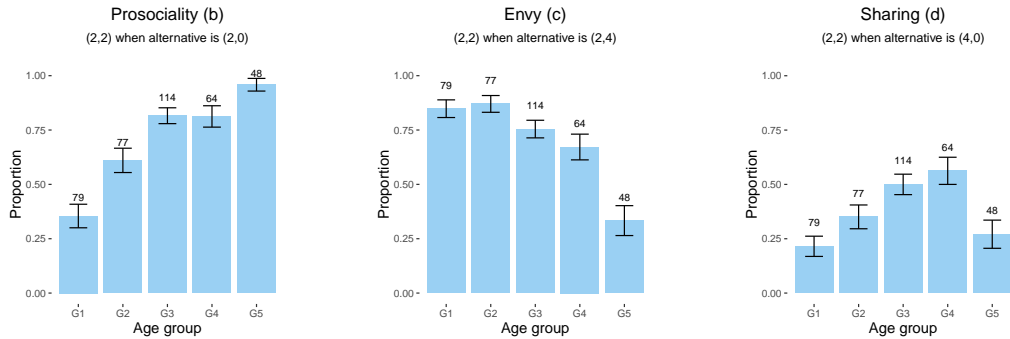
(graphs show standard error bars and number of subjects per age group from which proportions are determined)

Figure 12: Aggregate choices in the one-shot dictator games (b), (c), (d) by age group

Prosociality (b) increases with age (differences significant except for G3 vs. G4) and envy (c) decreases with age (differences significant except for G1 vs. G2, G1 vs. G3 and G3 vs. G4). Sharing (d) follows the same pattern as (a): it increases from G1 to G4 (differences significant except G1 vs. G2 and G3 vs. G4) and significantly drops between G4 and G5. Sharing within G5 is marginally higher (p-value = 0.057) when the sacrifice is collectively efficient ((a) rather than (d)), that is, when the relative price of giving is smaller. A difference between choices in (a) and (d) is not present in any other age group. It is a first indication that G5 is more strategic in their decision to sacrifice payoffs for others than the older school-age subjects.

Overall, we find sustained and systematic developmental changes. Choices between our two groups of younger school-age subjects (G1 and G2) are different but not widely so, and the same is true between our two groups of older school-age subjects (G3 and G4). The control population (G5) is an extreme version of older school-age subjects in terms of prosociality and envy but rather different in terms of their willingness to share.

We can also use the one-shot games to study other-regarding preferences. We define the same five types as in Fehr et al. (2008, 2013) depending on the choices in games (b), (c) and (d): "strongly egalitarian" (choices (2,2); (2,2); (2,2)), "weakly egalitarian" (choices (2,2); (2,2); (4,0)), "strongly generous" (choices (2,2); (2,4); (2,2)), "weakly generous" (choices (2,2); (2,4); (4,0)), and "spiteful" (choices (2,0); (2,2); (4,0)). Figure 13, reports the proportion of subjects who belong to each of these five categories in Fehr et al. (2008,

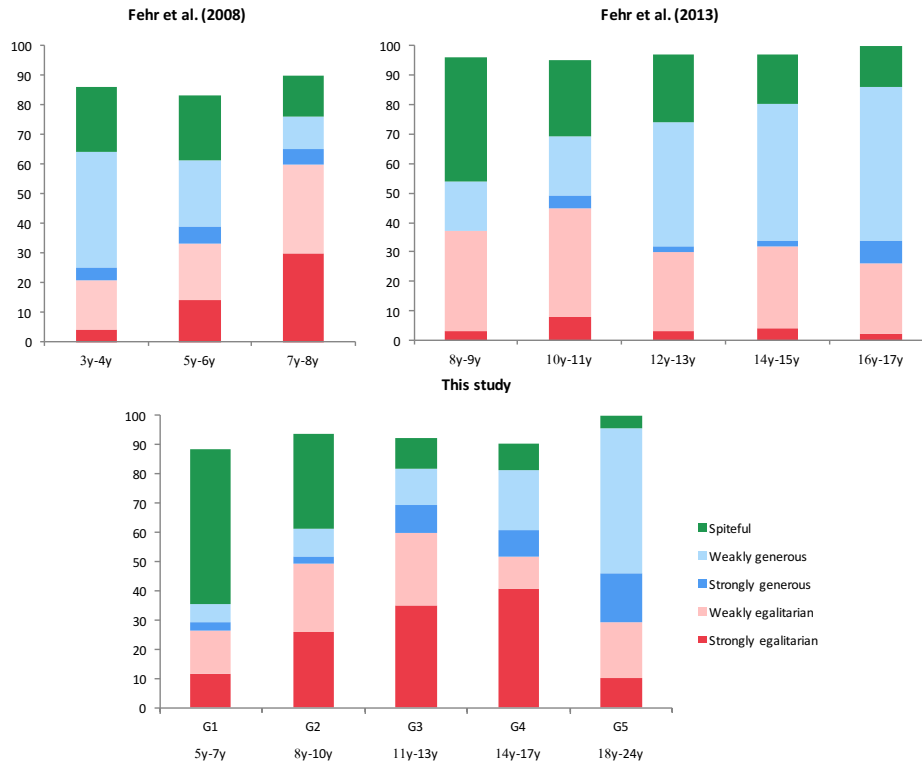2013) (upper graphs) and in our study (lower graph).

Figure 13: Evolution of other-regarding preferences.

The results between the papers are not directly comparable since the methods and age categories are not identical. Also, notice that behavior in the overlapping categories 7y-8y (Fehr et al., 2008) and 8y-9y (Fehr et al., 2013) are somewhat different. Despite the caveats, we find a remarkable consistency across studies in the evolution of behavior with age (if not in the levels). In all three studies, spite is found to decrease with age (though less noticeably in Fehr et al. (2008)). Children's spite can be interpreted as a reflection of their tendency to focus on one aspect of the decision (tokens for me) instead of incorporating both aspects (tokens for me and tokens for other), consistent with the centration hypothesis. As they grow, they develop some integrative reasoning and become more egalitarian and less spiteful. Starting at age 12-13, egalitarianism is progressively replaced by generosity. Weak generosity is dominant among young adults.

Appendix B: transcript of instructions (school-age subjects)

Introduction

Hi everyone, my name is Niree and these are my helpers. We are scientists from USC and we are here today with games for you to play. These games will help us learn more about how people your age make choices.

Your teachers and your parents have said that you can play these games if you want, but you don't have to. If you don't want to play our games, let us know and we'll take you back to class. So what do you think? Do you want to play our games?

Please go ahead and read the consent form that is on your desk. When you are done reading it and would like to play our games, go ahead and complete the section in the back with your full name, the date, and your signature.

Okay. You'll be playing a few games on your computers. In all of the games, you have a chance to win tokens. When we are all done today, the computer will count how many tokens you earned all together.

- For kindergarten and elementary school participants: At the end, you will exchange your tokens for toys! The more tokens you have, the more toys you can get.

- For middle and high school participants: But, we won't give you tokens at the end - we'll give you real money to spend on Amazon! We will give you an Amazon gift card with the money you earned on it. More tokens always means more money. Just so you have an idea about the amount, you should be able to buy a book or some songs, or something else in that range.

Are there any questions before we begin?

One-shot game: "Split game"

In this first game, your job is to tell us how you want to split tokens among you and someone else. You will see a screen like this:

[insert SCREEN 1]

The hand pointing out of the screen means "you" and the hand pointing to the side means "someone else." One thing you could tell us is that you and the other student should split 3 tokens such that you get 1 token and the other student gets 2. Or you could tell us that you and the other student should split 2 tokens such that you get 2 tokens and the other student gets 0 tokens.

If you want to split the tokens like this (point to top option), tap the screen anywhere in this box (point to top box) and if you want to split the tokens like this (point to top option), tap anywhere in this box (point to bottom box).

You will not know who the "other" is that you are splitting with and the computer won't know either. After you make each choice, the computer will randomly pick someone else to receive the coins you gave away. That's going to happen after every choice you make. So, after every choice you make, the computer picks someone randomly and gives them the tokens you chose to give away.

Are there any questions?

Now, turn to your tablets and look at the first choice. When you come to the end, you will see a stop sign.

Supergame 1: "partner game"

Now for the next game. In this game, you will be partnered up with someone else in this room but neither of you will know you're partners. You will be partners with same person for the whole game. No one will know who they're partnered with and it's not the point of the game to find out. In this game, you can have two roles: you can be choosing or you can be waiting. The computer will decide which of you is choosing first and then you will switch roles after that.

Your job is to tell us how you and your partner should split tokens. If it's your turn to choose, you'll see a screen like this:

[insert SCREEN 2]

You will always see these two boxes when it's your turn to chose and your job is to tell us which one you like better.

One thing you could tell us is that you should get 6 tokens and your partner should get 1. Or you could tell us that you should get 4 tokens and your partner should get 4 as well.

If you want to split the tokens like this (point to top option), tap the screen anywhere in this box (point to top box) and if you want to split the tokens like this (point to top option), tap anywhere in this box (point to bottom box).

You can change your mind if you like, but when you tap "OK" your choice will be locked-in.

Now, when you are choosing, your partner will be waiting, and their screen will look like this:

[insert SCREEN 3]

Let's say that you choose 6 tokens for yourself and 1 for your partner. Your screen will then look like this:

[insert SCREEN 4]

This means that you chose to keep 6 tokens and give your partner 1. Your partner will see a screen like this:

[insert SCREEN 5]

The tokens you give yourself will show in blue on the middle of your screen (point to history box) and the amount your partner sends you will show up in red right here. Below that, you can find the total tokens you have so far from this game. For the next choice, you will wait and your partner will choose. You will keep switching between choosing and waiting every round.

After, let's say five rounds, your screen might look like this:

[insert SCREEN 6]

Can someone remind me who the blue tokens are from? What about the red ones? OK, let's go over what happened in each round.

The bottom row corresponds to the first round. In the first round, you gave yourself 6 tokens. Then what happened in the second round? (your partner gave you 1 token) What about in the third round? (you gave yourself 4 tokens) What happened in the fourth round? (your partner gave you 4 tokens) What happened in the fifth round? (you gave yourself 6 tokens) This is just an example. During the experiment you can choose any option you want.

Remember that you will keep the same partner for the whole game and that there will be many alternating rounds. Any questions?

Now, turn to your tablets and look at the first choice. When you come to the end, you will see a stop sign.

Supergame 2: "partner game"

OK. We are going to play this game one more time but this time, you are partnered up with someone else in this room.

We'll be doing the same thing, but this time with a new partner. You will be playing with your new partner for the whole game. No one will know who their partner is and it's not the point

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of the game to find out. Again, you can have two roles: you will either be choosing or waiting. The computer will decide which of you is choosing first and after that you will keep switching roles with your partner. Again, there will be many alternating rounds in this game.

Are there any questions?

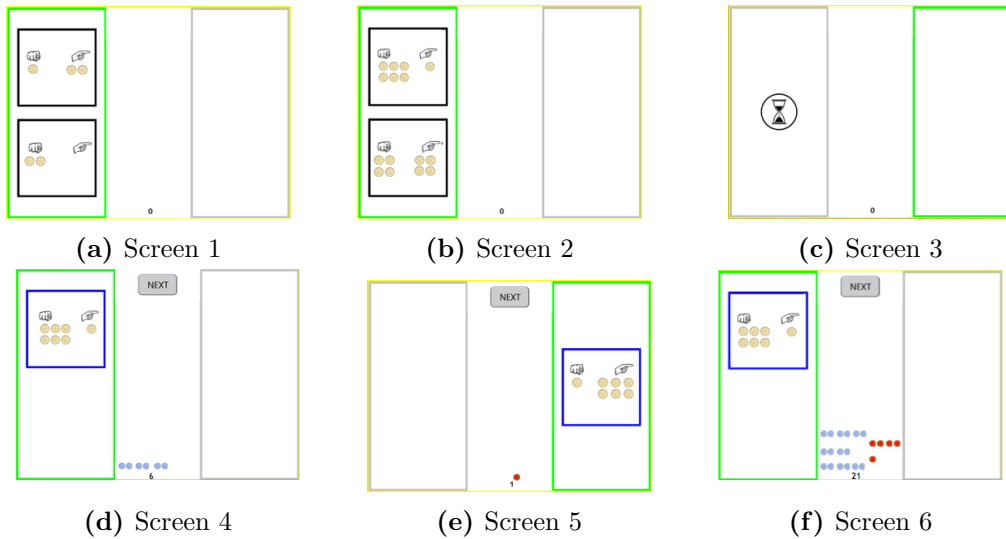Now, turn to your tablets and look at the first choice. When you come to the end, you will see a stop sign.

(a) Screen 1   (b) Screen 2   (c) Screen 3

(d) Screen 4   (e) Screen 5   (f) Screen 6

Figure 14: Screenshots for the instructions