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Empirical Article

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Cognitive predictors of equity-based social evaluation: Dissociation between proportional reasoning and cognitive control

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Abstract

Young children understand principles of fairness, including *merit*, *equality*, and *charity*. However, *equity*, which considers starting opportunities, is less explored. In a pre-registered study with 96 children aged 5–7 (55 girls, 41 boys; 33% Asian, 43% White; data collected in the United States between 2019 and 2023), we explored two potential cognitive mechanisms of equity-based fairness: proportional reasoning and cognitive control. While proportional reasoning was associated with evaluating more positively those with lower starting opportunities, cognitive control increased the likelihood of identifying the nicer individual in trials that did not call for equity reasoning. Our findings suggest a developmental trend in how children use relational information to evaluate generosity and are discussed in light of how cognitive skills influence social behavior.

Keywords equity, fairness, proportional reasoning, resource allocation, merit

Lay summary

This study investigated what predicts children's abilities to engage in evaluating others on the basis of equity (i.e., figuring out who gives more with respect to how much they already had). We found that 5- to 7-year-old children struggled with making equity judgments. However, their proportional reasoning was associated with evaluating others with respect to equity, whereas cognitive control was linked to making simple social evaluations that required paying attention to who gave more.

One challenging aspect of understanding inequality is the ability to appreciate and adjust for unequal starting opportunities. To evaluate who may be kinder between two people—one who shared two cookies and only had two cookies compared to someone who also shared two cookies but had 10 cookies—one must attend not only to the surface features of their actions but also to each person's starting opportunities (in this case, the number of cookies to begin with). More generally, the fact that two people (or groups of people) have differing access to resources pervades many real-life decisions, including resource redistribution, evaluation of job candidates, and judgments of merit and deservingness in schooling contexts.

The ability to make evaluations that account for and adjust for starting opportunity forms the basis of what we refer to as *equity* judgments. Although children can make sophisticated social evaluations of other people based on a number of principles, including helpfulness (Dunfield & Kuhlmeier, 2010), equality (Rakoczy et al., 2016), and merit (Baumard et al., 2012; Kanngiesser & Warneken, 2012), they struggle with making equity-based decisions (Chernyak et al., 2020; Hurst et al., 2020b; McCrink et al., 2010). For example, preschool-aged children's social evaluations of others' sharing often reflect an attention to the amount shared, without appreciation for the context in which the sharing decision was made. In an influential study, McCrink and colleagues (2010) examined children's reasoning about equity across four different situations. In each, children were presented with two agents who had varying amounts of resources (i.e., Agent A had 4 chips vs. Agent B had 12 chips) and gave some amount to the child (i.e., Agent A shared three chips vs. Agent B shared one chip). Children were then asked to judge which agent was nicer. Five-year-olds generally made evaluative inferences based on information about how much someone gave (e.g.,

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someone who gave 3/4 was nicer than someone who gave 1/12) as well as information about how much they had to begin with (e.g., someone who gave 1/4 was nicer than someone who gave 1/10). However, they had trouble integrating the two pieces of information (giving behavior and starting opportunity). In other words, they did not make equity-based judgments when the amount the agent gave conflicted with the amount the agent started with. Recent work has begun to chart out the developmental trajectory of equity-based reasoning (e.g., Elenbaas et al., 2020; Elenbaas & Killen, 2019), but little is known about the developmental mechanisms that drive its emergence. Moreover, equity-based reasoning continues to show individual and political differences even in adults (Rasinski, 1987). One possibility is that children's motivations are pervaded by early wealth biases (Ahl & Dunham, 2019), which dictate that they prefer those who have more or those who give more, rather than those who expend higher costs to give more. This is consistent with research revealing that preschool-aged children are less likely, relative to older children, to consider the *cost* of actions when evaluating them (Starmans & Bloom, 2016; Wong et al., 2023; though see also Chernyak & Kushnir, 2013; Zhao & Kushnir, 2023), and tend to normalize existing resource inequalities rather than actively seeking to correct them (Paulus & Essler, 2020).

Another non-mutually exclusive possibility for the relatively later development of equity-based social judgments is that doing so relies on another later-developing cognitive ability: childrens' *proportional reasoning* (Damon, 1975; Inhelder & Piaget, 1964; Singer-Freeman & Goswami, 2001; Spinillo & Bryant, 1991). While implicit sensitivity to proportions emerges as early as 6 months of age (McCrink & Wynn, 2007; Wellman et al., 2016), preschoolers seem not to pay attention to proportion when evaluating social situations. Children's struggle with reasoning about proportional information mimics their response patterns in equity-based judgments: preschoolers often exhibit interference from whole number information, leading them to incorrectly judge proportions (Boyer et al., 2008; Hurst & Cordes, 2018 ; Jeong et al., 2007). This overreliance on whole numbers is not limited to children, as evidence suggests that the extent to which people encode proportional information shows individual differences even in adulthood (e.g., Hurst et al., 2020a; 2023; Hurst & Cordes, 2016). When making equity-based social evaluations, younger children tend to focus on the absolute amount shared rather than on integrating information about both the amount shared and the initial endowments. This focus on absolute quantity is consistent with the challenges children face when reasoning about proportions, particularly in attending to denominators. In support of the possibility that proportional reasoning and equity judgments are linked, recent findings show that drawing children's attention to relations by using resources that are presented in a continuous format (Hurst et al., 2020b), encouraging children to count starting opportunity resources, or creating a social motivation to attend to proportional information (through presenting equity tasks framed in a collaborative context; Ng et al., 2011), improves children's equity-based judgments in social evaluation tasks.

There are also at least two possible ways that proportional reasoning may be related to equity judgments. One possibility is that absolute numerical information is more salient to children, analogous to a "whole number bias" (Ni & Zhou, 2005), and that this salience, regardless of the context, draws children's attention away from the relevant proportional information. An alternative and related possibility is that children who struggle with proportional reasoning are less likely to use it—or use it correctly—in equity contexts. These two factors—spontaneous attention to proportional information and fluency in using proportional information when relevant—are difficult to disentangle. In the current study, we include two measures of proportional reasoning that tap into each of these dimensions.

In addition to proportional reasoning, we considered cognitive control. Cognitive control refers to a set of interrelated cognitive processes, including the ability to ignore irrelevant information, inhibit impulses, proactively plan for the future, and working memory (Simpson & Carroll, 2019). Here, we focused specifically on *inhibitory control*, or the extent to which people can override a prepotent response. Specifically, we reasoned that cognitive control could help children override a general "wealth bias" or preference for those who have more resources (Ahl & Dunham, 2019). We included a facet of cognitive control—inhibitory control—due to its relationship to proportional reasoning (Abreu-Mendoza et al., 2020), and thus we wanted to investigate whether any potential relationships between proportional reasoning and equity judgments might instead be driven by cognitive control. Alternatively, inhibitory control may serve as an additive predictor alongside proportional reasoning; specifically, it may be helpful in allowing children to attend to multiple pieces of quantitative information and may specifically help children inhibit their "whole number bias" when making equity judgments (i.e., inhibit that one person gave more cookies to consider the fact that another person gave proportionally more).

In this work, we investigated developmental differences in equity-based decisions in a social evaluation task and three cognitive abilities: proportional comparison, focusing on proportion, and cognitive control. We presented 5- to 7-year-old children with a social evaluation task adapted from McCrink et al. (2010), in which they viewed two agents with differing initial resources (juice boxes or sandwiches) who then shared some number of those resources with a third person. Children were asked to make three social evaluations of the giver (who was nicer, who was a better sharer, and whom they would like to be friends with). We chose this age range because we wanted to capture the developmental time period when children undergo changes in equity reasoning (Chernyak et al., 2020; Chernyak & Blake, 2017; McCrink et al., 2010; Ng et al., 2011), proportional reasoning (e.g., Boyer et al., 2008; Hurst & Cordes, 2018), and cognitive control (Gerstadt et al., 1994; Lagattuta et al., 2011). We were interested in examining whether children selected the poorer person (i.e., the one with less starting resources) in each trial. After the social evaluation task, children completed three cognitive tasks: a proportional comparison task, a focusing on proportion task (Hurst & Cordes, 2019), and a cognitive control task (Lagattuta et al., 2011). We included two separate measures of proportional reasoning meant to assess two distinct but interrelated aspects of proportional reasoning skills: a *Focus on Proportion Task*, which assessed the extent to which children spontaneously opted to use proportions instead of absolute number (Hurst et al., 2023; Hurst & Cordes, 2019), and a *Proportion Comparison Task* that measured children's competence in using proportional information when the task specifically required it. We expected both proportional tasks to be positively related to equity-based social evaluation. However, we did not have strong predictions about the effect of cognitive control. Together, these three cognitive tasks provide unique insight into the various cognitive skills that may be relevant for making equity-based judgments.

Method

Participants

As pre-registered, we recruited 96 children (mean age = 6.31 years, range = 4.70–7.99; 55 girls, 41 boys) from a database of child participants, public parks, preschools, local children's museums, and online platforms. Children were tested either via a moderated Zoom interview (n = 77) or in-person at a local children's museum or in the lab (n = 19). Twelve additional children participated but were excluded due to failure to complete the tasks (n = 5), experimenter error (n = 3), equipment malfunction (n = 2), parental interference (n = 1), and prior participation in a similar version of the task (n = 1). Participants were compensated with either a $5 Amazon gift card (online participants) or a small toy or prize (in-person participants). We used a fully within-subjects design, and sample size was chosen based on prior work using a similar experimental design and analytic strategy (Chernyak & Blake, 2017). Data collection occurred between August 2019 and November 2023.

Parents were provided with an optional demographics form, and 51% self-disclosed their child's race/ethnicity. Of those, 33% reported their child as Asian or Pacific Islander, 2% as Black, 43% as White, 10% as Hispanic/Latinx, and 12% as "Other." Additionally, of the 46% of parents who self-disclosed their household income, 44% reported it as over $120 K, 18% as $90-$119 K, 20% as $60–89 K, 11% as $30–59 K, and 7% as less than $30 K.

Procedure

Children first completed a social evaluation task, adapted from McCrink et al. (2010). Children then completed the remaining three tasks in a randomized order.

Social evaluation task

Children were given eight trials presented via PowerPoint slides. In each trial, two child characters (represented via silhouettes) with differing initial resources shared items (juice boxes or sandwiches) with a friend who did not have any resources. Each trial presented three new characters (always two givers, one receiver). The eight trials included four trial types (two trials per type): (1) *baseline trials* in which the starting opportunities were the same but the number of items shared varied (i.e., one person shared one out of four sandwiches and another shared two out of four); (2) *absolutely equal* trials in which the absolute amount shared was the same but the starting opportunities differed (e.g., one out of two vs. one out of four); (3) *proportionally equal* trials in which the proportion shared was the same but the absolute amount differed (i.e., one out of two vs. two out of four); and (4) *conflict* trials in which one person shared more proportionally, but the other shared a greater absolute amount (i.e., one out of two vs. two out of six). Following prior work on social evaluation judgments (e.g., Chernyak & Ashqar, 2025; Hurst et al., 2020b; Wong et al., 2023; Zhao & Kushnir, 2023), children were asked (1) which person was nicer, (2) which person was better at sharing, and (3) which person they would want to be friends with (in that order). After answering the three questions, children were told they would now continue on to the next trial. In each trial, children were first shown both characters' initial endowments and told that each character shared some of their resources (sandwiches or juice boxes) with a friend who was previously described as not having any.

Our critical dependent variable was whether children would choose the poorer person in each trial type for each question. In the proportionally equal and the conflict trials, both the initial resources and the number of resources shared were different between the two givers. Thus, to consider equity in social judgments, children needed to consider both the amount a person had and the amount a person gave. Given that this is likely a challenging task for young children, as suggested by prior work (Chernyak & Ashqar, 2025 ; McCrink et al., 2010), we expected children to struggle with making equity-based judgments in these two trials. In the absolutely equal trial, the number of resources shared was the same and the only difference between givers was the number of resources they started with, which may have facilitated children's attention to this information. Thus, we hypothesized that children were more likely to select the person with less starting opportunities on the absolutely equal trial compared to the proportionally equal and the conflict trials. In the baseline trial, there was no "poorer person" because the starting opportunities were the same across the two givers (e.g., both had four items). In this trial, children only needed to focus on the amount shared because it was the only thing that varied. This trial functioned as a baseline condition to assess whether children were able to make judgments based on the number of resources shared. Because there was no "poorer person", for the purposes of comparison with the other trials, we coded the more "correct" answer (i.e., the person who gave more resources) as akin to the "poorer person" in the other trial types. Given that we did not observe strong differences across Question Types (i.e., nicer, better at sharing, desire to be friends), as pre-registered, we collapsed the three question types for each participant (however see *Supplementary Materials* for exploratory analyses on Question Type).

Counterbalancing

We created two fraction comparison types for each trial type: a small and large number comparison (represented in Figure 1, Panel A). We counterbalanced the order of the Trial Type, the order of the bigger vs. smaller fraction pairs, the side of the proportionally higher giver, and the side of the character that gave first. Additionally, Block Type (sandwiches vs. juice boxes) was presented in a fixed alternating order, starting with juice boxes, such that the first, third, fifth, and seventh trials presented juice boxes, and the remaining trials had sandwiches. Due to a minor procedural error, seven children received an extra juice box trial on the eighth trial (and one fewer sandwich trial). We confirmed that our results did not meaningfully change when excluding these children, and also that Block Type was not a significant effect in any of our analyses. We thus included and reported the full sample.

Focus on proportion task

This task was modeled after Hurst and Cordes (2019) and assessed the extent to which children spontaneously focused on proportion at the cost of focusing on absolute number. The task was presented via Inquisit 5 (2016) .

Children were introduced to an animal character (a bird called Birdie on the computer screen) who "likes something, but not the other things." In a familiarization trial, children were shown a Bird that consistently liked one kind of fruit (apples) and shown two examples of what Birdie liked (a red apple and a yellow apple). Then they were presented with two new fruit choices: a match to what Birdie had been shown to like (a red apple) and a novel object (a yellow banana) and asked "Birdie only likes one of these, which other one would Birdie like?" The goal of this trial was to familiarize children with the structure of the task without introducing any proportional or numerical information. We counterbalanced whether the apple was shown on the left vs. right.

Children then completed five test trials. In each trial, children were introduced to a different animal character who liked two shapes colored in a specific amount and shown two examples of what the character liked (e.g., a circle with three of four pieces colored in yellow and a square with three of four pieces colored in yellow). Note that at this point, children could interpret the animal as *either* liking shapes that have 75% coloring or shapes that had three pieces colored in. Children were then asked which of two shapes the character would also like: a proportional match (e.g., a square that had 6 of 8 pieces colored in) or a numerical match (e.g., a square that had 3 of 10 pieces colored in; Figure 1, Panel B). We coded the number of trials on which children chose the proportional match to create a *Focus on Proportion Score.* The side of the proportional vs. numerical match and the ordering of the trials were randomized via Inquisit software.

Proportion comparison task

Also modeled after Hurst and Cordes (2019), this task assessed children's non-symbolic proportional reasoning and was presented on a computer using Inquisit 5 (2016) . Children were first introduced to a cardboard spinner divided into equal pieces with a small black arrow (Hurst & Cordes, 2018). They were informed that the yellow pieces represented "winning pieces," while the gray pieces represented "losing pieces." Following this introduction, the experimenter spun the arrow twice and asked the child to interpret the outcome: "What happens if you land on yellow? And what happens if you land on gray?" Children were given corrective feedback if they did not answer correctly.

Following this introduction, children completed eight test trials. During each trial, children were presented with two spinners, one each on the left and right side of the computer screen, and asked to judge which spinner would give them a better chance of winning (i.e., the spinner with a higher probability of landing on yellow; Figure 1, Panel C). Spinners appeared in three different sizes (small, medium, and large) so that children could not reliably compare the yellow area alone. On half of the trials, the proportional information was consistent with the numerical information, such that the spinners with a higher proportion of yellow also had more pieces in yellow (e.g., 2/6 vs. 5/8; "consistent trials"). On the other half of trials, the spinners with a greater proportion of yellow had fewer yellow pieces (e.g., 5/10 vs. 4/5;

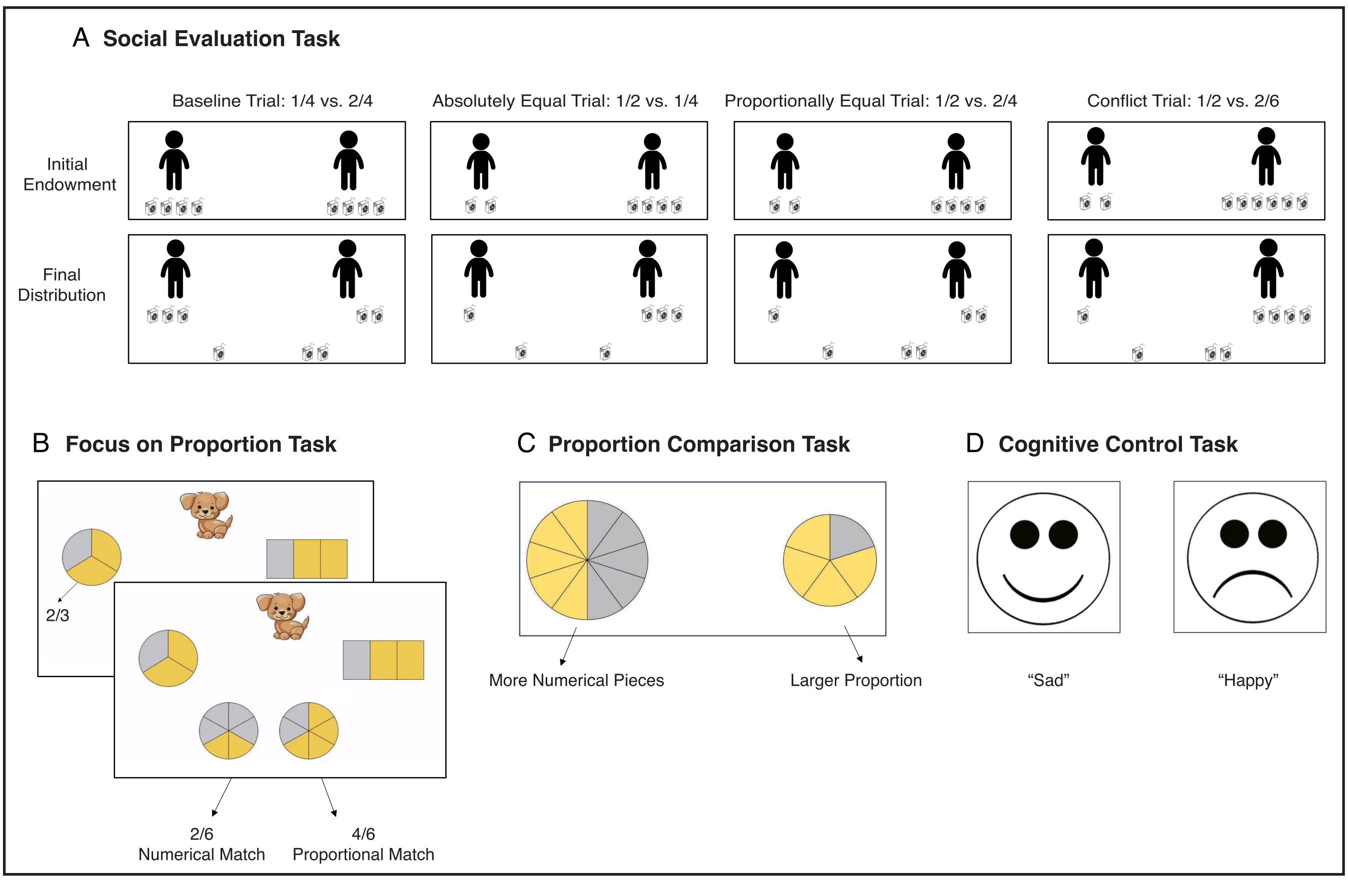

Figure 1 Example stimuli. Panel A shows the stimuli for the Social Evaluation Task. Panel B is an example of the Focus on Proportion Task and Panel C is an example of the Proportion Comparison Task. Panel D shows the Cognitive Control task.

"misleading trials"). We counterbalanced whether the correct answer was on the left vs. right on each trial; trial order was randomized. We coded for the number of trials on which children chose the correct (proportionally larger) spinner to create a *Proportion Comparison Task Score*.

Cognitive control

Children completed a cognitive control task modeled after Lagattuta et al. (2011) that assessed the extent to which children could inhibit a prepotent response and follow the experimenter's stated rule. We chose this task based on prior work which has shown that this task continued to show variability through the upper end of the age range we tested (Lagattuta et al., 2011). The task was presented either with laminated cards (in-person participants) or via PowerPoint (online participants) (see Figure 1, Panel D). Children were first introduced to the rules of a game by being shown a happy face and a sad face, asked to label them ("Is this face happy or is it sad?"), and then told that the rule would be to play an "opposite game" in which they need to provide the opposite label ("When I show you a picture of a happy face, you say *sad*. And, when I show you a picture of a sad face, you say *happy.*"). Experimenters then asked children to confirm the rules of the game and complete two practice trials with corrective feedback. This was repeated until children could complete the practice trials successfully.

Following training, children completed 20 trials featuring 10 happy and 10 sad faces presented in one of the two possible randomized orders. Children were encouraged to respond as quickly as possible. If children provided four incorrect responses in a row, the experimenter would remind them of the rule, "Remember, we are playing an opposite game. When I show you a picture of a happy face, you say *sad*. And, when I show you a picture of a sad face, you say *happy.*" Children were given a Cognitive Control Score (0–20) representing the number of times they successfully provided the correct response.

Coding

Children's sessions were video- or audio-recorded (with parental consent) for coding purposes, with the exception of three children whose parents did not provide video or audio consent and whose answers were transcribed by research assistants present at the time of the study. For each task, two independent coders recorded children's responses on a coding sheet during the experiment, then they viewed video or audio data separately, and entered data into REDCap (Harris et al., 2019). Inter-rater reliability was 94% and discrepancies between the two coders were resolved by a third coder.

Transparency, openness, and analysis approach

Our analysis plan followed our pre-registered analysis. The study was pre-registered at https://aspredicted.org/54k7-p5bh.pdf. All analyses were performed in R studio (Version 2023.09.1; R Studio Team, 2016). All stimuli, data, and R scripts are available on https://osf.io/mu6nd.

Results

Below, we show our pre-registered analyses and state when analyses were exploratory. Initial analyses found no effects of Gender or Block Type, so we collapsed data across these variables. We also checked the collinearity between all of our key variables (Age, Cognitive Control Task, Focusing on Proportion Task, and Proportion Comparison Task; see Table *S1 in Supplementary Materials*) and did not find any correlation higher than 0.29 (see *Supplementary Materials Table S2* for descriptive statistics for all key variables).

On average, replicating the results of McCrink et al. (2010), children were the most likely to select the "poorer" character in the baseline trial (i.e., the character who gave more resources), followed by the absolutely equal trial (Figure 2). In general, children selected the poorer person below chance levels in the proportionally equal and conflict trials and instead favored the "wealthier" character for both trials at above chance levels (Binomial p's $< .001$).

Following our pre-registered analysis, we then tested whether children's likelihood of selecting the poorer person varied across Age and Trial Type (coded as a four-level categorical variable). We ran a series of binomial generalized linear mixed models using Age, Trial type, and Age × Trial type as fixed effects, and the likelihood of selecting the poorer person as a response variable. Subject ID was entered as a random effect. For all effects below, we report likelihood ratio chi-squares testing whether each predictor significantly changed the model. Full models with beta coefficients are available in *Table S3 in Supplementary Materials*.

We found a main effect of Age, $\chi^2(1) = 15.679$, $p < .001$, and Trial type, $\chi^2(3) = 362.154$, $p < .001$, as well as a significant Age × Trial type interaction, $\chi^2(3) = 23.218$, $p < .001$ (see Figure 3, Panel A). Follow-up analyses examined the effect of Age in each trial type and found Age positively predicted choosing the poorer person in all trial types (all p's $< .008$) except for the proportionally equal trial ($p = .361$). This suggests a developmental pattern of children's growing attention to equity when making social evaluations. Notably, in the proportionally equal trial, the two people shared the same proportion of their resources. Therefore, if children increasingly attended to proportions with age, then this developmental change would not impact this trial as proportional information did not differentiate between the poorer person and the richer person.

In the next step, we examined the additional impact of cognitive predictors: namely, cognitive control, proportional comparison, and focusing on proportion. We thus added the three cognitive predictors to our first model. We ran several binomial mixed models, using Poorer Person Chosen as the dependent variable, Cognitive Control, Focusing on Proportion Task, Proportion Comparison Task, Age, Trial type, and interactions of each variable with Trial type as predictors, and SubjectID as a random intercept.

Similarly to our initial model, we found a main effect of Age, $\chi^2(1) = 12.015$, $p < .001$, a main effect of Trial type, $\chi^2(3) = 322.791$, $p < .001$, and an Age × Trial type interaction, $\chi^2(3) = 22.922$, $p < .001$. In addition, the results revealed a main effect of Proportion Comparison Task Score, $\chi^2(1) = 7.705$, $p = .006$, with children who performed better on the Proportion Comparison Task being more likely to choose the poorer person (Figure 3, Panel C), and a significant Trial Type × Cognitive Control interaction, $\chi^2(3) = 21.291$, $p < .001$ (see Figure 3, Panel D). There were marginally significant

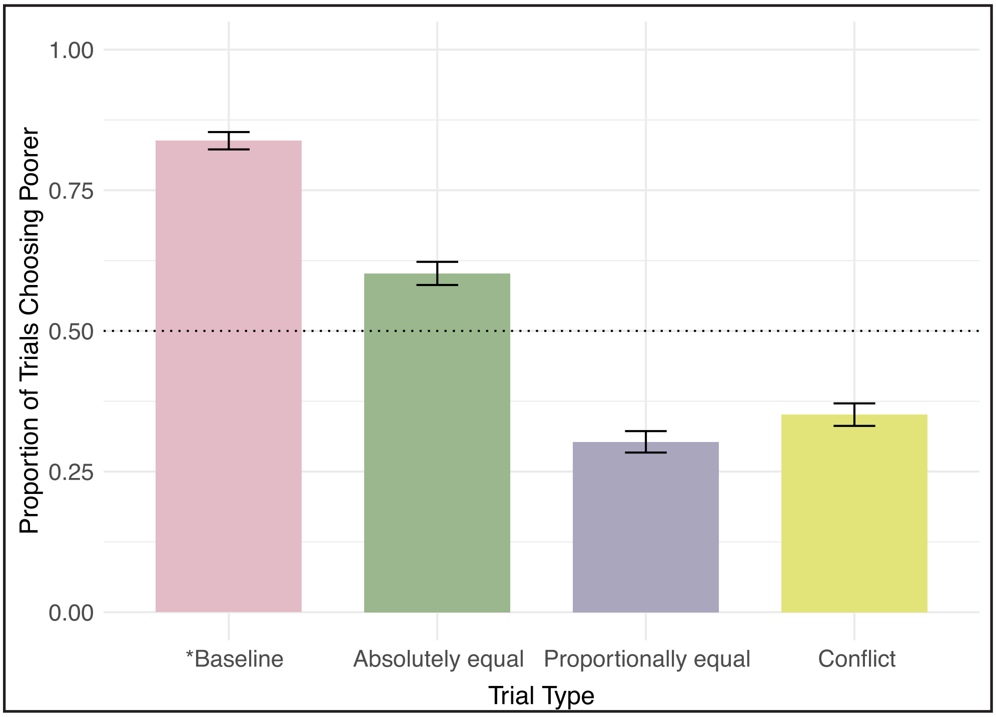

Figure 2 Children's selection of the poorer agent across conditions. The error bars represent 95% confidence intervals. *Note. On the baseline trial, the poorer agent is defined as the agent who shared more (because there is no poorer agent in terms of starting resources).

effects of Focusing on Proportion Task, $\chi^2(1)=3.106$, $p=.078$, such that children with higher scores on the Focusing on Proportion Task were more likely to select the poorer agent, and a marginally significant Trial Type × Focusing on Proportion Task Interaction, $\chi^2(3)=7.399$, $p=.060$ (due to the fact that the interaction was only marginally significant we did not explore or offer a richer interpretation). No other effects were significant (all p's > .21) (as pre-registered, we also ran both models looking at the conflict trial only, and the conclusions did not differ from the main results;see Table S4 in Supplementary Materials). To explore the interaction between Trial Type and Cognitive Control, we ran follow-up analyses looking at the effect of Cognitive Control within each trial type. Follow-ups showed the effect of Cognitive Control in the baseline trial, $\chi^2(1)=6.018$, $p=.014$, and effects were not significant in any other trial type (all p's > .26). Recall that the baseline trial did not have a "poorer" agent but rather compared two people who gave different amounts of resources (e.g., 1/4 vs. 2/4). Thus, cognitive control was associated with a greater likelihood of choosing the person who gave more resources, when both people had the same initial endowment, and thus only called for a simple numerical comparison in which participants had to compare the number of resources shared without paying attention to what proportion that amount represents. Thus, cognitive control may not be helpful for equity-based judgments and instead may be useful in completing simple numerical tasks, such as figuring out which of two people shared more (as was the case in the baseline trial).

Justifications

To better understand how children were interpreting the actions made by each of the characters, we also conducted exploratory analyses by coding children's justifications following their selection of each character. Justification categories were adapted from prior work investigating young children's social evaluations (Chernyak & Ashqar, 2025). Each explanation was coded for the presence of six non-mutually exclusive categories (described in Table 1 below) that fell along three dimensions. In the first dimension, we considered the extent to which children took the action to be diagnostic of a stable psychological trait and thus coded for references to (a) psychological traits (e.g., niceness, meanness) and (b) the actions of giving and sharing. In the second dimension, we coded for children's focus on (c) amount given and (d) initial endowment. Finally, in the last dimension, we were interested in capturing children's numerical precision and thus coded for references to (e) exact numbers and (f) non-exact quantities. Categories were not mutually exclusive, and thus a given explanation could fall into any number of the categories listed (or none). Non-responses (3.8% of the sample) were not coded; this resulted in a total of 13,212 codable explanations. Explanations were coded by two independent research assistants unaware of the study context, design, or hypotheses (inter-rater reliability = 70.3%), and discrepancies were resolved by a third independent coder, also unaware of the hypotheses and all study contexts.

Overall, explanations frequently referenced giving and sharing (66% of explanations), suggesting that children interpreted the task as a giving and sharing task. References to inexact quantities (many, both, all) were also relatively frequent (46%). For full percentages of each category type, see Table 1 and Figure 4. To investigate how category references shifted across age, trial types, question types, and cognitive predictors, we ran a series of binomial mixed models using Age, Trial type, Question type, whether participants selected the Poorer Person, and the three cognitive predictors (Proportional Comparison Task Score, Focusing on Proportion Task Score, Cognitive Control Score) as predictors, and each category reference as the response. Subject ID was

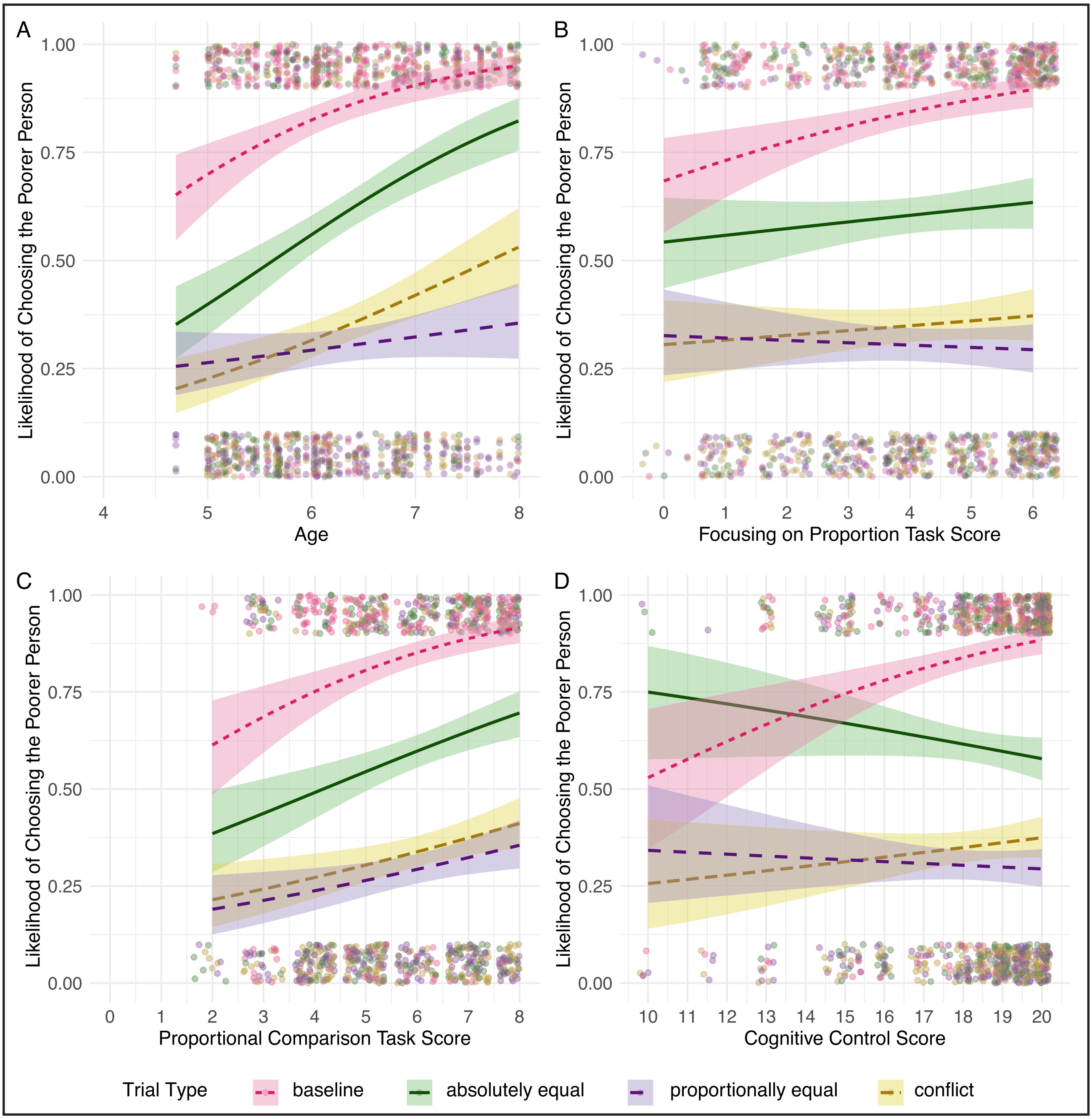

Figure 3 Results of the experiment. Because each data point is a 0 or 1, points are jittered along the X- and Y-axes to increase visibility. Shaded regions represent 95% confidence intervals on model estimated relations. (**A**) Children's Selection of the Poorer Agent across Ages. (**B**) Spontaneous Focus on Proportion Task as a Function of Trial Type and the Poorer Person Selected. (**C**) Proportion Comparison Task as a Function of Trial Type and the Poorer Person Selected. (**D**) Cognitive Control as a Function of Trial Type and the Poorer Person Selected. *Note.* Cognitive control score ranges from 0 to 20. No participant scored lower than 10.

modeled as a random effect. Given that these were exploratory analyses, we set the criterion of $p<.01$ to investigate any effects or interactions. Unless otherwise stated, only significant effects at $p<.01$ are reported.

For psychological traits, there was a significant effect of whether participants chose the Poorer Person, $\chi^2(1)=11.318$, $p<.001$, with participants being more likely to reference psychological traits if they chose the poorer person, and a significant effect of Question type, $\chi^2(2)=52.403$, $p<.001$. Follow-up post-hoc Tukey HSD tests comparing the proportion of references across question types showed that children made significantly more references to traits in the "Who would you rather be friends with?" question (118 of 763 responses; 15%) than in the "Who do you like more?" question (42/763; 5.5%), $z=-5.430$, $p<.001$, and in the "Who is nicer?" question (52/763; 6.8%), $z=-6.493$, $p<.001$ (Figure 4, Panel A). The latter two did not differ from one another, $z=1.313$, $p=.388$.

For references to giving and sharing, there was a significant effect of Question type, $\chi^2(2)=149.798$, $p<.001$, and a significant positive effect of Proportion Comparison Task Score, $\chi^2(1)=7.476$,

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Table 1 Justification categories and percentage of category references.

Category	Definition	Examples	Percentage of references
References to Traits	References to stable psychological traits such as niceness, meanness, greed	"He was nicer, that kid"	10%
References to Giving and Sharing	References to the actions of giving or taking	"Because she knows how to share"	66%
References to Amount Given	References to how many resources someone gave (i.e., focus on amount shared)	"Cause she gave one of the juiceboxes to her friend"	30%
Reference to Initial Endowments	References to how many resources someone had (i.e., focus on initial endowment)	"It has only four and it shared two"; "Because he has less"	18%
References to Numbers	References to an exact number	"Because he only shared one"; "Because he only has four sandwiches"	32%
References to Quantifiers	References to a non-numerical quantity (many, both, all, some, none)	"He's sharing more sandwiches"	46%

Note. Categories were not mutually exclusive and therefore the totals can sum to more than 100%.

$p = .006$. Follow-up post-hoc Tukey HSD tests comparing the proportion of references across question types showed that children made the most references to the action of giving and sharing in the "Who is nicer?" question (581/763; 76%), followed by the "Who do you like more?" question (501/763; 66%), and followed by the "Who would you rather be friends with?" question (371/763; 49%), all three of which differed from one another (z's > 4, p's < .001) (Figure 4, Panel B). These patterns suggest that children were most likely to reference giving and sharing when evaluating niceness but did so less in the other two questions. Importantly, children's proportional reasoning was significantly associated with making references to giving and sharing, even when controlling for Age.

We then considered references to amount given and initial endowments. For references to amount given, there was a significant effect of Question type, $\chi^2(2) = 153.639$, $p < .001$, and no other effects (p's > .03). Follow-up Tukey HSD tests showed that the three question types were different from one another: children made the most references to amount given when answering the "Who is nicer?" question (309/763; 40%), followed by the "Who do you like more?" question (238/763; 31%), and followed by the "Who would you rather be friends with?" question (109/763; 14%), z's > 3, p's < .001 (Figure 4, Panel C). Children were therefore more likely to reference the amount given when answering questions about who was nicer, relative to the other questions.

For references to initial endowment, there was a significant effect of Age, $\chi^2(1) = 7.253$, $p = .007$, a significant effect of Trial type, $\chi^2(3) = 43.869$, $p < .001$, and a significant effect of Question type, $\chi^2(2) = 35.740$, $p < .001$. Follow-up Tukey HSD tests investigating the effect of Trial type showed that children made more references to initial endowments in the absolutely equal trial (141/567; 25%) than they did in the baseline trial (69/570; 12%; $z = 6.523$, $p < .001$), the proportionally equal trial (93/582; 16%; $z = 3.364$, $p = .004$), and the conflict trial (102/570; 18%; $z = 2.591$, $p = .047$). Children also made fewer references to initial endowment in the baseline trial than in the conflict trial, $z = -3.756$, $p = .001$. All other trials did not differ significantly. Therefore, children made the most references to initial endowment in the absolutely equal trial, where it was possible that initial endowments were more salient because they were the only feature that varied. Follow-up Tukey HSD tests investigating the effect of Question type showed that children made more references to initial endowment when answering the "Who is nicer?" question (183/763; 24%) than in the "Who do you like more?" question (121/763; 16%), $z = 4.301$, $p < .001$, and in the "Who would you rather be friends with?" question (101/763; 13%), $z = 5.594$, $p < .001$; the latter two did not differ from one another, $z = 1.389$, $p = .347$ (Figure 4, Panel D).

Next, we investigated children's references to numbers and quantifiers. For references to numbers, there was a significant effect of Question type, $\chi^2(2) = 71.720$, $p < .001$. Follow-up Tukey HSD tests showed that all three question types differed in the prevalence of references to numbers: Children made the most references to numbers in the "Who is nicer?" question (302/763; 40%), followed by the "Who do you like more?" question (239/763; 22%), followed by the "Whom would you rather be friends with?" question (166/763; 22%), all pairwise z's > 3.8, all p's < .001 (Figure 4, Panel E).

Finally, for references to quantifiers, there was a significant effect of Age, $\chi^2(1) = 9.583$, $p < .001$, and a significant effect of Question type, $\chi^2(2) = 50.749$, $p < .001$. Overall, older children were more likely to quantify sharing (using quantifiers) specifically when making evaluations about preferences or kindness. Follow-up Tukey HSD tests showed that the three question types differed in prevalence of references to quantifiers: Children made most references to quantifiers in the "Who is nicer?" question (403/763; 53%), followed by the "Who do you like more?" question (340/763; 45%), followed by the "Whom would you rather be friends with?" question (279/763; 37%), all pairwise z's > 3.0, all p's < .005 (Figure 4, Panel F).

Discussion

Recent work has taken a strong interest in understanding the early roots of our ability to reason *structurally* (i.e., understand how differences in outcomes are constrained by the structures in people's environments; Amemiya et al., 2023; Vasilyeva et al., 2018; Vasil et al., 2024), and have found important social and motivational

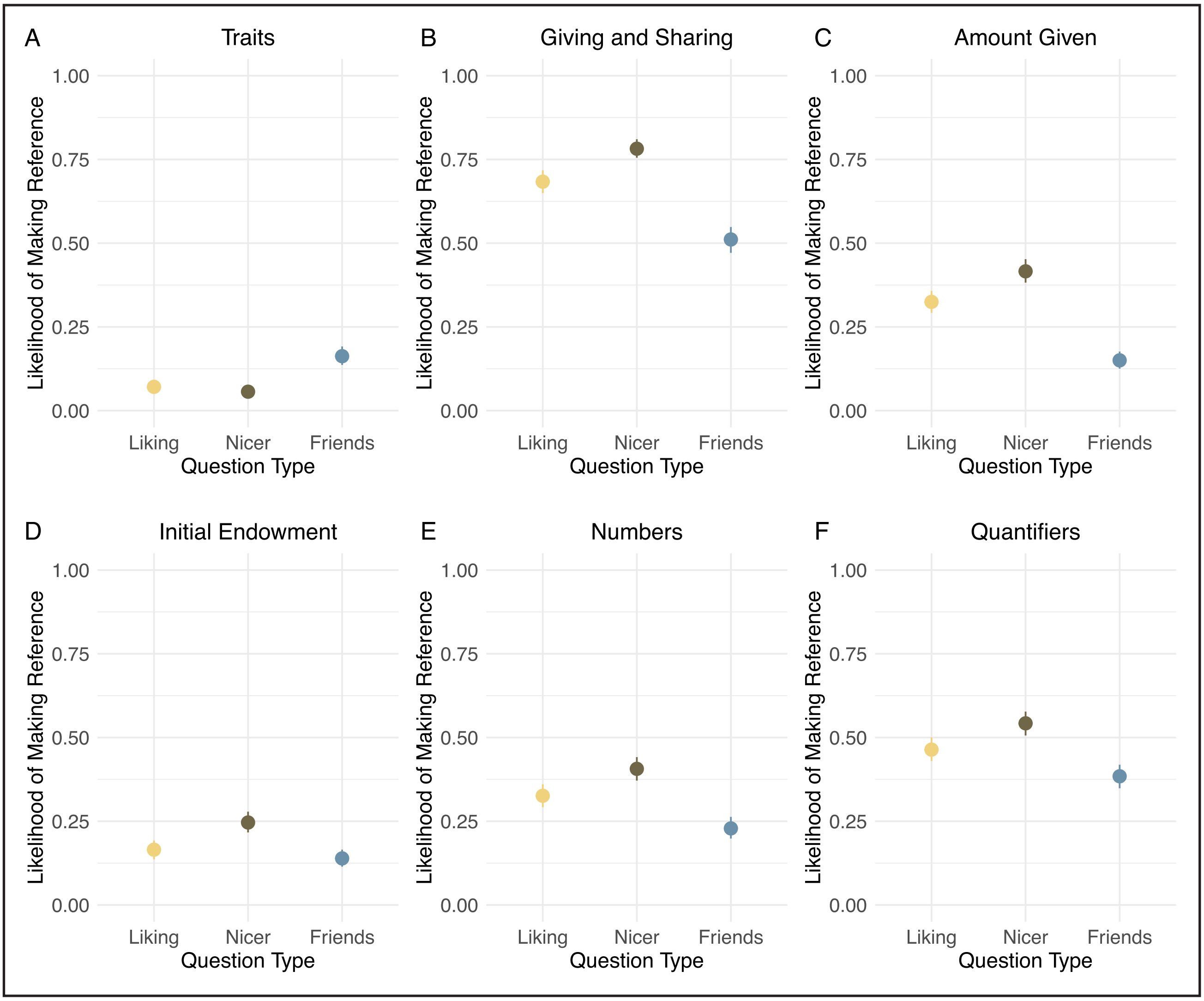

Figure 4 Proportion of references to each category across all trials as a function of question type. Note. Bars represent 95% confidence intervals.

predictors toward doing so (Rizzo & Killen, 2020; Rizzo et al., 2023). Here, we used a cognitive approach to better understand the individual differences that drive our abilities to attend to and use initial resource disparities in our evaluations of others. Specifically, we explored whether children's equity-based social evaluations were explained by three inter-related cognitive abilities: cognitive control, proportional comparison, and focusing on proportion. We join prior work in showing children have trouble making sophisticated social evaluations based on equity (Chernyak et al., 2020 ; Chernyak & Blake, 2017; Hurst et al., 2020b; McCrink et al., 2010; Ng et al., 2011; see also Rizzo & Killen, 2016). Our results point to how proportional reasoning and cognitive control skills help to explain individual differences in equity-based judgments. In doing so, we take a cognitive approach to understanding our social behavior: individual differences in how we reason about problems of fairness may ultimately depend on individual differences in other cognitive skills.

Our main finding suggests that proportional reasoning skills might be associated with children's sensitivity to equity-based social evaluations. Prior research pointed to two potential factors that underpinned equity judgments: motivational (Ng et al., 2011) and cognitive (Chernyak et al., 2020 ; Chernyak & Blake, 2017). Here we extended the previous research on cognitive predictors and show that developmental changes in proportional skills, as measured by a proportional comparison task, were associated with a greater likelihood of selecting the proportional giver on equity tasks. Of course, proportional reasoning skills cannot and do not explain *all* forms of structural reasoning or attending to group-based disparities: For example, young children (and adults) are often faced with explaining and making social evaluations that involve a complicated set of factors, including historical group-based disparities, cultural backgrounds, and structural inequities that are difficult to quantify. Nonetheless, many forms of inequality, and therefore, equity-based social evaluations, *can* be quantified as they involve attending to concrete resource disparities between two groups as well as making social evaluative decisions while attending to concrete, quantifiable group disparities (e.g., job candidate evaluations, allocating taxation, wealth redistribution). In those cases, our work suggests that individual differences in proportional reasoning skills are associated with the ability to account for substantial resource disparities when making social evaluations of others. At the same time, social evaluative decisions that do not traditionally involve concrete, quantifiable resources are often still represented using imprecise quantifiers (e.g., "He had a *more* privileged background"), and it thus remains an open question whether those types of social evaluations also draw on early proportional reasoning skills.

Notably, our task did not require any specific "correct" answer, nor were children instructed to evaluate in any specific way, and overall, the 5- to 7-year-old children in our sample relied heavily on absolute quantities (absolute amount given) when making equity-based judgments, and the youngest children predominantly used absolute amount given as the main cue to making social evaluations. Why do children (on average) tend to de-emphasize information about initial endowment when information about the amount given is available instead? One possibility is that children attempted to judge based on proportion or equity but failed to do so due to immature proportional reasoning skills. Consistent with this possibility, prior work has shown that children were better at solving proportional problems when presented with continuous amounts than discrete amounts, including social evaluative contexts where there is no right answer (Boyer et al., 2008; Chernyak et al., 2020; Hurst et al., 2020b). Alternatively, children may downplay proportion due to a deeply held theory in which they consider absolute information as the only type of information relevant to judging equity. Indeed, in children's justifications of their selection in the social evaluation task, only 18% of responses referred to initial endowments, and these were mostly found in the absolutely equal trial, where the absolute amounts did not differ between the two agents. This pattern supports the idea that children attend to the most salient cue available when explaining their judgments, and when the absolute amounts are the same, they are more likely to focus on the starting amounts. On this view, acquiring more mature proportional reasoning may shape children's views about what matters when making social evaluations, and thus change children's social norms. Future work may directly test for these possibilities.

Older children shifted their strategies and relied more heavily on proportional information when making social evaluations. One important question is the specific forms of reasoning that children may display in making equity-based judgments, and how these forms of reasoning may change over the course of development and with the acquisition of proportional reasoning. One possibility is that children move from recognizing *material cost* (i.e., amount of resources given) to recognizing *psychological cost* (the sacrifice that this cost represents). Prior work has documented that children of our chosen age range (4–8) undergo developmental changes in being able to represent *cost* (Wong et al., 2023; Zhao & Kushnir, 2023) when making social evaluations: our study suggests that proportional reasoning may be one cognitive prerequisite toward helping represent psychological cost. Another possibility is that children shift strategies when making social evaluations as they get older: while younger children may focus solely on amount given, older children may use the number of items each person retains. By design, across all trial types, the individual with fewer remaining resources is also the poorer individual. It is possible that attending to the number of items kept is one of several strategies children employ when making equity-based judgments. Such an account would be consistent with prior work showing that drawing children's attention to initial endowments, thus potentially highlighting amount kept (Chernyak et al., 2020), boosts their equity-based social evaluations. Future work should disentangle these possibilities to determine whether children's evaluations reflect proportional reasoning or attention to absolute amounts retained.

In the context of our study, there are several possibilities for how and why proportional reasoning was associated with equity-based judgments. The most obvious possibility is that proportional reasoning requires the ability to abstract the relation between two quantities, much like equity-based reasoning requires consideration of the relationship between the number of items shared and the initial endowment. Given that higher proportional comparison scores predicted better equity-based judgments, we propose that proportional reasoning skills drew children's attention to the relationship between the two pieces of information, which is at the core of equity-based judgments. There was a less consistent effect of focusing on proportion: the more children focused on proportion (at the cost of absolute number), the more likely they were to attend to equity, though this effect was not significant. Given the inconsistent pattern across the focus on proportion task and the proportion comparison task, additional work is needed to investigate whether these two aspects of proportional reasoning contribute to children's social evaluations in distinct ways. Another possibility is that a broad range of quantitative skills supports children's equity-based judgments. It is important to note that we only observed a main effect of the proportional comparison task, and we did not find any interaction between the proportional comparison task and trial type. Therefore, children's proportional reasoning skills were related to their equity-based judgments in all trials. To evaluate fairness in resource allocation scenarios, children need to compare quantities, such as the amount shared and the initial endowments, but these quantitative skills are not necessarily limited to proportional reasoning. In general, in addition to fluency with comparing numerical information inherent to equity tasks, one important additional predictor of individual differences may be the extent to which children use relational information and quantitative reasoning more generally. Further corroborating this point, interventions that have induced children's attention to proportional information have also helped increase equity-based considerations in social evaluations (Chernyak et al., 2020). It would be fruitful for future work to examine whether a wider set of quantitative skills contributes to children's equity-based evaluations.

The effect of proportional skills on equity cannot be entirely explained by cognitive control: even when accounting for individual differences in cognitive control and age, the proportion comparison task predicted significant unique variance. This suggests a dissociation between proportional reasoning and cognitive control in how they relate to children's social evaluations. Notably, higher cognitive control predicted children's social evaluations only in the baseline trial, in which they had to attend not to equity, but simply to how many resources each person gave. Those with low cognitive control tended to choose the person who gave fewer resources in this trial, suggesting that cognitive control may help children attend to simple numerical information and comparisons (i.e., attending to who gave two sandwiches and who gave one). An alternative hypothesis might be that cognitive control would predict equity-based judgments in the trials that called for children to attend to multiple conflicting pieces of information, which was the case in our conflict trial. However, we did not find this to be the case, suggesting instead that cognitive control and proportional reasoning may be related to equity-based judgments in different ways: proportional skills help attend to *relational* information, whereas cognitive control helps attend to simple numerical features of the task.

One potential concern is that children might be interpreting the social evaluation task as a math task. Given the context of the task, it is possible that older children would expect the task to test their math skills and thus focus on solving the math problem. However, our qualitative explanation for the social evaluation task suggests this is unlikely. We found that 66% of explanations mentioned giving and sharing and 46% of explanations referenced non-exact quantities, suggesting that children interpreted the social evaluation task socially. Instead, we propose that social-based reasoning is inherently quantitative, and as children grow older, they become more capable of applying their numerical reasoning to solve social problems. This is partly supported by the fact that older children were more likely than younger children to reference initial endowments when making social evaluations of the two agents.

Finally, our work points to several important directions for future work. First, it is important to note that the effect of age persisted even after controlling for our three cognitive tasks, suggesting that there may be other potential developmental mechanisms that drive the emergence of equity-based reasoning, which we believe is a fruitful area for future research. For example, one possibility, hinted at in prior work, is that children's emerging awareness of inequality within their immediate social contexts promotes equity-based reasoning (Elenbaas & Killen, 2019). We suggest that there may be two potential ways that such exposure to inequality promotes reasoning about equity: One possibility is that as children are aware of unequal amounts of starting opportunity (unequal wealth), they become more sensitive to it in third-party contexts and thus are more likely to make equity-based judgments (Peretz-Lange et al., 2022). A competing possibility, however, is that exposure to greater amounts of inequality helps children to normalize it (Midgette et al., 2023) and thus desensitizes children to unequal starting opportunity. It is important to explore how these social influences may interact with cognitive skills in shaping children's social evaluations. Another direction for future research is to examine how children evaluate individuals with greater disparities in wealth, of the kind that may be represented in real-world social inequality. In the current study, the difference in resources between richer and poorer individuals was relatively modest. However, social inequality problems often include wealth disparities that are both large and difficult to represent in exact quantities—future work may focus on how reasoning about these greater forms of inequalities may be similarly underpinned by distinct cognitive abilities. Additionally, our social evaluation task asked children to infer agents' traits (e.g., who was nicer, who was better at sharing, and whom they wanted to be friends with) based on a single instance of sharing behavior, requiring them to generalize from incomplete information. It is possible that children have a richer theory of the act itself than of the actor. Future work could compare children's evaluations using act-proximal questions (e.g., who shared more fairly this time?) alongside their trait judgments to capture children's inferences about actions versus traits.

In summary, the world is characterized by individual, developmental, and cultural differences in how people approach, represent, and ultimately attempt to resolve problems of justice, equity, and inequality. Our work takes a cognitive approach to understanding these differences. By investigating the cognitive skills that drive developmental changes in social reasoning, we may ultimately help uncover the cognitive features that also drive broader individual and cultural differences in how people think about higher-order social problems.

Supplementary material

Supplementary material is available at *Child Development* online.

Data availability

All stimuli, data, and R scripts are available on https://osf.io/mu6nd. The analyses presented here are pre-registered. The pre-registration is available at https://aspredicted.org/54k7-p5bh.pdf.

Author contributions

Rui Zhang (Data curation, Methodology [equal], Formal analysis, Project administration, Visualization, Writing—original draft, Writing—review & editing [lead]), Michelle Hurst (Conceptualization, Methodology [equal], Formal analysis, Supervision, Writing—review & editing [supporting]), and Nadia Chernyak (Conceptualization, Funding acquisition, Investigation, Resources, Software, Supervision, Validation [lead], Data curation, Methodology [equal], Formal analysis, Project administration, Visualization, Writing—original draft, Writing—review & editing [supporting])

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Conflicts of interest

The authors declare no conflicts of interest.

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Ethics statement

Procedures were approved by the University of California—Irvine IRB (protocol: 2018-4715).

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