Cognitive Development 74 (2025) 101572

Contents lists available at ScienceDirect

Cognitive Development

journal homepage: www.elsevier.com/locate/cogdev

Using numbers strategically: Proportional reasoning induces wealth in-group bias in an equity task

Nadia Chernyak [a,*], Taylor Ashqar [a,b]

[a] Department of Cognitive Sciences, University of California, Irvine, USA
[b] California State University, Long Beach, USA

ARTICLE INFO

Keywords:
Proportional reasoning
Equity
Fairness
Social status
In group bias

ABSTRACT

Prior work in cognitive development has shown a strong association between our numerical cognition abilities and our abilities to engage in equity-based social evaluation. At the same time, work in social development has found that children generally prefer wealthier others and prefer in-group members. Integrating these two perspectives, we investigated whether children's developing proportional reasoning skills might help *overcome* their in-group preferences, or alternatively, to *enact* them. In a social evaluation task (modeled after McCrink et al., 2010), 4–8-year-olds viewed a series of characters with different resource constraints (e.g., one character had 2 cookies and another had 6), each of whom then shared a proportion of their resources with a friend (e.g., one character shared 1/2 of his cookies while another shared 2/6). Children were then asked to make a series of social evaluations about the characters. We also assessed children's proportional reasoning skills, cognitive control, and subjective social status. Children's proportional reasoning skills prompted them to select their wealth-ingroup members: High-income children were more likely to select the richer participant if they had high proportional reasoning skills, whereas low-income children were more likely to select the poorer participant if they had high proportional reasoning skills. Results suggest that proportional reasoning abilities help enact strategic in-group bias.

One critical developmental milestone is the ability to enact *fairness*. By the preschool age, infants and young children engage in many sophisticated forms of fairness, including expecting others to share resources equally (Geraci & Surian, 2011; Rakoczy et al., 2016; Schmidt & Sommerville, 2011), recognizing that those who work harder deserve more resources in a joint effort task (Baumard et al., 2012; Elenbaas, 2019a; Jara-Ettinger et al., 2016; Kanngiesser & Warneken, 2012; Noh et al., 2019), and appreciating that those who are poorer deserve more resources in order to equalize opportunities (Elenbaas et al., 2020; Elenbaas & Killen, 2016; Paulus, 2014; Rizzo et al., 2016; Wörle & Paulus, 2018). At the same time that children develop sophisticated forms of *fairness*, they also develop sophisticated *social biases*: children prefer their own group members and engage in more positive social evaluations of them (Dunham et al., 2011), and they prefer and judge more positively those who are wealthier (Ahl et al., 2019; Ahl & Dunham, 2019; Horwitz et al., 2014; Paulus, 2014; Shutts, 2015). Thus, preschool-aged children develop both a strong sense of fairness and of social bias, and one important task in developmental psychology is to better understand the cognitive and social predictors that influence trends towards one or the other (Bian et al., 2018; Gonzalez et al., 2020, 2020; Jordan et al., 2014; McGuire et al., 2019; Shaw et al., 2012).

* Corresponding author.
E-mail address: nadia.chernyak@uci.edu (N. Chernyak).

https://doi.org/10.1016/j.cogdev.2025.101572
Received 8 May 2024; Received in revised form 18 March 2025; Accepted 21 March 2025
Available online 28 March 2025

One important cognitive mechanism recently proposed to underpin the development of fairness concerns is the development of numeracy skills: the development of symbolic counting has been found to be highly predictive of children's abilities to share resources equally (Chernyak et al., 2016, 2019, 2022; Muldoon et al., 2009; Sarnecka & Wright, 2013; Sohail et al., 2022; Squire & Bryant, 2002) or in accordance with merit-based considerations (Jara-Ettinger et al., 2016). In the same vein, proportional reasoning has been both proposed to and found to be related to children's ability to engage in equity-based social evaluations (i.e., evaluating someone's giving behavior not only with reference to how much they give, but also with respect to how many resources they have; Chernyak et al., 2020; Hurst et al., 2020).

To our knowledge, this work has exclusively focused on whether numeracy skills enable fairness behaviors or judgments: However, notably, numeracy skills may also be used *strategically* not to enact fairness but to strategically enact favoritism or in-group bias. That is, children may use their symbolic counting or proportional reasoning skills to enact *unfair* divisions, or divisions that are biased towards themselves and their own social groups. One way in which children can strategically use advanced socio-cognitive abilities is to strategically enact selfish or biased behaviors and/or conceal them from others: For example, young children will conceal how many resources they are endowed in order to appear fair when dividing them (Gonzalez et al., 2022) and they can strategically appear "fair" (by sharing half of their resources) while simultaneously being unfair and sharing valuable resources in ways that bias themselves or preferred others (Chernyak & Sobel, 2016; Shaw et al., 2012; Sheskin et al., 2016). Though this work has not explored children's hoarding behaviors with respect to their numerical cognition, the ability to manipulate quantities to appear fair while simultaneously *being* unfair should tap into advanced socio-cognitive skills, working memory, and numeracy.

One notable way in which children might use numeracy skills strategically is to enact in-group bias. Between preschool-age and middle childhood (between ages 4–10), they become more aware of wealth disparities between others, automatically notice and encode wealth differences, and use cues about wealth to form stereotypes about behavior (Ahl et al., 2019; Ahl & Dunham, 2019; Legaspi et al., 2023; Mandalaywala & Legaspi, 2023; Paulus, 2014; Shutts et al., 2016; Yang & Dunham, 2022). Critically, also during this period, children become increasingly more aware of their *own* wealth status relative to others (Amir et al., 2019; Peretz-Lange et al., 2022) - in an important paper by Peretz-Lange and colleagues (2022), children between the ages of 4–8 become increasingly *accurate* in their understanding of their social status relative to others; while 4-year-olds generally believed themselves to be of high status regardless of their parents' income, 8-year-olds' subjective social status aligned with their objective social status (i.e., parents' income). Together, this work suggests that between the ages of 4–8, children may begin to form ideas about their own *wealth group* and might hold biases in favor of that group.

In particular, we investigated how children use their emerging proportional reasoning skills to make social evaluations of others. In particular, we used an equity task that taps into proportional reasoning (McCrink et al., 2010), but also harbors a potential for displaying a wealth in-group bias. In this task, children view two people endowed with differing amounts of resources (e.g., one person has 2 cookies and another has 6), and share some of them (e.g., one person shares 1/2 cookies and the other shares 2/6). Children could choose the person who gave and was richer (reflecting a potential wealth bias) or give to the person who shared less but shared a higher proportion (reflecting an attention to *equity* in social evaluation). Importantly, in this work, choosing the person who gave a lower proportion also meant choosing the poorer person (the one with lower starting resources). We surveyed 4- to 8-year-old children, on the basis of three distinct findings in prior literature: (1) 4- to 6-year-olds undergo important age-related changes during this time period in proportional reasoning (Hurst & Cordes, 2018) and ability to engage in equity-based social evaluation (Chernyak et al., 2020; McCrink et al., 2010), and (2) by age 8, children also develop beliefs about their subjective social status that are in line with their objective social status (Peretz-Lange et al., 2022). Based on this prior work, we hypothesized that with age, children would improve in their abilities to engage in equity-based responding.

We explored children's choices alongside a measure of their proportional reasoning skills, inhibitory control, and subjective socioeconomic status. To measure subjective social status, we used the MacArthur Social Status Ladder, recently validated as a cross-culturally sensitive measure of social status (Amir et al., 2019) for children as young as 4 years of age. We used two additional cognitive tasks: a measure of proportional preference task (Hurst & Cordes, 2018), that measures individual differences in the extent to which children attend to proportional information and a inhibitory control task that measures response inhibition (Lagattuta et al., 2011).

We hypothesized several possible effects of subjective social status and proportional reasoning skills: If young children are *objective social evaluators* and the only constraint on their equity-based social evaluations is their developing proportional reasoning skills, then proportional reasoning skills alone would help attend to equity. Thus, regardless of their social status, children high in proportional reasoning skills would choose the poorer person when making social evaluations. Another possibility is that subjective social status (particularly, low subjective status) is a *social status as a driver of equity* - if this is the case, subjective social status helps draw our attention to resource status disparities, and proportional reasoning skills further help integrate that information with someone's sharing. This account predicts that social status might exert an *additive* effect of proportional reasoning skills in helping attend to equity judgments: In this case, equity-based judgments are more likely to appear when one is *either* of low subjective social status (by virtue of making resource differences more salient because they are self-relevant) *or* having high proportional reasoning skills (by virtue of being able to integrate resource differences in starting opportunities with differences in sharing behavior). Finally, if children use *proportional reasoning skills strategically,* subjective social status might simply serve to help provide the *content* of in-group social judgment (i.e., poor children would prefer poor others and rich children would prefer rich others), whereas proportional reasoning skills might help to effectuate that bias (those high in proportional reasoning skills would be more capable of doing so).

1. Method

1.1. Participants

Participants were 80 4- to 8-year-old children (42 boys, 38 girls; *Mean age* = 6 years;7 months; *Range* = 3 y;11mo - 9 y;0mo). Data collection occurred between July 2021 and June 2023. Seven additional children were tested but excluded due to experimental error, equipment malfunction, parental interference, or failure to complete the tasks and comply with instructions.

Parents of 78 participants (96 %) filled out an optional demographics form. Of these, 3 % reported their household income as < $30,000, 15 % as $30–59,000, 10 % as $60–89,000, 27 % as $90–119,000, and 45 % as $120,000 + . Participants were recruited from a broad US sample, with the majority recruited from Southern California. Using zip code information, we obtained the median income for each participant's city: *Mean* = $100,813; *Range* = $43,080 - $219,005). Thirty-one percent reported their child as Asian or Pacific Islander, 5 % as Black, 39 % as White, 5 % as Hispanic/Latinx, and 20 % as Other/Multiracial. Additionally, 58 % reported having a graduate degree, 34 % reported having a college degree, 3 % reported having some college education/associate's degree, and 4 % reported a high school diploma/GED. Additionally, 46 % reported their partners as having a graduate degree, 37 % as having a college degree, 13 % as having some college education/associate's degree, and 4 % as having a high school diploma/GED. Average reported household size was 4.4 people (Range = 2–7 people).

The entire procedure lasted approximately 20–25 minutes, and participants were compensated with a $5 gift card (for online participation) or a small toy (in-person participants).

1.2. Procedure

Children were interviewed either at a local children's museum ($n = 5$), via Zoom ($n = 73$), or at a local park ($n = 3$). Stimuli were presented using Inquisit 5 (2016) software and PowerPoint slides. All participants completed the following tasks. The Social Evaluation Task was always presented first, whereas the remaining tasks were counterbalanced for order.

1.2.1. Social evaluation task

All children first completed 6 trials of a *Social Evaluation Task* (presented within two 3-trial blocks): In each trial, 2 silhouettes of children (described in this manuscript as agents) were shown on the screen, each of whom was endowed with a set of resources (e.g., "Here are two children, and both have some [cookies/toys], but each have a friend who doesn't have any." During this time, participants' attention was drawn both to the starting resources of each agent ("This child has this many [cookies/toys] and this child has this many [cookies/toys]"). Both agents were then shown to have shared some set of their resources with the resource-less friend using an animated PowerPoint screen, and participants' attention was once again drawn to the sharing behavior of each agent ("Look! This child shared these many [cookies/toys] with a friend and this child shared these many [cookies/toys]" with another friend"). Children were then asked to answer four questions about the children they just watched (in a fixed order): *Niceness*: Which child is nicer?; *Better Sharer:* Which child is better at sharing?; *Friend Preference:* Which child would you want to be friends with more?; and *Needs More:* Which child needs more [toys/cookies]? Finally, children were prompted for an explanation by being asked *why* the child shared this many cookies/toys. See Supplementary Materials for analyses involving Explanations.

Children completed two blocks (order counterbalanced) of three trials each (trials also counterbalanced within block), totalling 6 total trials. One block used cookies as a resource and the other displayed toys as a resource. We used these two resources since they are associated with common items that children would be familiar with, were used (in the case of cookies) in the original equity-based reasoning task (McCrink et al., 2010), and represent "luxury" resources that tend to elicit equity- and merit-based reasoning in children of this age (Rizzo et al., 2016). Each block consisted of the following 3 trials (order counterbalanced within block):

1.2.1.1. Denominator Equal (Control) Trial. In this trial, starting resources between the two agents were the same (4 cookies each), but the amounts shared were different (one agent shared 1/4 of the resources and the other shared 2/4). The trial served as a control because children did not need to take into account starting resources and only needed to account for who shared more in order to make a social evaluation. Thus, no proportional reasoning was needed for this trial and prior work has found that even the youngest children generally select the person who shares more at very high rates (Chernyak et al., 2020; McCrink et al., 2010).

1.2.1.2. Absolutely Equal Trial. The starting resources between the two agents were different (one agent had 4 cookies and another had 8) but the absolute amounts shared were the same (2 cookies). Thus, the agents shared the same absolute amount but different proportional amounts (2/4 vs. 2/8).

1.2.1.3. Conflict trial. In this trial, both the starting resources and amounts shared were different (2/6 vs. 1/2), and thus the absolute amount shared (2 cookies vs. 1) was in conflict with the proportion.

In the two non-control trials (absolutely equal and conflict), selecting the poorer agent on each social evaluation question also meant making an *equity based judgment* (judging how much someone shared in *proportion* to what they were endowed them). For example, selecting the agent who gave 1/2 meant selecting the person who gave more proportionally and was poorer.

Trials were presented in two blocks: one block featured cookies, while the other featured toys, and block order was counterbalanced across children. Additionally, we counterbalanced the side of the "poorer" person, ordering of blocks within trials, and presentation of

the additional tasks (described below).

For each trial, we coded whether children selected the poorer person (also the person who shared proportionally). In the Denominator Equal (Control) trial, we coded whether children selected the person who gave more (since there was no poorer person).

1.3. Proportional preference task

Children then completed a Proportional Preference Task presented on Inquisit Software, modeled after Hurst and Cordes (2018), which has been found to show both individual differences and age-related changes during the preschool to middle childhood age range. We chose this measure because it would also be, in theory, related to equity-based judgments - in both tasks children are asked to attend to the relationship between initial endowments (4 cookies) and amounts shared (2 cookies).

In each trial of this task, children were shown an animal that likes shapes colored a specific way. To familiarize children with the structure of the task, children completed a familiarization trial that did not involve any proportional reasoning: An animal was shown as liking two different colored apples ("Birdie likes this one, and also this one"), and children were then shown two new fruits - an apple (not pictured before) and a banana, told that "Birdie likes only one of these" and asked "Which one would [Birdie] also like?" Following children's choices on the familiarization trial, they completed 5 test trials: In each test trial, children were introduced to a new animal who liked two shapes. The shapes were consistently colored such that they represented both a specific number and proportion (e.g., two shapes with 2 of 3 shape pieces colored in). Children were then shown two new shapes and asked which one the animal also likes: one shape that presented a numerical match (e.g., 2 of 6 pieces colored in) and one shape that represented a proportional match (e.g., 4 of 6 pieces colored in), and asked which one the animal would like more. The fractions used were ¾, ½, ¼, $^{2}/_{3}$, and $^{1}/_{3}$ and they were randomly ordered, while the characters were presented in a fixed order. Note that this task did not have a correct answer - the data presented to children about the animal's preferences were consistent with *either* a numerical or proportional match and therefore any selection of the proportion match reflected spontaneous attention or preference. Children were given a Proportion Preference Score from 0 to 5 reflecting the number of test trials on which they selected the proportional match.

1.4. Stroop task

Because proportional reasoning skills are related to inhibitory control (namely, the ability to suppress incorrect strategies, such as focusing only on the numerator), which also shows age-related changes during the preschool and middle childhood period, we also included a measure of inhibitory control to account for the possibility that any relationships between equity judgments and proportional reasoning skills were due to their association with inhibitory control. We used inhibitory control specifically since we reasoned that evaluating people on the basis of proportion may require suppressing wealth biases (i.e., preferring people who have more), or suppressing choosing in-group members, both of which are shown to be early intuitive "defaults" (i.e., early-developing propensities). To assess inhibitory control, we used the Happy/Sad Stroop task (Lagattuta et al., 2011), a measure of impulse control that shows individual and developmental differences through the 4- to 11-years of age. We opted for this task in particular for 3 reasons: (a) its

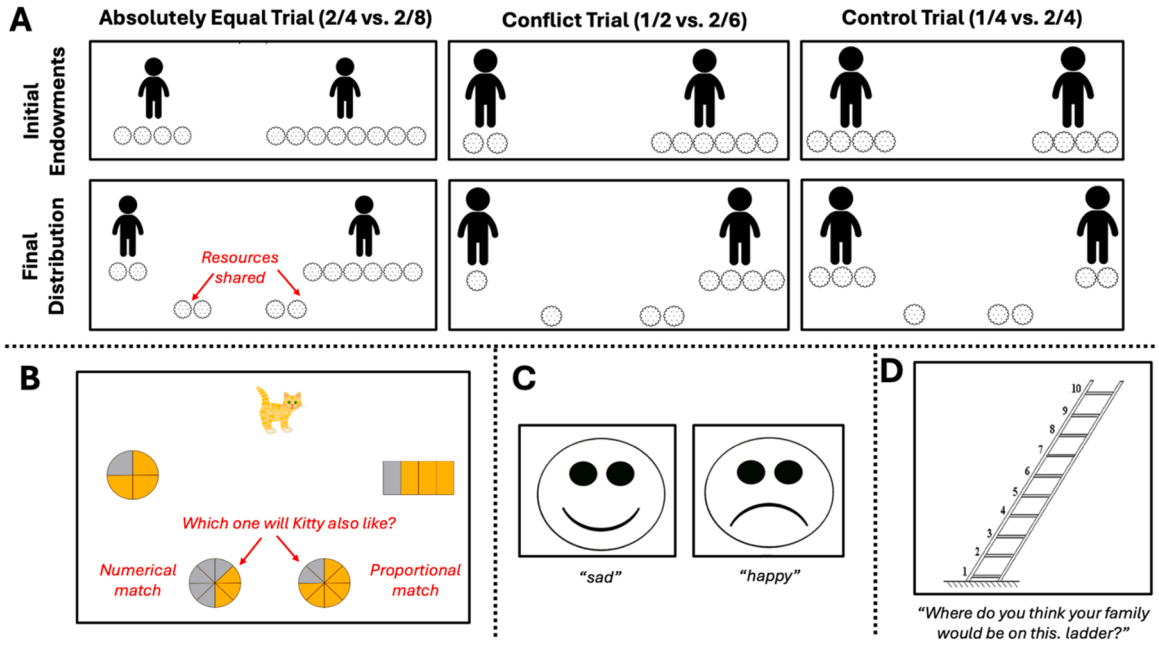

Fig. 1. Stimuli for the tasks. *Note.* Stimuli from example trials from the (A) Social Evaluation Task. (B) Proportional Preference Task. (C) InhibitoryControl Task, and (D) MacArthur Scale of Subjective Social Status. Words in red are added for explanatory clarity.

feasibility in administration (administration is approximately 5 minutes long, and also lends itself to both online and in-person formats), (b) it has been validated as an individual difference measure in the age group of interest in our study (Lagattuta et al., 2011), and (c) it has previously shown relationships with sharing behavior in young children (Chernyak & Blake, 2017; Chernyak et al., 2020).

Following procedures from Lagattuta et al. (2011), children completed a Happy/Sad Stroop task as a measure of inhibitory control. Children were introduced to the structure of the game by being shown two cards (a happy face and a sad face) and the experimenter ensured that children understood the labels for both. After this, children were told they would be playing an "opposite game" in which they had to provide the opposite labels for these two cards. For example, the child was told that they needed to say "happy" when presented with a "sad" face and to say "sad" when they see a happy face. Children were allowed four practice trials where feedback was provided if they were incorrect, and then proceeded to 20 test trials with no feedback. If any child received more than four trials incorrect in a row during test trials, they were reminded of the rules. Children received a Inhibitory Control Score of 0–20 reflection the number of test trials they answered correctly (1 =correct, 0.5 =self-correct, 0 =incorrect).

1.5. MacArthur scale of subjective social status

Following (Adler et al., 2000; Amir et al., 2019), children were shown a ladder ranging from 1 to 10, and told that the top of the ladder (10) represents people in their country that have the most resources and the bottom (1) represents the people with the least amount of resources (i.e. money, jobs, respect). The child is prompted to pick a number to identify where on the ladder they think their family is in relation to the people at the top (10) and bottom (1) of the ladder. Children received a Subjective Social Status Score (1−10) reflecting their status beliefs.

1.6. Coding

Data were entered into RedCap software (Harris et al., 2009, 2019). Each video and/or transcribed interview underwent initial coding by two independent research assistants who were also trained to conduct the study, with the exception of two children whose answers were transcribed by a researcher available at the time of interview. A third researcher (TA) then reviewed all available videos to ensure consistency in responses between the two coders and resolve any discrepancies. Inter-rater reliability was 99.95 %.

2. Results

All data, protocols, and analysis code are available at https://osf.io/szdk3/?view_only=cb0270e6f5bc4eb293ee44323ff40dbf. See Table 1 for descriptive statistics across our main variables.

Initial analyses showed no effects of Gender or Block Type (cookies vs. toys), so data were collapsed across these variables. Preliminary analyses did, however, find an effect of Trial Order, so we retained this as an effect in our subsequent analyses. We first confirmed that in the control trial (denominator equal trial), children selected the person who gave more at above chance levels. In line with our predictions and with prior work, children selected the person who gave more on 508 of 639 total trials (79.50 %; 95 % *CI* = 76.15–82.56 %), binomial test $p < 0.001$.

The next set of analyses sought to characterize children's responses on the critical test trials (the absolutely equal and conflict trials). In subsequent analyses, we used binomial mixed effects models (following Muradoglu et al., 2023) in which we accounted for subject level variability by using Subject ID as a random effect, and adding our focal effects of interest and their interactions as fixed effects. In the first step, we constructed a model with our focal effects of interest (Age, Trial Type, and Question Type) as well as their interactions as fixed effects. Because Trial Order explained a significant portion of the variance, we included it as an additional fixed effect. In the second step, we sought to understand how cognitive predictors explained children's responses. Thus, we retained any significant effects from our first model, and also added our focal effects of interest (Subjective SES, Proportional Preference Scores, Inhibitory Control Scores), and their interactions. Below we report likelihood ratio Chi-Squares testing whether each predictor significantly changes the model. Full model details are available in Supplementary Materials.

The first set of analyses investigated children's responses across age, trial types, and question types: we ran a binomial mixed effects model using likelihood of selecting the poorer person as the response and Trial Order, Age, Question Type, and Trial Type, and all interactions between Age, Question Type, and Trial Type as predictors (Overall Conditional $R^2 = 0.65$; Marginal $R^2 = 0.32$). Results showed a significant positive effect of Trial Order, $\chi^2(1) = 9.45$, $p = .002$, with children being more likely to select the poorer person on later trials; Age, $\chi^2(1) = 15.07$, $p < .001$, with older children being more likely to choose the poorer person than younger children; Trial Type, $\chi^2(1) = 41.01$, $p < 0.001$, $\chi^2(3) = 137.68$, $p < .001$, qualified by a Trial Type x Question Type interaction, $\chi^2(3) = 11.83$, $p = .008$. No other effects reached significance (all p's $> .10$). For further details, see Supplementary Table 1.

The interaction is shown in Fig. 2. To explore the Age x Trial Type interaction, we ran these models separately for each Question Type using Trial Order, Age and Fraction Type as predictors. As shown in Fig. 2, children generally showed high rates of selecting the poorer person when answering the "Who needs more?" question: children did so on nearly all trials (413 of 476 trials; 86.76 %). There was a significant effect of Fraction Type for all Question Types (all p's $< .05$), with children being less likely to select the poorer person in the conflict trial, though as noted by the significant interaction, the effect appeared strongest in the "Who is nicer?" question. Therefore, replicating prior work (McCrink et al., 2010), with age, children generally found the Conflict Trial, in which absolute amount given conflicted with proportion, to be more difficult than the Absolutely Equal Trial. Additionally, older children were more likely to make equity-based judgments than younger children. Finally, and importantly, *most* children across most trials could accurately detect the poorer participant. What varied was their tendency to use that information in making social evaluations about who

Table 1
Descriptive Statistics of Independent Variables Across Ages.

	Overall Mean (SD in Parentheses) Range at bottom	4–5-year-olds	6–7-year-olds	8-year-olds
Subjective Social Status	7.66 (2.12)	7.55 (2.56)	8.00 (1.78)	7.29 (1.69)
	1–10	1–10	5–10	5–10
Fraction Score	3.43 (1.51)	3.21 (1.41)	3.32 (1.66)	4.0 (1.36)
	0–5	0–5	0–5	0–5
Stroop Score	18.63 (1.61)	18.09 (1.94)	18.87 (1.34)	19.23 (0.95)
	12–20	12–20	15–20	17–20

Note. Mean shown in bold, SD's are in parentheses, and range at the bottom.

Table 2
Frequencies Across Age and Gender.

	Girls	Boys
4–5-year-olds	15	18
6–7-year-olds	16	15
8-year-olds	7	10

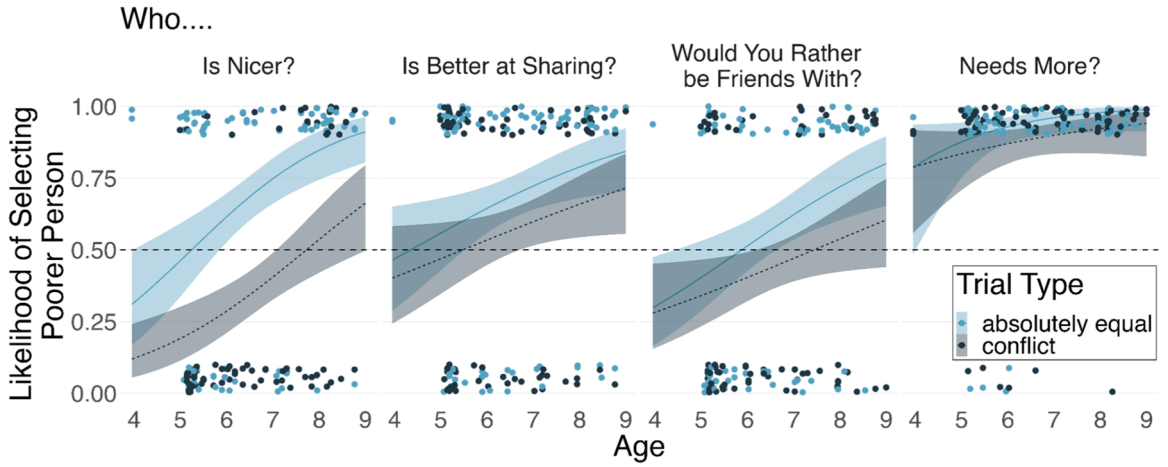

Fig. 2. Children's likelihood of selecting the poorer person as a function of Age, Trial Type, and Question Type. *Note.* For ease of interpretation, individual data points are jittered along the y- and x-axes. Bands represent 95 % confidence intervals.

was nicer, better at sharing, or whom they'd like to be friends with.

Our next question was whether social (Subjective Social Status)[1] and cognitive predictors (Proportion Preference Score and Inhibitory Control Score) would predict children's selection of the poorer person. We retained the significant effects from the model above (Trial Order, Age, Trial Type, Question Type, Trial Type x Question Type), and added social predictors (Subjective Social Status) and cognitive predictors (Proportion Preference Score and Inhibitory Control Score) to the model (Overall Conditional R^2 =.75; Marginal R^2 =.48). We also included interactions between social and cognitive predictors, and between all significant model 1 effects and newly added effects. As in the previous model, there was a significant effect of Trial Order, $\chi^2(1) = 10.00$, $p = .002$, Age, $\chi^2(1) = 11.45$, $p < .001$, Trial Type, $\chi^2(1) = 34.84$, $p < .001$, Question Type, $\chi^2(3) = 99.15$, $p < .001$, and Trial Type x Question Type interaction, $\chi^2(3) = 8.26$, $p = .04$. Critically, there was also a Proportion Preference Score x Subjective SES x Question Type interaction, $\chi^2(3) = 18.55$, $p < .001$, and no other significant effects (p's > .06). The interaction is displayed in Fig. 3 below.

To explore the interaction, we ran models separately for Question Type (using all significant effects from the previous model: Trial Order, Age, Trial Type, Subjective SES, Proportion Preference Score and the interaction of Subjective SES and Proportion Preference Score: there was a marginally significant Proportion Preference Score x Subjective SES interaction only for the "Which one is nicer?" question, $\chi^2(3) = 4.03$, $p = 0.05$, but this interaction was not significant for any of the other Question Types (all p's > .27). A closer analysis of trial types (Fig. 3) yielded three findings: (1) as already discussed, all children generally selected the poorer person for the

[1] We also ran models using objective (household income bracket), rather than subjective social status and obtained the same results as reported below (see *Supplementary Analyses* for details).

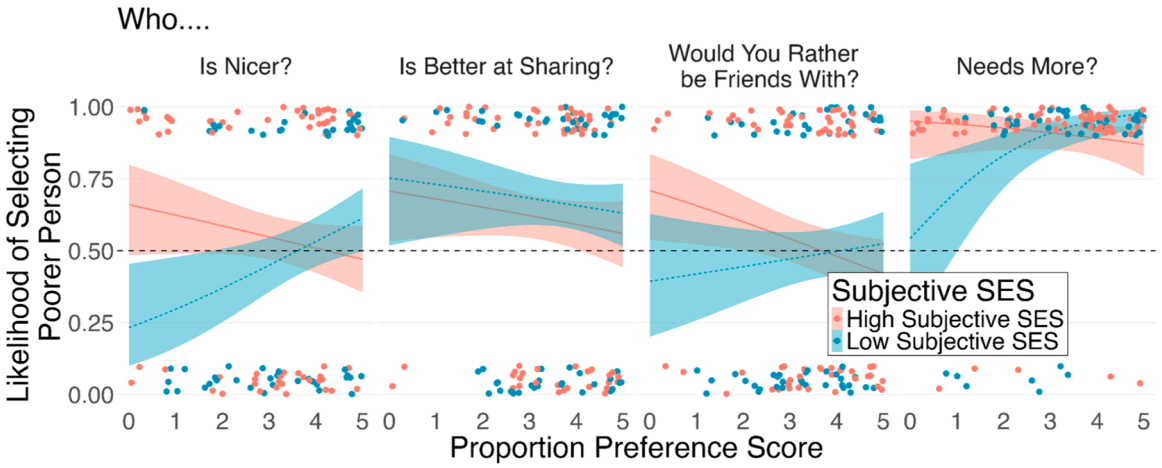

Fig. 3. Children's likelihood of selecting the poorer person as a function of Age, Question Type, and Subjective Social Status. *Note.* For ease of interpretation, individual data points are jittered along the y- and x-axes. Bands represent 95 % confidence intervals.

"Who needs more?" question, (413 of 476 trials; 86.76 %; Binomial $p < .001$); (2) Most children generally selected the poorer person on the "Who is better at sharing?" question (326 of 477 trials; 68.34 %; Binomial $p < .001$); and (3) low income children showed a *positive* association between their fraction scores and likelihood to select the poorer person on the "Who is nicer?" and "Who would you be friends with?" questions, whereas high income children showed a *negative* association.

Therefore, proportional reasoning generally helped children identify in-group members as those they'd like to be friends with or were nicer: children who perceived themselves to be low status were more likely to select poorer characters, and children who perceived themselves as high status were more likely to select richer characters - when they had the proportional reasoning abilities to do so.

3. Discussion

This study joins recent work in recognizing the importance of how cognitive and social abilities jointly influence beliefs about fairness, inequality, and social evaluations. Overall, we find evidence for strategic proportional reasoning in middle childhood: 4- to 8-year-olds used their developing proportional reasoning skills to give to wealthy in-group members; those who perceived themselves to be of high status gave to others of high status, and those who perceived themselves to be of low status gave to others of low status. Overall, our results suggest that children use their developing proportional reasoning skills when making social evaluations of others (Chernyak et al., 2020).

We also replicate prior work in showing that (preschool-aged) children struggle to form social evaluations on the basis of *equity* - i.e., evaluating someone for the amount of giving they do with reference to their starting opportunity or initial endowment (Chernyak et al., 2020; McCrink et al., 2010), suggesting that they have trouble integrating information about giving actions with information about initial endowments. A host of studies have focused on the cognitive and social underpinnings of our abilities to make *equity* judgments, finding, for example, that collaborative contexts (Ng et al., 2011) or drawing children's attention to initial endowments (Chernyak et al., 2020) influences equity judgments. One question that this work raises is the extent to which a *lack* of equity judgment occurs because children have trouble recognizing resource disparities between individuals (i.e., initial starting opportunities). Our work suggests this is not the case: as evidenced by children's high rates of identifying the character that "needs more" at all ages, the issues with making equity-based judgment do *not* result at the encoding level: That is, young children's failure to integrate initial endowments into their social evaluations are *not* because they do not or cannot attend to or encode initial resource disparities between people.

Our work joins recent work in showing that our preferences for fairness may develop alongside in-group biases. Recent literature has found that as children get older, they grow an increasing awareness of their social status (Peretz-Lange et al., 2022). The present experiment suggests that this increasing awareness also has downstream consequences: as children become increasingly more aware of their social status, they use their cognitive skills to show targeted wealth in-group preferences. What do children do before they are aware of their social status? One possibility is that they are aware, but not particularly accurate about it - and in fact prior work suggests this to be the case (Peretz-Lange et al., 2022). If this is the case, younger children's failures to display equity-based judgments may arise not *simply* due to errors of proportional reasoning, but because they are displaying a wealth bias and attempting to give to their in-group members. Consequently, one unintended positive benefit of becoming aware of one's relatively *lower* social status is that doing so promotes equity-based judgments in which children make social evaluations based on proportional sharing.

We find an association between proportional preference scores and 4- to 8-year-old children's reasoning about equity, even while controlling for age and inhibitory control, suggesting that numerical cognition plays a role even when considering other developmental achievements (Chernyak et al., 2022). However, in the present study, though proportional reasoning and Subjective Social

Status (SSS) explained some of the age-related changes, age continued to play a significant role in predicting equity-based judgments (selection of the poorer agent), suggesting that there may be other developmental achievements that explain the development equity concepts beyond the ones studied in the present manuscript. One important avenue for future research is to explore how equity-based judgments develop in concert with young children's general conceptual understanding of structural inequality (Amemiya et al., 2023; Vasil et al., 2024; Vasilyeva et al., 2018; M. Y. Zhang et al., 2024) - one possibility is that as children grow older, they become more coherent in their theories for *how* the relative resource abundance (or scarcity) of each agent would constrain their giving behaviors, and make social evaluations accordingly. Of course, it is important to investigate how attention to equity develops alongside strategic ingroup biases that we document in the present study.

While our work identifies cognitive predictors driving equity judgments, it is also important to note potential social predictors, such as moral reasoning about unfairness, and socialization surrounding equity. Prior work has identified, for example, that interwealth contact shifts young children's moral reasoning and their subsequent resource allocation to low-wealth peers (Elenbaas, 2019b). In the context of our study, one intriguing possibility is that interwealth contact may help attend to equity-based judgments by virtue of helping to develop proportional reasoning skills in the context of equity tasks: those who encounter wealth diversity may be more motivated to encode disparities among individuals and act accordingly. This possibility warrants further investigation. Similarly, parental socialization practices surrounding how wealth disparities are discussed within families may ultimately shape how children encode resource disparities among individuals - for example, family socialization surrounding either how one's own wealth is discussed (for example, see Jones et al., 2018) or how children conceptualize wealthy and poor (Ahl et al., 2019; Legaspi et al., 2023; Shutts et al., 2016; Yang & Dunham, 2022) would interact with their reasoning about equity.

One note to make about this study is that the majority of data collection took place online, which is a modality with which young children may have been less familiar. However, scores on cognitive tasks (namely, the Stroop Task) mirrored those collected using in-person modalities (e.g., Lagattuta et al., 2011) and children's responses on the equity task mirror age-related changes found in prior work (Chernyak et al., 2020; McCrink et al., 2010; R. Zhang et al., 2024). Therefore, though it is important to investigate how modalities may have shifted children's motivations, we find it unlikely to have played a significant role in the present study.

In general, children used their proportional reasoning skills when making social *evaluations* about who was nicer and whom they would like to be friends with, but *not* when making moral judgments of who was better at sharing, nor charity-based judgments of who needed more resources to begin with. Thus, children appear to show a dissociation between the types of cognitive skills needed to perceive resource constraints or identify whose sharing behavior was better given those constraints, and those needed to make social *preferences* about whom people would like to be friends with. Prior work has documented distinctions along these lines (Wong et al., 2023) - children's intuitions about whom they like are distinct from their evaluations of their *behavior*, suggesting that to some degree, children's social evaluative preferences might follow in-group biases, whereas their evaluations of behavior might follow fairness principles.

Overall, this study suggests that there are important developmental consequences to children's growing awareness of their own social status, especially when used in conjunction with their proportional reasoning skills. It is important for us to be aware of how children may be using their developing cognitive skills (such as their proportional reasoning), and to which ends, in order for parents and educators to better interpret children's behaviors in light of their cognitive skills. Our work joins others before it in showing how children's cognitive capacities, combined with their motivational goals, shape their emerging social cognition.

CRediT authorship contribution statement

Chernyak Nadia: Writing – original draft, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Ashqar Taylor:** Writing – review & editing, Project administration, Conceptualization.

Acknowledgements

We would like to thank members of the Development of Social Cognition Lab, especially Kiana Gee, Olivia Ramos Jacquez, Vivian Nguyen, Tati Rios, and Jose Ramirez for assistance with data collection and coding; Pretend City Children's Museum for use of space. This work was funded by a National Science Foundation CAREER award (#1945170). Correspondence may be addressed to nadia.chernyak@uci.edu

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.cogdev.2025.101572.

Data availability

Data are available at https://osf.io/szdk3/

References

Adler, N. E., Epel, E. S., Castellazzo, G., & Ickovics, J. R. (2000). Relationship of subjective and objective social status with psychological and physiological functioning: Preliminary data in healthy, White women. *Health Psychology, 19*(6), 586–592. https://doi.org/10.1037/0278-6133.19.6.586

Ahl, R. E., & Dunham, Y. (2019). "Wealth makes many friends": Children expect more giving from resource-rich than resource-poor individuals. *Child Development, 90*(2), 524–543.

Ahl, R. E., Duong, S., & Dunham, Y. (2019). Children employ wealth cues when predicting others' sharing. *Developmental Psychology, 55*(2), 303.

Amemiya, J., Mortenson, E., Heyman, G. D., & Walker, C. M. (2023). Thinking structurally: A cognitive framework for understanding how people attribute inequality to structural causes. *Perspectives on Psychological Science, 18*(2), 259–274.

Amir, D., Valeggia, C., Srinivasan, M., Sugiyama, L. S., & Dunham, Y. (2019). Measuring subjective social status in children of diverse societies. *Plos One, 14*(12), Article e0226550.

Baumard, N., Mascaro, O., & Chevallier, C. (2012). Preschoolers are able to take merit into account when distributing goods. *Developmental Psychology, 48*(2), 492.

Bian, L., Sloane, S., & Baillargeon, R. (2018). Infants expect ingroup support to override fairness when resources are limited. *Proceedings of the National Academy of Sciences, 115*(11), 2705–2710. https://doi.org/10.1073/pnas.1719445115

Chernyak, N., & Blake, P. R. (2017). The relationship between fairness, cognitive conrol, and numerical encoding. *Proceedings of the Annual Meeting of the Cognitive Science Soviety, 39*.

Chernyak, N., Harris, P. L., & Cordes, S. (2019). Explaining early moral hypocrisy: Numerical cognition promotes equal sharing behavior in preschool-aged children. *Developmental Science, 22*(1), Article e12695.

Chernyak, N., Harris, P. L., & Cordes, S. (2022). A counting intervention promotes fair sharing in preschoolers. *Child Development, 93*(5), 1365–1379. https://doi.org/10.1111/cdev.13775

Chernyak, N., Sandham, B., Harris, P. L., & Cordes, S. (2016). Numerical cognition explains age-related changes in third-party fairness. *Developmental Psychology, 52*, 1555–1562. https://doi.org/10.1037/dev0000196

Chernyak, N., & Sobel, D. M. (2016). Equal but not always fair: Value-laden sharing in preschool-aged children. *Social Development, 25*(2), 340–351.

Chernyak, N., Turnbull, V., Gordon, R., Harris, P. L., & Cordes, S. (2020). Counting promotes proportional moral evaluation in preschool-aged children. *Cognitive Development, 56*, Article 100969.

Dunham, Y., Baron, A. S., & Carey, S. (2011). Consequences of "minimal" group affiliations in children. *Child Development, 82*(3), 793–811.

Elenbaas, L. (2019a). Against unfairness: Young children's judgments about merit, equity, and equality. *Journal of Experimental Child Psychology, 186*, 73–82.

Elenbaas, L. (2019b). Interwealth contact and young children's concern for equity. *Child Development, 90*(1), 108–116.

Elenbaas, L., & Killen, M. (2016). How do young children expect others to address resource inequalities between groups? *Journal of Experimental Child Psychology, 150*, 72–86.

Elenbaas, L., Rizzo, M. T., & Killen, M. (2020). A developmental-science perspective on social inequality. *Current Directions in Psychological Science, 29*(6), 610–616.

Geraci, A., & Surian, L. (2011). The developmental roots of fairness: Infants' reactions to equal and unequal distributions of resources. *Developmental Science, 14*(5), 1012–1020.

Gonzalez, G., Ahl, R. E., Cordes, S., & McAuliffe, K. (2022). Children strategically conceal selfishness. *Child Development, 93*(1), e71–e86. https://doi.org/10.1111/cdev.13687

Gonzalez, G., Blake, P. R., Dunham, Y., & McAuliffe, K. (2020). Ingroup bias does not influence inequity aversion in children. *Developmental Psychology, 56*(6), 1080–1091. https://doi.org/10.1037/dev0000924

Harris, P. A., Taylor, R., Minor, B. L., Elliott, V., Fernandez, M., O'Neal, L., McLeod, L., Delacqua, G., Delacqua, F., Kirby, J., & Duda, S. N. (2019). The REDCap consortium: Building an international community of software platform partners. *Journal of Biomedical Informatics, 95*, Article 103208. https://doi.org/10.1016/j.jbi.2019.103208

Harris, P. A., Taylor, R., Thielke, R., Payne, J., Gonzalez, N., & Conde, J. G. (2009). Research electronic data capture (REDCap)—A metadata-driven methodology and workflow process for providing translational research informatics support. *Journal of Biomedical Informatics, 42*(2), 377–381. https://doi.org/10.1016/j.jbi.2008.08.010

Horwitz, S. R., Shutts, K., & Olson, K. R. (2014). Social class differences produce social group preferences. *Developmental Science, 17*(6), 991–1002.

Hurst, M. A., & Cordes, S. (2018). Attending to relations: Proportional reasoning in 3-to 6-year-old children. *Developmental Psychology, 54*(3), 428.

Hurst, M. A., Shaw, A., Chernyak, N., & Levine, S. C. (2020). Giving a larger amount or a larger proportion: Stimulus format impacts children's social evaluations. *Developmental Psychology, 56*, 2212–2222. https://doi.org/10.1037/dev0001121

Inquisit 5 [Computer software]. (2016). Retrieved from ⟨https://www.millisecond.com⟩.

Jara-Ettinger, J., Gibson, E., Kidd, C., & Piantadosi, S. (2016). Native Amazonian children forego egalitarianism in merit-based tasks when they learn to count. *Developmental Science, 19*(6), 1104–1110.

Jones, D. J., Loiselle, R., & Highlander, A. (2018). Parent–adolescent socialization of social class in low-income white families: Theory, research, and future directions. *Journal of Research on Adolescence, 28*(3), 622–636.

Jordan, J. J., McAuliffe, K., & Warneken, F. (2014). Development of in-group favoritism in children's third-party punishment of selfishness. *Proceedings of the National Academy of Sciences, 111*(35), 12710–12715. https://doi.org/10.1073/pnas.1402280111

Kanngiesser, P., & Warneken, F. (2012). *Young Children consider merit when Sharing Resources with others*.

Lagattuta, K. H., Sayfan, L., & Monsour, M. (2011). A new measure for assessing executive function across a wide age range: Children and adults find happy-sad more difficult than day-night. *Developmental Science, 14*(3), 481–489.

Legaspi, J. K., Pareto, H. G., Korroch, S. L., Tian, Y., & Mandalaywala, T. M. (2023). Do American children automatically encode cues to wealth? *Journal of Experimental Child Psychology, 234*, Article 105706.

Mandalaywala, T. M., & Legaspi, J. K. (2023). Automatic encoding across social categories in American children and adults. *Developmental Psychology*.

McCrink, K., Bloom, P., & Santos, L. R. (2010). Children's and adults' judgments of equitable resource distributions. *Developmental Science, 13*(1), 37–45.

McGuire, L., Elenbaas, L., Killen, M., & Rutland, A. (2019). The role of in-group norms and group status in children's and adolescents' decisions to rectify resource inequalities. *British Journal of Developmental Psychology, 37*(3), 309–322. https://doi.org/10.1111/bjdp.12274

Muldoon, K., Lewis, C., & Freeman, N. (2009). Why set-comparison is vital in early number learning. *Trends in Cognitive Sciences, 13*(5), 203–208.

Muradoglu, M., Cimpian, J. R., & Cimpian, A. (2023). Mixed-effects models for cognitive development researchers. *Journal of Cognition and Development, 24*(3), 307–340.

Ng, R., Heyman, G. D., & Barner, D. (2011). Collaboration promotes proportional reasoning about resource distribution in young children. *Developmental Psychology, 47*(5), 1230.

Noh, J. Y., D'Esterre, A., & Killen, M. (2019). Effort or outcome? Children's meritorious decisions. *Journal of Experimental Child Psychology, 178*, 1–14. https://doi.org/10.1016/j.jecp.2018.09.005

Paulus, M. (2014). The early origins of human charity: Developmental changes in preschoolers' sharing with poor and wealthy individuals. *Frontiers in Psychology, 5*. ⟨https://www.frontiersin.org/articles/10.3389/fpsyg.2014.00344⟩.

Peretz-Lange, R., Harvey, T., & Blake, P. R. (2022). From "haves" to "have nots": Developmental declines in subjective social status reflect children's growing consideration of what they do not have. *Cognition, 223*, Article 105027. https://doi.org/10.1016/j.cognition.2022.105027

Rakoczy, H., Kaufmann, M., & Lohse, K. (2016). Young children understand the normative force of standards of equal resource distribution. *Journal of Experimental Child Psychology, 150*, 396–403. https://doi.org/10.1016/j.jecp.2016.05.015

Rizzo, M. T., Elenbaas, L., Cooley, S., & Killen, M. (2016). Children's recognition of fairness and others' welfare in a resource allocation task: Age related changes. *Developmental Psychology, 52*, 1307–1317. https://doi.org/10.1037/dev0000134

Sarnecka, B. W., & Wright, C. E. (2013). The idea of an exact number: Children's understanding of cardinality and equinumerosity. *Cognitive Science, 37*(8), 1493–1506.
Schmidt, M. F., & Sommerville, J. A. (2011). Fairness expectations and altruistic sharing in 15-month-old human infants. *PloS One, 6*(10), Article e23223.
Shaw, A., DeScioli, P., & Olson, K. R. (2012). Fairness versus favoritism in children. *Evolution and Human Behavior, 33*(6), 736–745.
Sheskin, M., Nadal, A., Croom, A., Mayer, T., Nissel, J., & Bloom, P. (2016). Some equalities are more equal than others: Quality equality emerges later than numerical equality. *Child Development, 87*(5), 1520–1528.
Shutts, K. (2015). Young children's preferences: Gender, race, and social status. *Child Development Perspectives, 9*(4), 262–266.
Shutts, K., Brey, E. L., Dornbusch, L. A., Slywotzky, N., & Olson, K. R. (2016). Children use wealth cues to evaluate others. *PloS One, 11*(3), Article e0149360.
Sohail, S., Dunfield, K. A., & Chernyak, N. (2022). Dissociable Mechanisms for Diverse Prosocial Behaviors: Counting Skills Predict Sharing Behavior, but Not Instrumental Helping. *Journal of Cognition and Development, 23*(2), 289–303. https://doi.org/10.1080/15248372.2021.1998064
Squire, S., & Bryant, P. (2002). The influence of sharing on children's initial concept of division. *Journal of Experimental Child Psychology, 81*(1), 1–43.
Vasil, N., Srinivasan, M., Ellwood-Lowe, M. E., Delaney, S., Gopnik, A., & Lombrozo, T. (2024). Structural explanations lead young children and adults to rectify resource inequalities. *Journal of Experimental Child Psychology, 242*, Article 105896.
Vasilyeva, N., Gopnik, A., & Lombrozo, T. (2018). The development of structural thinking about social categories. *Developmental Psychology, 54*, 1735–1744. https://doi.org/10.1037/dev0000555
Wong, A., Cordes, S., Harris, P. L., & Chernyak, N. (2023). Being nice by choice: The effect of counterfactual reasoning on children's social evaluations. *Developmental Science, 26*(6), Article e13394.
Wörle, M., & Paulus, M. (2018). Normative expectations about fairness: The development of a charity norm in preschoolers. *Journal of Experimental Child Psychology, 165*, 66–84. https://doi.org/10.1016/j.jecp.2017.03.016
Yang, X., & Dunham, Y. (2022). Emerging complexity in children's conceptualization of the wealthy and the poor. *Developmental Science, 25*(4), Article e13225.
Zhang, R., Hurst, M.A., & Chernyak, N. (2024). Proportional Reasoning Explains Variability in Children's Equity-Based Social Evaluations. *Available at SSRN 4685694*.
Zhang, M. Y., Sullivan, J. N., Markman, E. M., & Roberts, S. O. (2024). Children's structural thinking about social inequities. *Child Development Perspectives, 18*(1), 19–25.