DOI: 10.1111/cdev.13775

EMPIRICAL ARTICLE

CHILD DEVELOPMENT

A counting intervention promotes fair sharing in preschoolers

Nadia Chernyak[1] | **Paul L. Harris**[2] | **Sara Cordes**[3]

[1]Department of Cognitive Sciences, University of California—Irvine, Irvine, California, USA

[2]Graduate School of Education, Harvard University, Cambridge, Massachusetts, USA

[3]Department of Psychology and Neuroscience, Boston College, Chestnut Hill, Massachusetts, USA

Correspondence
Nadia Chernyak, Department of Cognitive Sciences, University of California, Irvine, 2334 Social & Behavioral Sciences Gateway, 92697 Irvine, California, USA.
Email: nadia.chernyak@uci.edu

Funding information
John Templeton Foundation, Grant/Award Number: 56348; National Science Foundation, Grant/Award Number: 1920660

Abstract

Recent work has probed the developmental mechanisms that promote fair sharing. This work investigated 2.5- to 5.5-year-olds' ($N = 316$; 52% female; 79% White; data collected 2016–2018) sharing behavior in relation to three cognitive correlates: number knowledge, working memory, and cognitive control. In contrast to working memory and cognitive control, number knowledge was uniquely associated with fair sharing even after controlling for the other correlates and for age. Results also showed a causal effect: After a 5-min counting intervention (vs. a control), children improved their fair sharing behavior from pre-test to post-test. Findings are discussed in light of how social, cognitive, and motivational factors impact sharing behavior.

A core aspect of fairness is the ability to divide resources fairly among others. As such, recent work in developmental psychology has focused on the cognitive competencies that enable children's abilities to understand, recognize, and enact the fair distribution of resources. Although sharing *in general* (i.e., giving up desired resources to help others) is a relatively early-developing capacity (Hay et al., 1999) that has been linked to social achievements such as theory of mind and perspective taking (Cowell et al., 2015; Wu & Su, 2014; Xiong et al., 2016), there is open debate about the cognitive competencies that enable our abilities to share resources *fairly*. Work to date points to at least two potential mechanisms that enable fair sharing behavior in young children: cognitive control (Blake et al., 2015; Steinbeis & Over, 2017) and the acquisition of verbal, symbolic counting (Chernyak et al., 2016, 2019, 2020; Muldoon et al., 2009; Sarnecka & Wright, 2013; Sohail et al., 2021; Squire & Bryant, 2002).

However, work to date has been correlational, and has generally explored one cognitive correlate of fair sharing behavior at a time (either cognitive control *or* symbolic counting; Chernyak et al., 2016, 2019; Sohail et al., 2021; Steinbeis & Over, 2017), while failing to account for the others. Given that the preschool period, when changes in fair sharing behavior occur, is associated with the acquisition of *multiple* cognitive abilities, there is an open question as to which abilities, jointly or individually, retain truly unique effects on fair sharing. In this work, we investigate: (a) potential cognitive correlates of fair sharing behavior in preschool-aged children, and (b) the potential causal impact of counting on fair sharing.

Correlational work points to symbolic counting as an important cognitive mechanism: prior work has found that children who were proficient counters (i.e., understood the cardinal principle, as measured by the Give-N task; Wynn, 1990) were more likely to share an endowment of stickers equally between two parties than children who were not yet proficient counters (Chernyak et al., 2016, 2019). Similarly, even among children who failed to share their resources equally, proficient counters gave allotments of stickers that were *closer to* equality than non-proficient counters (e.g., proficient counters gave 4 of 6 stickers vs. 1 of 6). Based on this work, we have argued that symbolic counting helps children recognize how to quantitatively distribute resources between others and themselves through creating equal sets.

Abbreviation: %DFE, percent deviation from equality.

Cognitive control has also been proposed as a unique driver of sharing behavior. During the same developmental time window (the preschool years), children also develop the ability to inhibit impulses (Gerstadt et al., 1994), flexibly switch between following different rules (Zelazo et al., 2003), and proactively engage in goal-directed planning (Munakata et al., 2012). Broadly, these abilities are referred to as executive functioning, and have been linked to various social abilities, such as theory of mind (Marcovitch et al., 2015; Sabbagh et al., 2006) and norm-following behavior (Blake et al., 2015). With respect to fair sharing, cognitive control may enable children to inhibit their own desires (i.e., wanting all resources) in favor of flexibly balancing the desires of others. However, the relationship between cognitive control and sharing behavior has proven somewhat mixed, with some studies finding a strong and causal relationship (Steinbeis & Over, 2017), and others finding no relationship once controlling for age or other cognitive capacities, such as affective perspective taking (Heck et al., 2018; Smith et al., 2013).

In order to explore the cognitive correlates of sharing behavior, we tested the impact of symbolic counting alongside two other cognitive achievements: cognitive control, which has previously been proposed to be linked to sharing behavior (as reviewed above), and working memory, because working memory is often linked to both cognitive control (Engle, 2010) and counting abilities (Kroesbergen et al., 2014; Soltész et al., 2010).

Importantly, although prior studies on symbolic counting and sharing have thus far reported a correlation between these two abilities, no work has determined whether this relationship is causal. The studies reported here are the first to investigate whether symbolic counting exerts a causal impact on sharing behavior by employing a pre-post-test design in which we assessed children's sharing behavior before and following a short intervention aimed at promoting young children's counting. Specifically, we reasoned that children who do not share fairly would benefit from the modeling of proper counting behaviors, thereby providing them with a behavioral tool that would facilitate fair sharing.

We capitalized on a recent study that successfully developed a short intervention aimed at promoting counting behaviors in young children (Posid & Cordes, 2018). In that study, children first completed Give-a-Number task, an assessment aimed at classifying children into either *cardinal principle knowers* (i.e., proficient counters who understand that the last word in a count list refers to the cardinality of the set) or *subset knowers* (children who can produce only a specific subset of items—for example, a 3-knower who can reliability produce and identify a set containing up to, but not more than, three items). In this study, children classified as non-proficient counters then underwent either a 5-min Counting Intervention task, or a time-matched Control task that did not involve counting. In the Counting Intervention, the experimenter presented the child with a series of trials, each depicting a set of 2 cards depicting varying sets of animals (e.g., 6 pictures of giraffes). The experimenter then promoted counting behaviors by first labeling the cardinality of the set ("This card has 6 animals on it"), pointing to and enumerating the items in the set ("one, two, three, four, five, six"), and encouraging the child to do the same ("Count with me!"). In the Control task, children were shown the exact same card stimuli, and the cardinality of the set was labeled for the child ("This card has 6 animals on it"), but the experimenter did not point to individual items or count the items on the card. Following the Counting Intervention or Control task, children were given a task in which they were asked to identify which of two cards contained *six* animals, and then again participated in the Give-N task. Relative to children in the Control group, children in the Counting group showed greater improvements in their performance on both tasks, suggesting that providing children with behavioral counting tools improved their performance in two subsequent numerical tasks. By implication, the counting intervention provided children with strategies that promoted effective performance on numerical tasks: notably, the practice of pointing to individual items, labeling those items with the corresponding order in the set size, and stating the cardinal value of the set size at the end. We note that this intervention was not aimed at promoting deeper conceptual knowledge, but rather was aimed at providing children with a specific behavioral tool to promote more accurate performance on numerical tasks.

Inspired by this finding, we look at whether the promotion of counting behaviors using a similar procedure also improves children's fair sharing behavior. Across two studies, we used a pre-post-test design in which we first gave children a sharing task where they distributed a valuable resource (stickers) between themselves and another individual. We then divided children into either a Counting intervention or Control group, modeled after Posid and Cordes (2018), and re-assessed children's sharing behavior following the intervention. Additionally, we assessed children's pre-test symbolic counting, their cognitive control, and their working memory capacity to look at the impact of each of these cognitive skills (as well as age) on children's sharing behavior.

Based on prior findings (Huang et al., 2010; Posid & Cordes, 2018), we reasoned that the children most likely to benefit from a counting intervention would be those that had *not* yet mastered the principles of counting, and thus would benefit most from modeling of proper counting. We also explored whether children's sharing behavior was related to their initial (pre-test) counting skills, above and beyond other domain-general skills, such as cognitive control and working memory.

STUDY 1

Study 1 explored: (a) the relationship between sharing behavior and counting, cognitive control, and working

memory, and (b) whether sharing behavior could be improved with a short counting intervention.

Method

Participants

Participants were 97 preschoolers (M_{age} = 4.3, range = 3.0–5.8 years; 42 female) tested in the laboratory or at a local school. Fourteen additional children were tested but excluded due to experimental error (n = 1), equipment malfunction (n = 2), parental interference (n = 1), or failure to complete the tasks and comply with instructions (n = 10). Data collection occurred between April and December 2016.

We administered an optional demographics form for any participants tested in the lab. Across both studies (Study 1 N = 97; Study 2 N = 219), 53 (17%) completed the demographics form. Of these participants, 79% reported their child's ethnicity as White, 8% as Asian or Pacific Islander, 4% as Black, 4% as Other or Multiracial, and 2% did not report a Race or Ethnicity.

Procedure

All children completed the following tasks:

Pre-test resource allocation trial

Following procedures in our prior work (Chernyak et al., 2019), children were presented with a stuffed animal ("Ellie") that was described as feeling sad and wanting stickers. Children were then shown six stickers laid out in a linear array and told that the stickers were theirs, but that they had the option to keep them or give some to Ellie to make her feel better. This procedure has been used to provide both a motivation to share, but also an attractive resource that children are simultaneously hesitant to give away. Children were then shown two wooden boxes, one box that was described as being placed to hold the child's stickers, and a second that was described as belonging to Ellie the puppet, and prompted to split the stickers between themselves and the puppet, however, they wished. If any stickers were left on the table, children were re-prompted until they placed each sticker into one of the corresponding boxes. The side of the puppet's box versus the child's was counterbalanced across participants. To assess children's beliefs about what had occurred, children were asked whether they gave more to themselves, Ellie, or gave both the same.

Symbolic counting assessment (knower level)

Following resource allocation, children were given a symbolic counting assessment following Give-N task. Children were presented with 10 ducks and a small basket (described as a "pond"). Children were then prompted to place N ducks into the pond, where N corresponded to a number between 1 and 6. After the child completed placing ducks into the pond, the experimenter asked "Is that N?", and continued to the next trial only if the child affirmed their choice (otherwise, children were asked to try again). All children began with N = 1 as practice, and then moved on to N = 3, after which the task used an individualized titration method: if children succeeded on N, they moved onto $N + 1$; if they failed on N, they went back to $N - 1$. The task finished when children had either (a) two successes on N and two failures on $N + 1$, or (b) two successes on N = 6. Children were given a Knower-Level Score of 1–6 based on the highest numbered trial they had successfully passed (i.e., 3-knowers succeeded at least twice on N = 3 and failed at least twice on N = 4). Table 1 shows the descriptives of children across the different scores.

Intervention

Children were randomly assigned to either a *Counting Intervention* or a *Control* Group. Procedures were based on Posid and Cordes (2018), in which children either had counting behaviors modeled for them, or a control interaction. Both groups were shown pairs of cards denoting a set of animals (one card denoted 6 animals, and another card denoted a contrasting value of 2, 3, 4, 9, and 12 items). In the Counting group, the experimenter first labeled the cardinality of the card with six items ("This card has 6 animals on it"), and then modeled the *process* of how she arrived at this conclusion. That is, she showed children how to individuate each item by

TABLE 1 Means (*SE* in parentheses) of descriptives across knower levels

Knower-Level Score	N	M_{age}	Mean Cognitive Control Score	Mean Working Memory Score
0	1	3.833	2.000	3.000
1	2	4.166 (1.095)	6.500 (2.500)	3.000 (0)
2	8	3.382 (0.111)	9.000 (1.969)	2.000 (0.463)
3	9	3.729 (0.241)	7.625 (2.130)	2.285 (0.418)
4	4	3.718 (0.309)	9.000 (2.550)	2.250 (0.750)
5	8	4.223 (0.284)	5.714 (2.289)	3.000 (0.500)
6	63	4.452 (0.089)	11.372 (0.715)	3.450 (0.183)

pointing and stating its cardinal number (e.g., "1, 2, 3, 4, 5, 6!"), then stated that the paired card did not have six items ("This card does *not* have 6 animals on it") and proceeded to count the items on the paired card ("1, 2, 3 … etc."). This intervention was thus aimed at promoting children's stating of a verbal count list while individuating items—not necessarily to induce conceptual change in their understanding of number. A total of five trials, each with a 6 card (and a contrasting value) was presented in the following order: 2 versus 6; 3 versus 6; 4 versus 6; 9 versus 6; and 12 versus 6. The left-right placement of the two cards was randomly chosen, but the card with six animals on it was always counted first. Children were encouraged to count along with the experimenter ("Count these with me!") at the beginning of each trial.

In the Control group, children saw the exact same stimuli and received the same labels for the cards ("This card has 6 animals on it!"… "This [other] card does *not* have 6 animals on it!"), but with no modeling of how to count the items. In order to equate the two groups for amount of time taken and account for the fact that pointing and counting take longer than simply labeling the items, the control group cycled through the stimuli twice.

Immediately following the Counting or Control intervention, children completed three trials during which they were shown 2 cards (6 vs. 4, 6 vs. 9, and 6 vs. 3) and were asked to point to the one with six items. Children were not given corrective feedback, but of critical interest was whether children counted the items on the cards (as indexed by pointing to individual items and vocalizing number words) in order to solve the task.

In order to make the procedure of reasonable length for the youngest participants (2- to 3-year-olds), we did not include a post-test symbolic counting assessment. However, prior work has shown a large effect of this exact counting intervention on children's subsequent performance on the Give-N task across all knower-level groups (Posid & Cordes, 2018).

Post-test resource allocation tasks

Children then completed two resource allocation Trial Types: a 4-trial and an 8-trial (order counterbalanced). The post-test trials mimicked the pre-test resource allocation trial, except that children were shown new puppets (either a Hedgehog or a Panda which were also sad and wanted stickers) and were given either 4 or 8 stickers to distribute.

Other cognitive tasks

Finally, to test whether our hypothesized relationship between symbolic counting and sharing behavior was driven by domain-general cognitive skills, children completed two domain-general cognitive assessments: a *cognitive control* task and a *working memory* task (order of these two was counterbalanced).

The cognitive control task was a version of the Day-Night Stroop (Gerstadt et al., 1994), in which children were presented with two cards (one depicting "day" and one depicting "night") and told they would be playing an "opposite game" in which they had to provide the opposite labels for these two cards. Children were allowed two practice trials (with feedback), and then proceeded to 16 test trials (no feedback). Children who got more than four trials incorrect in a row during test trials were reminded of the rules. Children were given a score of 0–16 corresponding to the number of trials they correctly answered.

The working memory assessment (Isaacs & Vargha-Khadem, 1989) was a version of the Forwards-Word Span task in which the experimenter read aloud a list of colors (e.g., "pink", "blue") and children were asked to repeat the words back to the experimenter in the exact order. Children were given two practice trials (with two items each; feedback was provided if they did not answer correctly), and then proceeded to test trials. Children progressed through successive numbers of items on each trial and there were two trials of each type (i.e., two 3-color trials, two 4-color trials, etc.). The assessment stopped once children had two failures on the same trial type (e.g., got both 5-trials wrong). Children were given a score corresponding to the highest number reached prior to the two failures (e.g., a score of 4 if they stopped once getting both 5-trials incorrect).

Coding

All videos were coded by one of several research assistants trained to conduct the study. A separate researcher, blind to conditions and hypotheses then coded all available videos to verify reliability for Stickers Shared, Give N, Stroop Task, and Words Span Performance. Interrater reliability was 92%.

Results

Data for both studies are available via https://osf.io/cgz6v/. Initial results showed no effects of gender, so data were collapsed across this variable. Our main dependent variable was percent deviation from fairness. Following prior work (Chernyak et al., 2019) showing that better symbolic counting is related to closer approximations of sharing to equality, we calculated the *percent deviation from equality* (%DFE) through the following formula:

$$\%\,\text{deviation from equality (\% DFE)} = \frac{|\text{stickers given} - \#\,\text{representing equality}|}{\#\,\text{representing equality}}.$$

In the above equation, the number representing equality corresponded to the number of stickers that

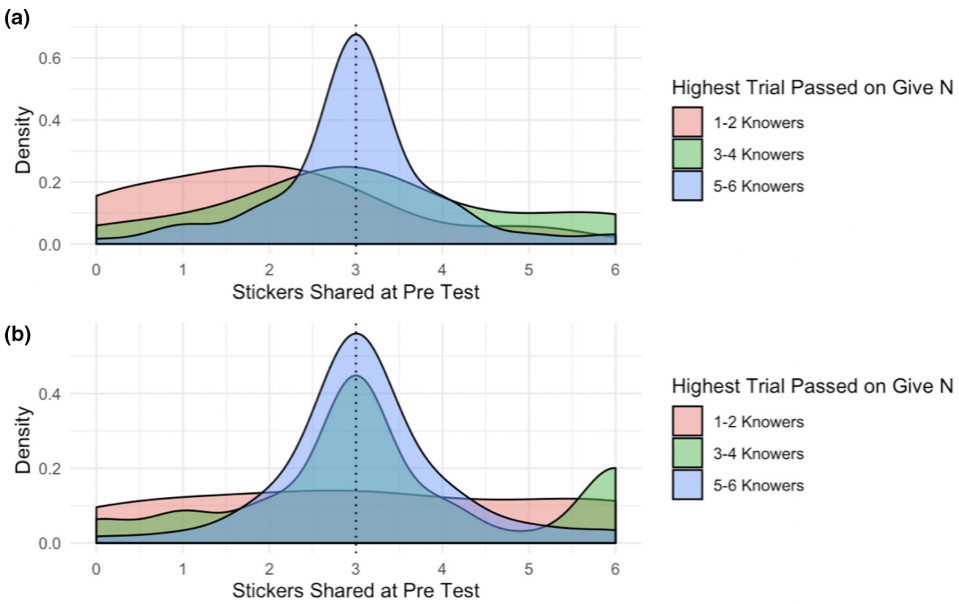
represented a fully equal split (e.g., 3 stickers given away if there were 6 stickers total). Thus, a score of 0 would mean a perfectly fair division of resources, and a score of 1 would indicate a complete departure from equality (keeping or giving away all stickers). This coding scheme allowed us to (a) look at equal sharing behavior in a continuous manner (rather than simply looking at whether or not children shared equally), as well as (b) more readily compare trial types between pre- and post-test where there were differing numbers of stickers by standardizing the stickers given into a percentage. Notably, this scoring system, used in prior work both on sharing (Chernyak et al., 2019) and other numerical cognition tasks (Opfer & Siegler, 2007), treats errors in either direction (in this case, over-sharing and under-sharing) the same way, and thus looks at *deviation* from equality, rather than generosity or selfishness. Preliminary results showed that children in these studies, as in prior work (Chernyak et al., 2019) were just as likely to make errors in either direction (see Figure 1 for distribution of sticker giving).

For all models presented, we use continuous-dependent variables of percent deviation from fairness in order to capture nuances in children's behaviors (not simply *whether* they shared equally, but how close they were to approximating equal sharing if they did not). In our Supplementary Analyses, we also present alternative models in which we use *equal sharing* as a binary dependent variable. As shown in Supplementary Analyses, those results remain consistent with what is reported in the main manuscript. Analyses are confirmatory, except where explicitly labeled as exploratory.

What are the cognitive correlates of fair sharing behavior?

Our first set of analyses examined the cognitive correlates of fair sharing. We first ran a linear model predicting pre-test %DFE, using Age as the predictor. As anticipated, Age predicted how close children were to approximating equality: the older children were, the less they deviated from equal splits in their sharing behavior (see Table 2, Model 1).

We then tested whether our three cognitive predictors (knower level, working memory, and cognitive control) might explain age-related changes in deviations from equality. We ran three additional models (Models 2–4 in Table 2), including age, but also including Knower-Level Score (Model 2), Working Memory (Model 3), or Cognitive Control Score (Model 4) as the predictor. Once age was controlled for, only knower level retained a unique effect on %DFE scores (Model 2). When adding all effects into the model (Model 5), knower level continued to uniquely predict %DFE scores. Figure 1 displays the number of resources shared (stickers given) as a function of number knowledge—children with better Knower level scores were more likely to approach equality when sharing resources. A formal Sobel mediation test showed that Knower-Level Score significantly mediated



Note. Panel A shows Study 1; Panel B shows Study 2 densities (proportion of children giving each type of sticker allocation). Dashed lines indicated equality.

FIGURE 1 Density of stickers given at pre-test across knower-level groups. *Note*: Panel a shows study 1; Panel b shows study 2 densities (proportion of children giving each type of sticker allocation). Dashed lines indicated equality

TABLE 2 Parameter estimates (*SE*s in parentheses) for models predicting percent deviation from fairness (%DFE) for study 1

	Dependent variable: %DFE				
	Model 1	**Model 2**	**Model 3**	**Model 4**	**Model 5**
Age	**−0.091 (0.041)***	−0.035 (0.045)	**−0.096 (0.044)***	**−0.113 (0.045)***	−0.051 (0.049)
Knower-Level Score (0–6)		**−0.061 (0.023)****			**−0.060 (0.025)***
Working Memory Score (0–7)			0.010 (0.023)		0.022 (0.026)
Cognitive Control Score (0–16)				−0.004 (0.006)	−0.004 (0.006)
Constant	**0.641 (0.180)****	**0.704 (0.177)****	**0.634 (0.190)****	**0.778 (0.192)****	**0.737 (0.196)****

Note: Significant effects in bold.
Abbreviation: %DFE, percent deviation from equality.
*$p < .05$.; **$p < .01$.

TABLE 3 Means (*SE*s in parentheses) of pre- and post-test %DFE across knower levels and post-test trial types for study 1 (collapsed across both conditions)

Knower-Level Score	Mean pre-test %DFE	Mean post test %DFE: 4 trial	Mean post test %DFE: 8 trial
0	0.333	0.500	0.500
1	0.667 (0.333)	1.000 (0)	0.875 (0.125)
2	0.458 (0.125)	0.563 (0.147)	0.406 (0.141)
3	0.333 (0.373)	0.278 (0.088)	0.167 (0.083)
4	0.583 (0.250)	0.625 (0.239)	0.500 (0.289)
5	0.167 (0.126)	0 (0)	0.187 (0.063)
6	0.180 (0.034)	0.190 (0.041)	0.210 (0.033)

Abbreviation: %DFE, percent deviation from equality.

age-related changes in %DFE scores, $z = -2.363$, $p = .018$. Thus, the results of Study 1 suggest that symbolic counting uniquely predicted fair sharing behavior.

Does symbolic counting causally predict fair sharing behavior?

Our next question was whether the counting intervention improved fair sharing behavior. Before we tested this, we first confirmed that there were no inadvertent condition differences at Pre-Test %DFE, $t(93.287) = -1.237$, $p = .219$. Table 3 shows the distribution of Pre-Test %DFE and Post-Test %DFE across Knower-Level Scores.

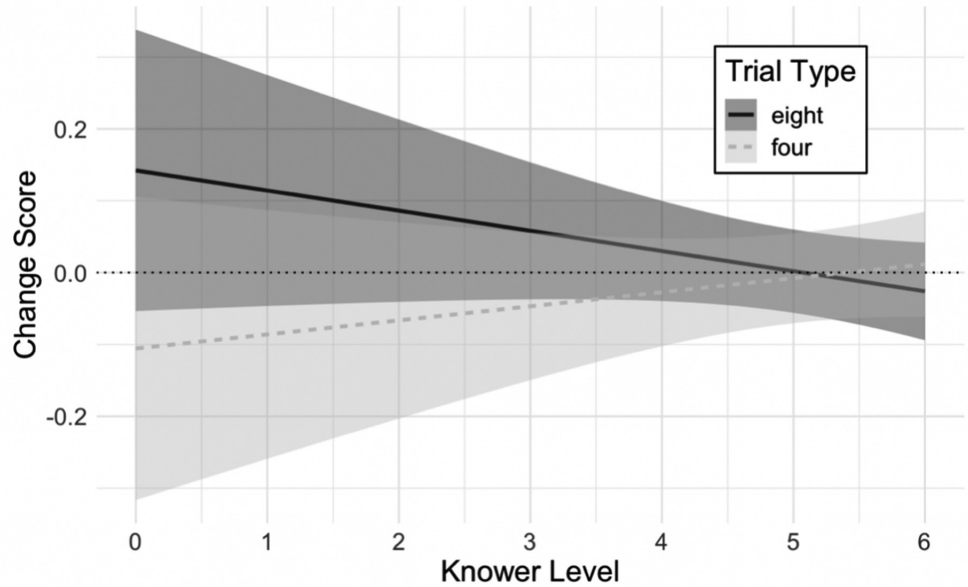
We then confirmed that the Counting condition did in fact induce greater counting behavior. To do this, we considered the number of cards (0–3) on which children counted on the three test trials (when children were no longer explicitly asked to count). We ran a linear model using Age, Knower-Level Score, and Condition as predictors, and the number of cards on which children displayed counting behaviors as the response. Results showed a significant effect of Counting Condition, Wald $\chi^2(1) = 8.987$, $p = .002$, and no other effects (both $ps > .25$), (35% of children in the Counting Condition versus 11% of children in the Control Condition counted; Counting Condition: $M = 0.827$ of 3 cards, $SD = 1.249$; Control Condition: $M = 0.222$, $SD = 0.670$). Thus, our Counting condition did in fact successfully induce greater counting behavior, and did so across children of all knower levels.

In general, we saw a large relationship between how children shared at pre- and post-test, $r(192) = .586$, $p < .001$. Therefore, for our primary dependent variable, we calculated %Change Scores by subtracting Post-Test %DFE from Pre-Test %DFE. Thus, positive scores indicated that children *improved* in fair sharing (produced a more equal distribution) post-manipulation; negative scores indicated that children *worsened* in fair sharing (produced a more unequal distribution) post-manipulation; and scores of 0 indicated no change. We note that this change score thus assessed each child's *improvement* from pre-test rather than absolute performance at post-test: thus, any effects of knower level can be more readily attributed to improvements in sharing, rather than due to the fact that those who had better Knower-Level Scores might show both higher pre- and post-test fair sharing scores.

We specifically predicted that we would see an effect of Condition for children who were at the optimal point of learning (Posid & Cordes, 2018)—that is, those who had not yet mastered counting principles, and those who are dealing with difficult trial types. We, therefore, ran a mixed effects model using Change Score as the response variable and Condition, Knower-Level Score, Post-Test Trial Type (4 trial vs. 8 trial, reflecting the number of stickers presented during each post-test resource allocation task), and all interactions as predictors. We also included Age as a covariate and Subject ID was entered as a random effect. Initial results showed a significant Knower-Level Score × Trial Type Wald $\chi^2(1) = 6.325$, $p = .012$ interaction (Figure 2 below), and no other significant effects (all $ps > .16$). Generally, children with lower Knower-Level Scores who completed the hardest trial type showed the greatest improvements in sharing behavior—this was the group that would be expected to struggle the most, and thus may have been able to benefit the most from additional practice.

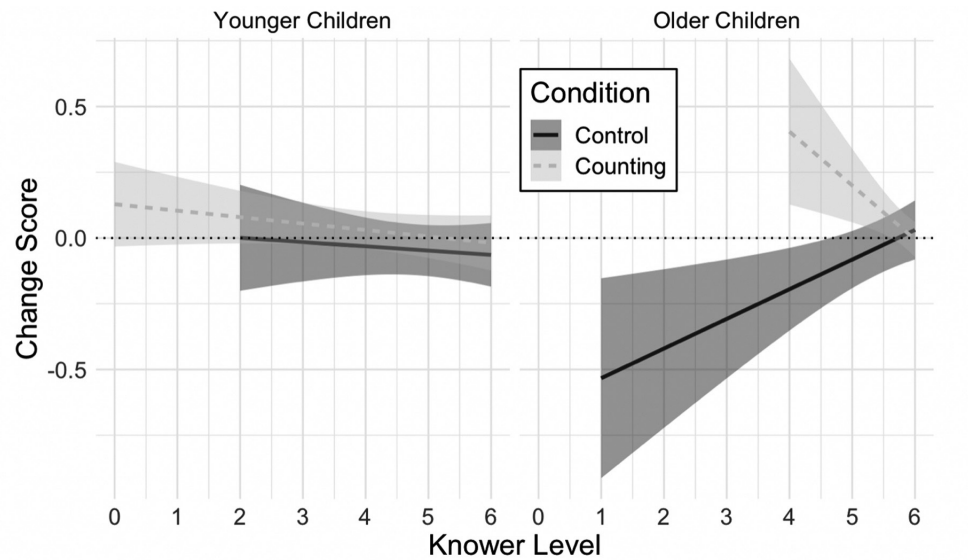
We also ran an additional exploratory model including all interactions with Age. Results showed a Knower-Level Score × Trial Type interaction, Wald $\chi^2(1) = 4.995$, $p = .025$, a significant Condition × Knower-Level Score × Age interaction, Wald $\chi^2(1) = 4.176$, $p = .041$, and no other significant effects (all $ps > .19$). The two-way interaction is displayed in Figure 2. The three-way interaction is displayed in Figure 3. As shown in Figure 3, the group that was most likely to benefit from the counting intervention were older children who were also not yet proficient counters.

Additional exploratory analyses on the sub-group of children who *did not share equally* at pre-test (and thus was the group of children likely to show improvements from our intervention) showed consistent effects: There was a significant Age × Knower-Level Score × Condition



Note. Dashed line represents no change in sharing behavior.

FIGURE 2 Change scores as a function of knower level and post-test trial type in study 1. *Note*: Dashed line represents no change in sharing behavior



Note. For ease of presentation, Age is defined via a median split (*Median age* = 4.36), but is used continuously in all presented models. Dashed line represents no change in sharing behavior.

FIGURE 3 Change scores as a function of age, knower level, condition in study 1. Positive change scores indicate improvements in fair sharing. *Note*: For case of presentation, age is defined via a median split (median age = 4.36), but is used continuously in all presented models. Dashed line represents no change in sharing behavior

interaction, $\chi^2(1) = 4.693$, $p = .030$, consistent with the models reported above.

Does symbolic counting predict beliefs about fairness?

Finally, we analyzed children's tendencies to state that they shared stickers equally both at pre-test and at post-test. As in prior work, the majority of children tended to state that they shared equally at pre-test: of the 88 children who provided codable explanations, 60 (69%) stated that they had shared equally, which far exceeded chance levels of 33% (children were provided with 3 options), binomial $p < .001$. It also significantly exceeded the proportion of children who actually *did* share equally (52 of 97; 53%), McNemar's $\chi^2(1) = 4.654$, $p = .031$, suggesting that, in line with prior work (Chernyak et al., 2019; Smith et al., 2013), preschoolers develop social norm beliefs about equality prior to showing equality in their sharing behavior. In exploratory analyses, we then checked for predictors of children's tendency to state they had shared resources equally at pre-test. We ran a binary logistic model predicting tendency to claim equal sharing at pre-test as the response and Age, Knower-Level Score, Cognitive Control Score, Working Memory Score, and whether the child *had* actually shared equally at pre-test as the predictors. Not surprisingly, the results showed that children who had actually shared equally were more likely to report that they had done so, $\chi^2(1) = 15.710$, $p < .001$. Consistent with prior work showing age-related changes in children's acquisition of equality as a social norm (Chernyak et al., 2019), there was also a significant effect of Age, $\chi^2(1) = 9.489$, $p = .002$, and no other significant effects. Thus, Knower-Level Scores predicted whether children actually shared equally, but age predicted their tendency to claim that they had shared equally—whether or not they had done so.

We performed these same exploratory analyses for the tendency to claim equal sharing at post-test. Of the 180 trials on which children provided codable explanations, children stated that they shared equally on 109 (61%) of them, which far exceeded chance levels of 33% (children were provided with 3 options), binomial $p < .001$. It did not significantly exceed the proportion of trials in which children actually *did* share equally (103 of 194; 53%), McNemar's $\chi^2(1) = 2.75$, $p = .098$. Finally, we ran a binary mixed model predicting the tendency to claim equal sharing at post-test as the response and Age, Knower-Level Score, Condition, Trial Type, Cognitive Control Score, Working Memory Score, Trial Type, and whether the child *had* actually shared equally at pre-test as the predictors. The results showed an effect of whether the child had actually shared equally, $\chi^2(1) = 21.512$, $p < .001$, and no other significant effects (all ps > .201).

Study 1 Discussion

Together, these results provide strong evidence that counting skills promote fair sharing, even when accounting for other domain-general cognitive skills. Replicating prior work (e.g., Chernyak et al., 2019), we find that children's symbolic counting uniquely predicted their fair sharing behavior at pretest, above and beyond cognitive control and working memory.

Moreover, we provide the first evidence that this relationship may be causal. Children's resource distributions were closer to equality following a counting intervention aimed at prompting individuating behaviors, but only for children who had not yet mastered the principles of counting. The effect was strongest for children who were older. In contrast, younger children, who may not have been as receptive to the modeling of counting behaviors in our counting intervention, as well as those who scored highest on the Give-N task (for whom there was no expectation that they would benefit from the counting intervention) and could presumably already apply the principles of counting, tended to show little to no change in their fair sharing behavior following the intervention.

We note, however, that our results employed a fairly small sample of children across each knower-level group, and relied on exploratory subgroup analyses. Thus, our analyses did not allow us to make firm conclusions about which specific children may benefit most from the intervention. For Study 2, we aimed to replicate our results using a larger sample of children, with a fuller distribution of knower levels, to investigate how the counting intervention may benefit children as a function of their initial counting proficiency.

STUDY 2

In Study 2, we sought to conceptually replicate the effects observed in Study 1, as well as enhance our counting intervention by increasing structural similarities between the counting task and the sharing task. In particular, we reasoned that some children may have had trouble seeing the connection between the items they were prompted to count (cards with animals) and the items that were then used in the sharing game (stickers). Thus, to facilitate transfer between the two tasks, we used the same set of stimuli, but increased linguistic cues by marking both stimuli (those used during the counting intervention and stickers used during sharing tasks) as "animal stickers." Children were also encouraged to transfer newly gained skillsets by being asked to count stickers during the post-test sharing tasks. Finally, we made sure to include a larger sample size of children across knower levels, to allow a more thorough investigation of the characteristics of children who may benefit the most from our counting intervention.

Method

Participants

Participants were 219 preschoolers (M_{age} = 3.766, range = 2.160–5.558 years; 121 female) tested in the laboratory, at a local park, or at a local school. Sixty-five additional children were tested but excluded due to failure to complete tasks or attend to instructions (n = 22), equipment malfunction (n = 2), or experimenter error (n = 36), insufficient command of English (n = 3), or parental or sibling interference (n = 3). We note that of these 36, 15 were excluded for a specific experimental error: An early review of videotapes revealed a consistent experimental error due to a misunderstanding during training: namely, some experimenters corrected children's counting of stickers during post-test tasks. All such videos were excluded and researchers were re-trained. Data collection occurred between January 2017 and June 2018.

Procedure

Procedures largely followed those of Study 1, with the following modifications: First, in order to ensure that the procedure was of a reasonable length for the youngest children tested (we attempted to recruit a larger set of children of differing knower levels for this study) and because we found no effects of working memory on sharing behavior in Study 1, we did not include a working memory assessment. Second, because the Happy-Sad Stroop task generally shows greater individual variability, we used it instead of the Day-Night Stroop task as our cognitive control measure (Lagattuta et al., 2011). Table 4 below shows the breakdown of knower levels.

Third, to equate the presence of cognitive control assessments and symbolic counting assessments, all cognitive assessments (the symbolic counting assessment and the cognitive control assessment) were presented *before* the pre-test allocation trials (number knowledge was presented first and cognitive control second).

To increase structural similarity and facilitate transfer between the tasks, the experimenter referred to all stimuli during the counting intervention and resource allocation tasks as "animal stickers." Thus, children encountered what were referred to as "animal stickers" when the experimenter prompted them to count (or simply showed them the stimuli) as well as when they were later asked to share the stickers. To further encourage counting during resource allocation, the experimenter prompted children to count their stickers during post-test resource allocation trials (in both conditions) by presenting the stickers and saying: "I have these animal stickers here—can you count them for me?". A small subset of children (n = 15) were not prompted on at least one of the trials due to minor experimenter error. Our reported analyses remain consistent when excluding this subsample, so analyses including the full sample are reported here. If the child refused or did not wish to participate, the experimenter re-prompted the child, and began by counting the first sticker ("One, …"). If the child still did not participate, the experimenter moved through the rest of the trial. Children were not provided with feedback on incorrect counting during this time. Finally, we slightly increased the difficulty of one of the post-test trials by replacing the 4-trial with a 6-trial instead. Thus, children completed a 6-trial at pre-test and then a 6- and 8-trial at post-test.

TABLE 4 Means (*SE* in parentheses) of descriptives across knower levels

Knower-Level Score	N	M_{age}	Mean Cognitive Control Score
0	3	3.669 (0.779)	2.000 (1.000)
1	13	3.061 (0.151)	5.154 (1.300)
2	40	3.252 (0.060)	5.500 (0.718)
3	24	3.267 (0.072)	8.682 (1.148)
4	25	3.461 (0.093)	8.720 (0.894)
5	25	3.800 (0.115)	9.912 (0.960)
6	88	4.348 (0.072)	10.529 (0.450)

Coding

All videos were coded by one of several research assistants trained to conduct the study. A separate researcher, blind to conditions and hypotheses then coded all available videos to verify reliability for Stickers Shared on each of the three trials, Number of Test Trials Counted, Give N Score, and Stroop Task Score, and whom children said received more stickers on the pre-test trials. Inter-rater reliability was 91%.

Results

Our study was pre-registered on aspredicted.org (https://aspredicted.org/uv425.pdf). We deviated from our pre-registration in two ways: (1) We entered the Give-N score continuously (0–6) instead of binning children into Knower-Level groups (defined in our pre-registration as 1–2 knowers; 3–4 knowers, and Cardinal Principle knowers—i.e., children who passed all trials of the Give-N task and are considered proficient counters). We did this in order to increase our power (Altman & Royston, 2006), to avoid arbitrary binning of children into categories, and to ensure that we captured the full range of knower levels in a continuous way (e.g., 5-knowers). However, all of our reported results remain consistent if we run our pre-registered analyses (see Supporting Information). (2) In models assessing the overall number of stickers shared, we used the proportion of stickers

shared as the outcome measure, rather than the absolute number shared, in order to equate the outcome across the two post-test trials. This was an oversight in our original pre-registration. All analyses are confirmatory, except where explicitly labeled as exploratory.

The results again showed no effects of gender, so data were collapsed across this variable.

What are the cognitive correlates of fair sharing behavior?

Once again, our first question was whether symbolic counting uniquely predicted fair sharing behavior at pre-test. We first ran a linear model predicting pre-test %DFE, and using Age as the predictor. As predicted, Age predicted how close children were to approximating equality: the older children were, the less they deviated from equal splits in their sharing behavior (see Table 5, Model 1).

We then tested whether our cognitive predictors (Knower-Level Scores and cognitive control) might explain age-related changes in deviations from equality. We ran two additional models (Models 2–3 in Table 5), including age, but also including Knower-Level Scores (Model 2), or Cognitive Control Scores (Model 3) as the predictor. All predictors continued to show significant effects on %DFE scores. Unlike in Study 1, cognitive control did retain an effect on sharing behavior. Critically, however, knower level still continued to exert a unique effect even when age and domain-general assessments such as cognitive control were accounted for. Again, a formal Sobel mediation test showed that Knower-Level Score (scored 0–6) significantly mediated age-related changes in %DFE scores, $z = -3.865$, $p < .001$.

Does symbolic counting causally predict fair sharing behavior?

Our next question was whether children who were prompted to count would increase their fair sharing behavior. Before we tested this, we first confirmed that, as in Study 1, there were no differences in Pre-Test %DFE across the two conditions, $t(216.32) = -0.030$, $p = .726$. Table 6 shows the distribution of Pre-Test %DFE and Post-Test %DFE across Knower-level Scores.

We then confirmed that the Counting condition did in fact induce greater counting behavior. To do this, we considered the number of cards (0–3) on which children counted on the three test card trials (i.e., when children were no longer explicitly asked to count). We ran a linear model using Age, Knower-Level Score, and Condition as predictors, and the number of cards on which children displayed counting behaviors as the response. Results showed a significant effect of Condition, Wald $\chi^2(1) = 14.656$ $p < .001$, such that children in the Counting condition ($M = 0.930$, $SE = .121$) counted on significantly more trials than those in the Control condition ($M = 0.340$, $SE = .088$; 38% of children counted in the Counting condition and 15% counted in the Control). Results also revealed a significant effect of Knower-Level Score, Wald $\chi^2(1) = 3.910$ $p = .048$, with children being more likely to engage in counting if they scored highly on the symbolic counting assessment. There was no effect of Age ($p > .80$). Thus, our counting condition did in fact successfully induce greater counting behavior.

As in Study 1, we saw a strong relationship between how children shared at pre- and post-test, $r(431) = .625$, $p < .001$. Overall, children shared equally on 48.2% of trials at pre-test and on 42.5% of trials at post-test. Once again, we calculated %Change Scores by subtracting Post-Test %DFE from Pre-Test %DFE. Thus, negative scores indicated that children *worsened* in equal sharing (produced a more unequal distribution) post-manipulation; positive scores indicated that children *improved* in equal sharing (produced a more equal distribution) post-manipulation; and scores of 0 indicated no change.

We ran a mixed linear model using Change Score as the response variable and Condition, Knower-Level Score, Post-Test Trial Type (reflecting the number of stickers presented during each of the post-test resource allocation trials—6-trial and 8-trial), and all interactions as the predictor variables. Age was included as a covariate and Subject ID as a random effect. Results indicated a significant Knower-Level Score × Condition interaction, Wald $\chi^2(1) = 6.661$, $p = .010$, qualified by a Trial Type × Knower-Level Score × Condition interaction, Wald $\chi^2(1) = 8.057$, $p = .005$, and no other significant effects or interactions (all $ps > .19$).

TABLE 5 Parameter estimates (SEs in parentheses) for models predicting percent deviation from fairness (%DFE) for study 2

	Dependent variable: %DFE			
	Model 1	**Model 2**	**Model 3**	**Model 4**
Age	**−0.2251 (0.032)****	−0.121 (0.040)	**−0.180 (0.036)*****	**−0.106 (0.041)****
Knower-Level Score (0–6)		**−0.067 (0.016)****		**−0.058 (0.017)****
Cognitive Control Score (0–20)			**−0.018 (0.005)****	**−0.014 (0.005)****
Constant	**1.168 (0.123)****	**1.073 (0.121)****	**1.176 (0.125)****	**1.107 (0.124)****

Note: Significant effects in bold.

Abbreviation: %DFE, percent deviation from equality.

*$p < .05$.; **$p < .01$.; ***$p < .005$.

To formally explore the interactions with Trial Type, we ran two additional follow-up models: one for the 6-trial and one for the 8-trial. For each model, we used Age, Knower-Level Score, Condition, and Knower-Level Score × Condition as predictors and Change Score as the response variable. There were no significant effects for the 6-trial (all *p*s > .20). For the 8-trial, there was a significant Condition × Knower-Level Score interaction, Wald $\chi^2(1) = 13.456$, $p < .001$, and no other significant effects (all *p*s > .26). As shown in Figure 4, children who scored the lowest on the symbolic counting assessment benefitted the most from the Counting intervention in the 8-trial.

Additional analyses on the sub-group of children who *did not share equally* at pre-test showed consistent effects: There was a significant effect of Condition, $\chi^2(1) = 4.078$, $p = .043$, qualified by a Condition × Knower-Level Score × Trial Type interaction, $\chi^2(1) = 4.943$, $p = .026$.

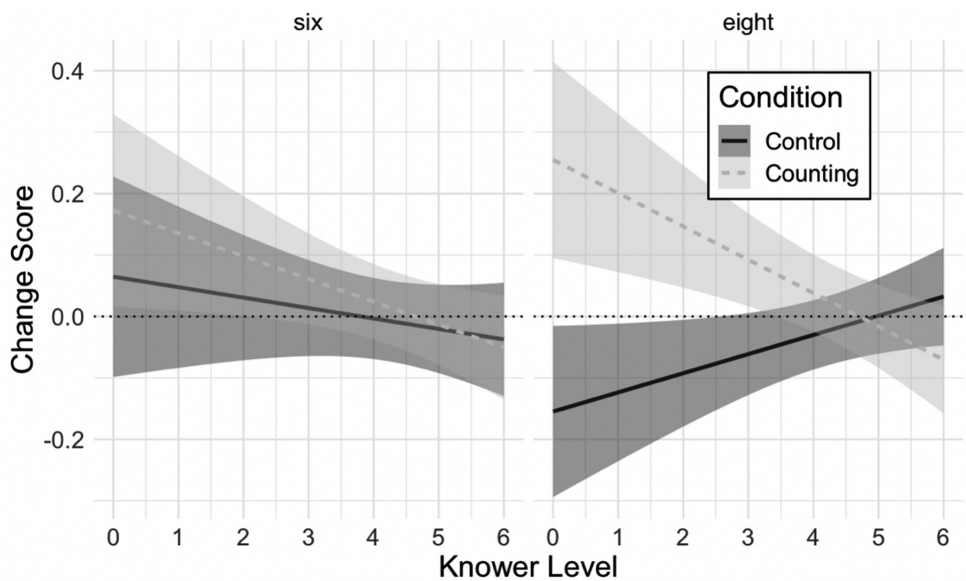
TABLE 6 Means (SEs in parentheses) of pre- and post-test %DFE across knower levels and post-test trial types for study 2

Knower-level score	Mean pre-test %DFE	Mean post test %DFE: 6 trial	Mean post test %DFE: 8 trial
0	0.556 (0.222)	0.667 (0.192)	0.583 (0.300)
1	0.692 (0.122)	0.590 (0.137)	0.634 (0.112)
2	0.558 (0.065)	0.488 (0.064)	0.519 (0.060)
3	0.458 (0.092)	0.390 (0.075)	0.420 (0.080)
4	0.307 (0.074)	0.440 (0.069)	0.360 (0.071)
5	0.293 (0.070)	0.253 (0.059)	0.280 (0.060)
6	0.155 (0.027)	0.203 (0.034)	0.174 (0.031)

Abbreviation: %DFE, percent deviation from equality.

Does symbolic counting predict beliefs about fairness?

Finally, as in prior work, we analyzed children's tendencies to state that they shared stickers equally both at pre-test and at post-test. As in prior work, the majority of children tended to state that they shared equally at pre-test: of the 209 children who provided codable explanations, 139 (67%) stated that they had shared equally, which far exceeded chance levels of 33% (children were provided with three options), binomial $p < .001$. It also significantly exceeded the proportion of children who actually *did* share equally (106 of 220; 48%), McNemar's $\chi^2(1) = 16.695$, $p < .001$, confirming once again that preschoolers' social norm knowledge of sharing equally exceeded their actual behavioral production of equality. As in Study 1, we ran exploratory analyses to check for predictors of children's tendency to state they had shared resources equally at pre-test. We ran a binary logistic model predicting tendency to claim equal sharing at pre-test as the response and Age, Knower-Level Score, Cognitive Control Score, and whether the child *had* actually shared equally at pre-test as the predictors. Not surprisingly, the results showed an effect of whether children had actually shared equally, $\chi^2(1) = 12.660$, $p < .001$. There was also a non-significant trend of Age, $\chi^2(1) = 3.249$, $p = .071$, a non-significant trend of Cognitive Control, $\chi^2(1) = 2.880$, $p = .090$, but no effect of Knower-Level Score ($p > .25$). Thus, again, symbolic counting predicted children's equal sharing *behavior*, but not their tendency *to state* they had shared resources equally.



Note. Bands represent standard errors. Dashed line represents no change.

FIGURE 4 Regression lines showing change scores as a function of post-test trial type, Knower-Level Score, and condition in study 2. *Note*: Bands represent standard errors. Dashed line represents no change

We found the same pattern of results for children's answers at post-test. We performed these same exploratory analyses for the tendency to claim equal sharing at post-test. Of the 415 trials on which children provided codable explanations, children stated that they shared equally on 258 (62%) of them, which far exceeded chance levels of 33% (children were provided with three options), binomial $p < .001$. It also significantly exceeded the proportion of trials on which children actually *did* share equally (187 of 440; 43%), McNemar's $\chi^2(1) = 38.252$, $p < .001$. Finally, we ran a binary mixed model predicting the tendency to claim equal sharing at post-test as the response and Age, Condition, Knower-Level Score, Cognitive Control Score, Trial Type, and whether the child *had* actually shared equally at pre-test as the predictors. The results showed an effect of whether the child had actually shared equally, $\chi^2(1) = 25.787$, $p < .001$, a significant effect of Cognitive Control, $\chi^2(1) = 4.668$, $p = .030$, and no other significant effects (all ps > .70).

Study 2 Discussion

As in Study 1, we again replicate the effect of symbolic counting on children's fair sharing behavior, even when controlling for individual differences in age and cognitive control. We also find an effect of our counting intervention—children who were not yet proficient counters benefited from the counting intervention in the most difficult trial (the 8-trial), one that they had not experienced at pre-test. (Notably, non-proficient counters in the Counting condition were also more likely to share fairly in the 6-trial than in pre-test, however, their level of improvement was only slightly better than what was found in the Control condition.) Unlike in Study 1, our results are not consistent with the possibility that children simply regressed to the mean. Together with Posid and Cordes (2018), these results suggest that children are responsive to counting prompts before they have yet become proficient counters, and these counting prompts can promote performance on both numerical and sharing tasks. Finally, we find striking similarities in the rates of children's reports of fair sharing—overall, children stated that they shared resources equally at high rates, and the tendency to state having done so did not depend on number knowledge. We thus continue to find a dissociation between the cognitive predictors of social norm knowledge and the predictors of fair sharing behavior.

Overall analyses

We combined data from Studies 1 and 2 to run a cross-study analysis using the variables that were common to the two studies. First, we ran a model predicting pre-test percent deviation from fairness scores from Age, Knower-Level Score, Cognitive Control, and Study (1 or 2). Confirming the main finding in this paper, the results showed a continued significant effect of Knower-Level Score, $\chi^2(1) = 21.220$, $p < .001$. There were also significant effects of Age, $\chi^2(1) = 8.672$, $p = .003$, and of Cognitive Control, $\chi^2(1) = 5.076$, $p = .024$. While the effect of cognitive control remained, it was significantly weaker than the effect of symbolic counting (comparison of standardized Betas: $\chi^2(1, 288) = 12.825$, $p < .001$). Thus, we find that children's fair sharing behavior is explained by their symbolic counting proficiency, even when controlling for other cognitive abilities.

Second, we ran an omnibus analysis of Condition on fair sharing behavior. We calculated change scores and ran a model predicting change scores from Age, Cognitive Control, Study Type, Knower-Level Score, Condition, and the predicted Knower-Level Score × Condition interaction, entering Subject ID as a random effect. We found a significant Knower-Level Score × Condition interaction $\chi^2(1) = 6.337$, $p = .011$, and no other significant effects (all ps > .20).

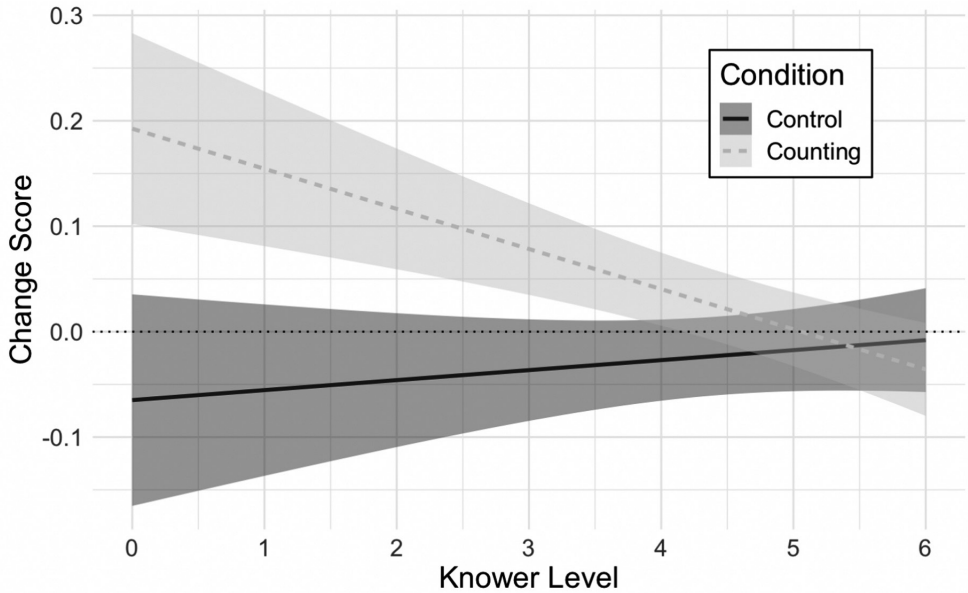
To formally explore the interaction, follow-up models were run on each condition separately (using Age, Cognitive Control, Study Type, and Knower-Level Score as the predictors). There were no significant effects in the Control Condition model, whereas the model using the Counting condition showed a significant effect of Knower-Level Score, $\chi^2(1) = 3.827$, $p = .050$, and no other significant effects.

This interaction is displayed in Figure 5: Children who showed the lowest knower levels scores benefitted the most from the counting intervention (namely, children who initially scored into levels 0–3 on Give-N). In contrast, proficient counters and children in the control condition had change scores close to 0, indicating no change in sharing behavior between pre- and post-test.

GENERAL DISCUSSION

Across two studies, we found evidence for the influence of symbolic counting on sharing behavior, even when accounting for other domain-general cognitive skills, such as cognitive control, working memory, and general maturation (age). We also found evidence that children's fair sharing can be promoted with a counting intervention, suggesting a causal link between symbolic counting and children's abilities to distribute resources fairly.

In general, while a host of recent work has been devoted to uncovering the mechanisms underlying our prosocial behavior, the literature has delivered mixed results: while some studies find an effect of theory of mind and perspective taking on equal sharing (Heck et al., 2018; Wu & Su, 2014), others find that theory of mind predicts strategic, rather than equal sharing (Cowell et al., 2015). Similarly, while some studies find that cognitive control exerts an effect on fair sharing (Blake et al., 2015; Steinbeis & Over, 2017), others show little or no effect (Blake, 2018;



Note. Bands represent standard errors. Dashed line represents no change.

FIGURE 5 Change scores across studies as a function of condition and knower levels. *Note*: Bands represent standard errors. Dashed line represents no change

Heck et al., 2018). In our own study, we find an effect of cognitive control, though this was specific to Study 2. In Study 2, children at lower knower levels, but with high cognitive control exhibited a stronger trend toward equal sharing than other subgroups (see Supplementary Analyses). Thus, one possibility, supported by our prior work (Chernyak et al., 2016), is that children who do not yet possess the requisite skill of counting, are able to solve the problem of fair sharing through turn-taking resources (e.g., alternating which recipient receives which resource until all resources are doled out), a strategy that may require cognitive control in order to carry out precisely.

Our second major finding is that prompting children to count *causally* influenced their tendency to distribute resources fairly. We show this for the group of children that we expected, based on prior work (Posid & Cordes, 2018) to benefit from our counting intervention—namely, children who have not yet attained counting proficiency. For the most part, children's allocation strategies were consistent between pre- and post-test (there were strong correlations between the two, and the modal change score tended to be 0), suggesting that individual differences in motivation may also impact children's choice of allocation strategies: those who share equally tend to continue doing so throughout, as do those who share generously and selfishly. Importantly, however, counting helped a significant portion of children shift toward more equal strategies.

It is worth asking *which* specific aspect of our counting intervention impacted children's abilities to share fairly. Our counting intervention was based on prior work showing that those who completed the procedure improved their performance on the Give-N Task (Posid & Cordes, 2018). Here, we saw evidence that children who were given the counting intervention were more likely to use pointing and counting during subsequent test trials, and were more likely to share their resources fairly. Therefore, we suspect that the counting intervention helped provide children with appropriate behavioral tools (e.g., pointing, verbal number labels, and individuating) that enabled children to properly track the distribution of resources and ensure better approximations to equality between the two sets. We note that it is unlikely that the counting intervention promoted deep conceptual change in *either* sharing or counting. Instead, we propose that counting provided children who were already motivated to share—and had some rudimentary understanding that the resources were countable—with an effective strategy for executing their preferred distribution.

Admittedly, a host of motivational, situational, and individual cognitive factors may impact the extent to which this intervention is successful. Prior work has already documented the importance of motivational constraints on sharing behavior (Smith et al., 2013). In these types of studies, motivational constraints are maximal, because children frequently are asked to anonymously donate to an unknown recipient peer. Thus, children are likely to share at relatively low rates due to motivational factors. In contrast, our studies are designed to *increase* motivation to share, by introducing a non-anonymous, present recipient and making the recipient's need salient. When motivational constraints are lifted, we find that cognitive constraints (symbolic counting) explain

a large part of the variation in fair sharing. Our study demonstrates that the absence of fair sharing cannot be explained by appealing only to motivational constraints. Instead, motivational constraints are likely to influence children's *intended* allocations, and cognitive constraints are likely to explain how closely children are able to align their *intended* allocations with their *achieved* allocations.

The counting intervention we used has largely been successful in improving the counting skills by prompting children to point to, individuate, and track items (Posid & Cordes, 2018). The observed effects appeared stronger in Study 2, in which we introduced more structural similarity between the intervention and the resource allocation tasks, suggesting that children may have trouble applying newly gained knowledge to new tasks. Future work should investigate how to promote transfer between two structurally dissimilar tasks, or consider using a longitudinal design in order to test the amount of time children need before being comfortable with applying newly gained counting knowledge within the social domain.

It is worth asking whether symbolic counting *drives* prosocial behavior, or whether it provides children with a tool to *enact* prosocial behavior. We believe our data, along with prior work, strongly suggests the latter. First of all, even infants expect equitable resource distribution (Geraci & Surian, 2011; Schmidt & Sommerville, 2011). Second, preschool-aged children articulate the norm of *equal* sharing prior to displaying it in their behavior (Smith et al., 2013). Finally, prior work finds that symbolic counting is associated with *behavioral fairness* but is not associated with the acquisition of fairness as a social norm (Chernyak et al., 2019). Our results conceptually replicate this finding: Age, but not Knower-Level Socre, predicts stating that one had shared resources equally (see also Chernyak et al., 2016). Thus, we believe that these data, combined with prior work, strongly suggest that the motivation to share resources equally is present before children's abilities to do so. In general, prior work finds that preschoolers display a host of *both* prosocial sharing tendencies (e.g., Chernyak & Kushnir, 2013; Hamann et al., 2011) and selfish ones (Blake & McAuliffe, 2011; Smith et al., 2013), suggesting that both prosocial and selfish drives are present in early childhood in the context of resource distribution. One intriguing possibility is that symbolic counting may provide children with a tool for *resolving* these two salient drives.

We conclude by pointing to the fact that recent work has taken a great deal of interest in understanding why children show an awareness of fairness principles but fail to abide by them (Smith et al., 2013). We argue that individual differences in fairness stem in part from individual children's abilities to count and enumerate resources. We suggest that children's apparent "errors" in fair sharing can be explained not with respect to lower cognitive resources or an immature understanding of norms, but rather as a normative stage in development in which young children have not yet learned to apply their emerging counting skills to the social task of creating equality. Our results have two main implications for future work in this area: First, we propose that these results may shed light on work showing strong cultural, age, and individual differences in our principles of fairness (e.g., Blake & McAuliffe, 2011; House et al., 2013; Schäfer et al., 2015; see also Jara-Ettinger et al., 2016). While we do not propose that cultural differences are solely driven by numerical abilities, one intriguing possibility may be that these cultural differences are driven by differences in how children and adults process, respond, emphasize, and encode numerical information. Second, our work suggests that individual developmental differences in social abilities ought to be interpreted with respect to children's developmental stages in their *cognitive* abilities. Thus, further work may explore how social skills can be encouraged through enabling children to acquire the requisite cognitive abilities. We suggest that bridging the two domains may be particularly fruitful for understanding each one individually.

ACKNOWLEDGMENTS

We thank members of the Infant and Child Cognition Lab at Boston College, especially Raychel Gordon for leading data collection, coding and recruitment efforts. We also thank Lucy Stowe and Jessica Gonzalez for feedback on an earlier draft. This work was funded by Grant #56348 from the John Templeton Foundation and Grant #1920660 from the National Science Foundation.

ORCID

Nadia Chernyak https://orcid.org/0000-0003-3061-0523
Paul L. Harris https://orcid.org/0000-0003-4907-0539

REFERENCES

Altman, D. G., & Royston, P. (2006). The cost of dichotomising continuous variables. *British Medical Journal*, *332*(7549), 1080. https://doi.org/10.1136/bmj.332.7549.1080

Blake, P. R. (2018). Giving what one should: explanations for the knowledge-behavior gap for altruistic giving. *Current Opinion in Psychology*, *20*, 1–5. https://doi.org/10.1016/j.copsyc.2017.07.041

Blake, P. R., & McAuliffe, K. (2011). "I had so much it didn't seem fair": Eight-year-olds reject two forms of inequity. *Cognition*, *120*(2), 215–224.

Blake, P. R., Piovesan, M., Montinari, N., Warneken, F., & Gino, F. (2015). Prosocial norms in the classroom: The role of self-regulation in following norms of giving. *Journal of Economic Behavior & Organization*, *115*, 18–29. https://doi.org/10.1016/j.jebo.2014.10.004

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), e12695. https://doi.org/10.1111/desc.12695

Chernyak, N., & Kushnir, T. (2013). Giving preschoolers choice increases sharing behavior. *Psychological Science*, *24*(10), 1971–1979.

Chernyak, N., Sandham, B., Harris, P. L., & Cordes, S. (2016). Numerical cognition explains age-related changes in third-party fairness. *Developmental Psychology*, *52*(10), 1555–1562. https://doi.org/10.1037/dev0000196

Chernyak, N., Turnbull, V., Gordon, R., Harris, P. L., & Cordes, S. (2020). Counting promotes proportional moral evaluation in preschool-aged children. *Cognitive Development*, *56*, 100969. https://doi.org/10.1016/j.cogdev.2020.100969

Cowell, J. M., Samek, A., List, J., & Decety, J. (2015). The curious relation between theory of mind and sharing in preschool age children. *PLoS One*, *10*(2), e0117947. https://doi.org/10.1371/journal.pone.0117947

Engle, R. W. (2010). Role of working-memory capacity in cognitive control. *Current Anthropology*, *51*(Suppl. 1), S17–S26. https://doi.org/10.1086/650572

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.

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 312–7 years old on a stroop- like day-night test. *Cognition*, *53*(2), 129–153. https://doi.org/10.1016/0010-0277(94)90068-X

Hamann, K., Warneken, F., Greenberg, J. R., & Tomasello, M. (2011). Collaboration encourages equal sharing in children but not in chimpanzees. *Nature*, *476*(7360), 328–331.

Hay, D. F., Castle, J., Davies, L., Demetriou, H., & Stimson, C. A. (1999). Prosocial action in very early childhood. *The Journal of Child Psychology and Psychiatry and Allied Disciplines*, *40*(6), 905–916. https://doi.org/10.1111/1469-7610.00508

Heck, I. A., Chernyak, N., & Sobel, D. M. (2018). Preschoolers' compliance with others' violations of fairness norms: The roles of intentionality and affective perspective taking. *Journal of Cognition and Development*, *19*(5), 568–592. https://doi.org/10.1080/15248372.2018.1504052

House, B., Henrich, J., Sarnecka, B., & Silk, J. B. (2013). The development of contingent reciprocity in children. *Evolution and Human Behavior*, *34*(2), 86–93.

Huang, Y. T., Spelke, E., & Snedeker, J. (2010). When is four far more than three? Children's generalization of newly acquired number words. *Psychological Science*, *21*(4), 600–606.

Isaacs, E. B., & Vargha-Khadem, F. (1989). Differential course of development of spatial and verbal memory span: A normative study. *British Journal of Developmental Psychology*, *7*(4), 377–380. https://doi.org/10.1111/j.2044-835X.1989.tb00814.x

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.

Kroesbergen, E. H., van't Noordende, J. E., & Kolkman, M. E. (2014). Training working memory in kindergarten children: Effects on working memory and early numeracy. *Child Neuropsychology*, *20*(1), 23–37. https://doi.org/10.1080/09297049.2012.736483

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. https://doi.org/10.1111/j.1467-7687.2010.00994.x

Marcovitch, S., O'Brien, M., Calkins, S. D., Leerkes, E. M., Weaver, J. M., & Levine, D. W. (2015). A longitudinal assessment of the relation between executive function and theory of mind at 3, 4, and 5 years. *Cognitive Development*, *33*, 40–55. https://doi.org/10.1016/j.cogdev.2014.07.001

Muldoon, K. P., Lewis, C., & Freeman, N. (2009). Why set-comparison is vital in early number learning. *Trends in Cognitive Sciences*, *13*(5), 203–208. https://doi.org/10.1016/j.tics.2009.01.010

Munakata, Y., Snyder, H. R., & Chatham, C. H. (2012). Developing cognitive control: Three key transitions. *Current Directions in Psychological Science*, *21*(2), 71–77. https://doi.org/10.1177/0963721412436807

Opfer, J. E., & Siegler, R. S. (2007). Representational change and children's numerical estimation. *Cognitive Psychology*, *55*(3), 169–195. https://doi.org/10.1016/j.cogpsych.2006.09.002

Posid, T., & Cordes, S. (2018). How high can you count? Probing the limits of children's counting. *Developmental Psychology*, *54*(5), 875–889. https://doi.org/10.1037/dev0000469

Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind: A comparison of Chinese and US preschoolers. *Psychological Science*, *17*(1), 74–81. https://doi.org/10.1111/j.1467-9280.2005.01667.x

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. https://doi.org/10.1111/cogs.12043

Schäfer, M., Haun, D. B., & Tomasello, M. (2015). Fair is not fair everywhere. *Psychological Science*, *26*(8), 1252–1260.

Schmidt, M. F., & Sommerville, J. A. (2011). Fairness expectations and altruistic sharing in 15-month-old human infants. *PloS One*, *6*(10), e23223.

Smith, C. E., Blake, P. R., & Harris, P. L. (2013). I should but I won't: Why young children endorse norms of fair sharing but do not follow them. *PLoS One*, *8*(3), e59510. https://doi.org/10.1371/journal.pone.0059510

Sohail, S., Dunfield, K. A., & Chernyak, N. (2021). Dissociable mechanisms for diverse prosocial behaviors: Counting skills predict sharing behavior, but not instrumental helping. *Journal of Cognition and Development*, 1–15. https://doi.org/10.1080/15248372.2021.1998064

Soltész, F., Szűcs, D., & Szűcs, L. (2010). Relationships between magnitude representation, counting and memory in 4-to 7-year-old children: A developmental study. *Behavioral and Brain Functions*, *6*(13). https://doi.org/10.1186/1744-9081-6-13

Squire, S., & Bryant, P. (2002). From sharing to dividing: young children's understanding of division. *Developmental Science*, *5*(4), 452–466. https://doi.org/10.1111/1467-7687.00240

Steinbeis, N., & Over, H. (2017). Enhancing behavioral control increases sharing in children. *Journal of Experimental Child Psychology*, *159*, 310–318. https://doi.org/10.1016/j.jecp.2017.02.001

Wu, Z., & Su, Y. (2014). How do preschoolers' sharing behaviors relate to their theory of mind understanding? *Journal of Experimental Child Psychology*, *120*, 73–86. https://doi.org/10.1016/j.jecp.2013.11.007

Wynn, K. (1990). Children's understanding of counting. *Cognition*, *36*(2), 155–193.

Xiong, M., Shi, J., Wu, Z., & Zhang, Z. (2016). Five-year-old preschoolers' sharing is influenced by anticipated reciprocation. *Frontiers in Psychology*, *7*, 460. https://doi.org/10.3389/fpsyg.2016.00460

Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., & Sutherland, A. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development*, *68*, i–151.

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

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