

## BRIEF REPORT

# Numerical Cognition Explains Age-Related Changes in Third-Party Fairness

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Young children share fairly and expect others to do the same. Yet little is known about the underlying cognitive mechanisms that support fairness. We investigated whether children's numerical competencies are linked with their sharing behavior. Preschoolers (aged 2.5–5.5) participated in third-party resource allocation tasks in which they split a set of resources between 2 puppets. Children's numerical competence was assessed using the Give-*N* task (Sarnecka & Carey, 2008; Wynn, 1990). Numerical competence—specifically knowledge of the cardinal principle—explained age-related changes in fair sharing. Although many subset-knowers (those without knowledge of the cardinal principle) were still able to share fairly, they invoked turn-taking strategies and did not remember the number of resources they shared. These results suggest that numerical cognition serves as an important mechanism for fair sharing behavior, and that children employ different sharing strategies (division or turn-taking) depending on their numerical competence.

*Keywords:* sharing, fairness, numerical cognition, preschoolers, prosocial behavior

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By the preschool age, young children show many precursors of fairness. Although the ability to share fairly often does not appear until middle childhood (e.g., Fehr, Bernhard, & Rockenbach, 2008), early hints of fairness appear in children's explicit endorsements of fairness as a social norm (Damon, 1979; Smith, Blake, & Harris, 2013), in their affective responses toward receiving inequalities (LoBue, Nishida, Chiong, DeLoache, & Haidt, 2011), and in their own distribution of resources between third parties (Olson & Spelke, 2008). By middle childhood, children go to great

lengths to be fair and to appear fair to others, even in third-party contexts, in which they presumably have no stake: they discard resources in order to avoid inequalities (Shaw & Olson, 2012) and they spontaneously correct an adult's unequal distribution of resources (Paulus, Gillis, Li, & Moore, 2013). Thus, children appear to show sufficient motivation to be fair at an early age—they recognize what fairness is and understand why it is important. Yet little is known about the mechanisms that bring about active fair sharing in young children. In our work, we explore the extent to which children's understanding of number underpins their abilities to share fairly with others.

Recent theoretical work has begun to ask how to reconcile children's early developing understanding and endorsement of fairness with its relatively late behavioral emergence. Uncovering the mechanisms by which children achieve fairness is important given recent theoretical work in prosocial behavior on the "knowledge-behavior gap": Although young children recognize situations that are fair or unfair (Schmidt & Sommerville, 2011; Sloane, Baillargeon, & Premack, 2012), they do not always behave fairly themselves (see Blake, McAuliffe, & Warneken, 2014; Sheskin, Chevallier, Lambert, & Baumard, 2014). Although children may be able to recognize fair sharing, they may not act accordingly.

We argue that certain cognitive abilities, such as numerical understanding, might underpin young children's abilities to share

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fairly. To begin, we wish to draw attention to the distinction between *first-party fairness* (costly fairness), in which children divide resources between themselves and another recipient, and *third-party fairness* (costless fairness), in which children distribute resources between two third parties. In the former case, inconsistency between explicit knowledge of social norms and actual behavior is not surprising—even adults display basic moral hypocrisy (e.g., Batson, Kobrynowicz, Dinnerstein, Kampf, & Wilson, 1997). Children, even more so, may be subject to a series of constraints that prevent them from acting fairly despite recognizing that they should. Preschool-aged children are still developing requisite skills such as inhibitory control (Aguilar-Pardo, Martinez-Arias, & Colmenares, 2013), self-regulation (Blake, Piovesan, Montinari, Warneken, & Gino, 2015), and theory of mind (e.g., Moore & Macgillivray, 2004)—all of which enable sharing with others at a cost to the self. Therefore, first-party fairness, which involves sharing at a cost to oneself, may be a later-developing ability that emerges in concert with these behavioral and cognitive abilities.

Whether and why the knowledge-behavior gap might appear in the context of third-party fairness, however, is less clear. In contrast to first-party fairness, third-party fairness requires no cost to the child, and thus should not require advanced self-regulatory skills or behavioral inhibition. Given the relatively lower demands of third-party fairness, it is an open question whether younger children might show a knowledge-behavior gap in that context. Studying third-party fairness, which recent evidence suggests that even infants can recognize (Schmidt & Sommerville, 2011), and even preschoolers are motivated to direct third-parties to do (Olson & Spelke, 2008) allows us to test for potential cognitive mechanisms to fairness in a context that is unconfounded by potential motivational concerns. To our knowledge, no work in the prosocial behavior literature has documented age-related changes in children's ability to spontaneously produce fair sharing distributions (but see also Posid, Fazio, & Cordes, 2015). Therefore, our first question concerned whether there might be age-related changes in third-party fairness. Our second and critical question, concerned the cognitive mechanisms underlying third-party fairness. In particular, we propose that numerical cognition might underpin young children's abilities to share fairly.

Many instances of sharing are inherently number-based. In order to understand how six candies should be shared between three people, one should understand that six divided by three results in two candies each. Similarly, a division is unfair if it does not show cardinal equivalence—if, for example, one person received three candies, and another received only one. Such simple numerical calculations underlie our understanding of higher-order concepts such as fairness, equality, and generosity. In spite of the clear connection between sharing and numerical cognition, few studies have charted how number knowledge might relate to children's resource distribution.

Several earlier findings suggest that numerical cognition and sharing are, in fact, related: First, older work found that in middle childhood, children come to understand concepts of division through the action schema of sharing (Correa, Nunes, & Bryant, 1998; Desforges & Desforges, 1980; Frydman & Bryant, 1988; Squire & Bryant, 2002a, 2002b). That is, children find division problems easier when they are presented with the end goal of sharing resources fairly (“How many candies are in each box?”)

than when the end goal is to figure out the number of recipients present during fair sharing (“How many boxes did we use?”). Second, understanding the cardinal principle (CP)—that the last word in a count represents the entire set—appears particularly critical for an understanding of equality, or fairness. Younger children, with presumably limited numeracy skills, have difficulty splitting resources fairly and fail to recognize the connection between sharing and cardinal equivalence (i.e., do not recall correctly that each recipient has the same amount; Frydman & Bryant, 1988; see also Pepper & Hunting, 1998). Conversely, children's ability to detect violations in fair sharing relates to their abilities to understand the cardinal equivalence of two identical sets (Muldoon, Lewis, & Berridge, 2007; Muldoon, Lewis, & Freeman, 2009). Finally, outside of sharing contexts, children's number knowledge (understanding of the CP) has been documented to relate to children's understanding of set equivalence, which is a key component to understanding equality and fairness (Sarnecka & Wright, 2013).

This converging evidence suggests that children's numerical competencies might be related to their ability to behave fairly, and may help explain the knowledge-behavior gap in fairness. That is, one possibility as to why young children understand equality but do not act accordingly may be the fact that they have not yet developed full-fledged numerical competencies. Our focal research question thus centered on whether age-related changes in fairness are related to children's numerical cognition. We investigated these questions by looking at children's resource distribution across the preschool period (2.5 to 5.5) in relation to their understanding of cardinality (as assessed by a Give-*N* task).

Secondary analyses focused on the types of strategies children use when accomplishing a fair distribution. Prior work has documented that young children, who do not yet explicitly recognize the connection between sharing and cardinal equivalence, distribute resources using “simpler” strategies, such as one-to-one correspondence (e.g., giving each recipient one resource in turn until they run out of resources; Frydman & Bryant, 1988). We were interested in whether the use of such strategies may be more prevalent among children who do not have the requisite numerical cognition to use more advanced number-based sharing strategies. Finally, we probed children's memories for the resources they had shared and their sharing justifications.

Children were prompted to share a set of resources (four items and six items) between two recipients. We coded whether children successfully shared these fairly resources between the two recipients, the strategy they used, their memory for the number of stickers given to each recipient, and their sharing justifications when making resource distribution decisions (through forced choice prompts and explanatory responses). We related all of these behaviors to children's individual numerical competence as assessed via a version of the Give-*N* task (Sarnecka & Carey, 2008; Wynn, 1990).

## Method

### Participants

Seventy-three children (28 male, 45 female) were tested at a local children's museum or during a laboratory visit (*M* age = 3y;8m, range = 2y;6m – 5y;6m). Nineteen additional children

were excluded due to experimenter error ( $n = 7$ ), parental/sibling interference ( $n = 4$ ), failure to complete the task ( $n = 3$ ), or due to no video (either recording error or lack of parental consent to video record;  $n = 5$ ).

## Materials

A schematic of the materials is displayed in [Figure 1](#). Materials for the resource distribution task were four plush animals (hedgehog, panda, dog, and elephant), four wooden boxes—one for each puppet with pictures of the puppet on the tops and insides, and 10 small purple dinosaur toys. Materials for the Give- $N$  task were a set of small yellow rubber ducks and a blue basket used to symbolize a pond.

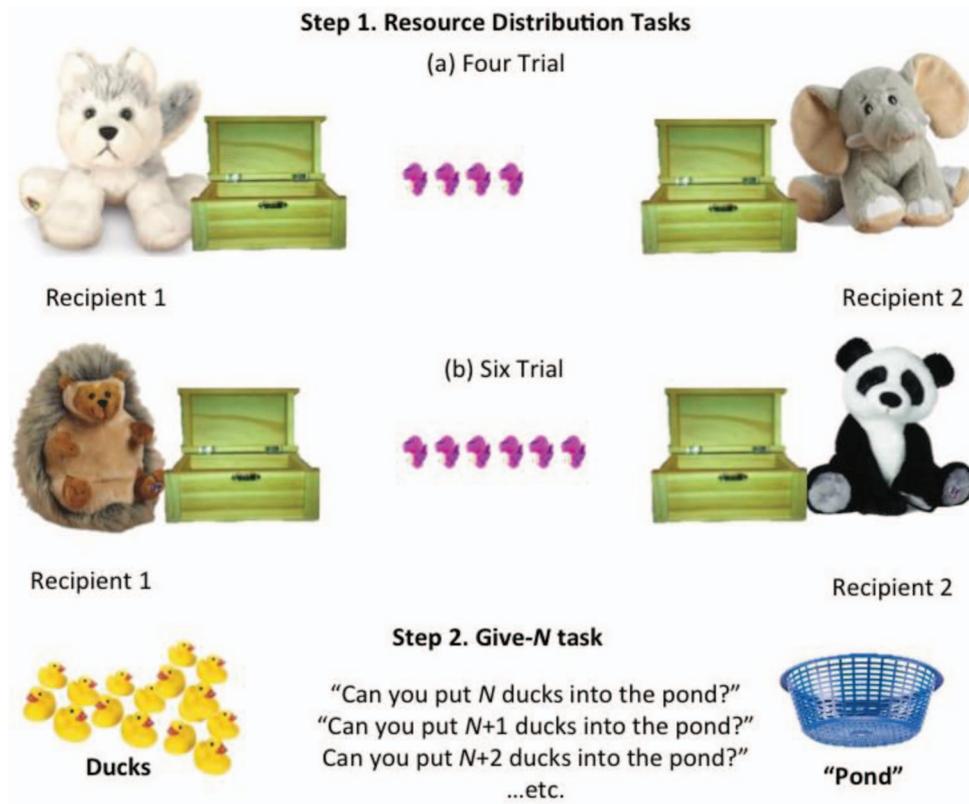
## Procedure

**Resource distribution tasks.** Children were presented with two trials: one in which they were presented with *four resources* and one in which they were presented with *six resources* (order counterbalanced). In each trial, the child was introduced to two puppets in succession (e.g., “Doggie” and “Ellie”) and a set of dinosaur toys (either four in the four-resource trial or six in the six-resource trial). The researcher arranged the toys linearly between the two puppets and pointed to each toy in turn without any verbal counting. The researcher then placed two wooden boxes in front of the puppets and told the child that s/he would get to split

the toys between the puppets: “You get to decide which toys to give to [Recipient 1] and which ones to give to [Recipient 2]. So whichever toys you want to give to [Recipient 1], you can put right here [point to Recipient 1’s box], and whichever ones you want to give to [Recipient 2], you can put right here [point to Recipient 2’s box]”. Children who left any toys on the table were reprompted (“And what do you want to do with these?”) until all toys were placed into the boxes.

**Sharing recall and sharing justification.** Immediately after each resource distribution trial, the two boxes were closed and children were asked two *sharing (quantitative recall)* questions, one about each puppet (“How many did you give to [Recipient 1]? And how many did you give to [Recipient 2]?”) followed by a *sharing (qualitative recall)* question (“So does [Recipient 1] have more, does [Recipient 2] have more, or do they have the same?”). Next, the boxes were opened, and children were asked for a *sharing justification* (“So you gave  $X$  to [Recipient 1] and  $Y$  to [Recipient 2] – why did you do that?”), where  $X$  and  $Y$  were the number of toys the child had *actually* given to each puppet. Children who did not answer any of the questions were reasked, and then continued to the next question or task if they still refused to answer.

**Give- $N$  task.** Following the resource sharing tasks, each child completed a version of the Give- $N$  task (Sarnecka & Carey, 2008; Wynn, 1990, 1992) to determine his or her number knower-level. Children were given a set (approximately 10) of ducks and a blue



*Figure 1.* Schematic of materials and procedure. Puppets used and order of the two resource distribution trials were counterbalanced. See the online article for the color version of this figure.

basket (labeled a “pond”). They were then asked to place  $N$  ducks “into the pond”, in which  $N$  varied from 1–6. On every trial, after responding, children were asked “Is that  $N$  ducks?” and were allowed to change their response if they wanted. The experimenter first asked for 1 duck and continued to 3 if the child correctly placed 1 duck into the pond. The experimenter then continued to ask for  $N + 1$  if the child successfully placed  $N$  ducks into the pond or  $N - 1$  if the child failed to place  $N$  ducks into the pond. The experiment concluded after the child either (a) had two successes on  $N$  and two failures on  $N + 1$ , or (b) succeeded twice on  $N = 6$  ducks. Following prior procedures (Le Corre & Carey, 2007), children were classified as either subset knowers (42 children; who were able to produce the correct number up to a specific numeral—e.g., 3-knowers correctly produced 1, 2, and 3 ducks but not 4) or CP knowers (31 children; children who understood that the purpose of counting is to determine the cardinality of a set). See Table 1 for the distribution of ages and classifications.

### Coding

All data were videotaped for later coding with the exception of two children’s Give- $N$  performance (due to a camera error), which was instead recorded by the experimenter online. All videos were coded by the first author. Two separate coders then coded 20% of the data: one coded the sharing tasks and stayed blind to the child’s number knowledge; the second coded the Give- $N$  task and stayed blind to the child’s performance on the sharing tasks. Interrater reliability was 94% and 100%, respectively. During each trial, we coded the following data:

**Fair sharing.** Whether the child successfully shared fairly on each of the two resource distribution trials was coded (0 or 1 on each trial).

**Sharing strategy.** For each trial, children’s sharing strategies were coded as either: Sharing by division (making immediate splits: e.g., immediately giving 3 toys to one recipient and 3 to another without taking turns between the two), Sharing by turn-taking which included taking turns giving resources to each puppet (e.g., 1 for Doggie, 1 for Ellie, and so on), or sharing by a combination strategy in which children first divided a small set (e.g., 4 resources) and then used turn-taking to divide the rest. Only a small set ( $n = 8$ ) of sharing instances could not be coded into one of these strategies. Children were given a code between 0 and 2, with 2 corresponding to the most advanced division strategy, 0 corresponding to the turn-taking strategy, and 1 corresponding to the combination strategy (invoking both turn-taking and division).

**Quantitative accurate recall score (0–2 per trial).** Children were asked a quantitative recall question (“How many toys did you give to Puppet X?”) with respect to each puppet on a given trial,

and were given a score of 0–2 (for each trial) corresponding to the number of times they correctly recalled the number of toys they distributed to the two puppets. Correct responses included: (a) stating the exact number the child had provided to the puppet, (b) holding up the number of fingers corresponding to the correct number, or (c) an answer indicating cardinal equivalence (e.g., “the same as I gave Panda”) if the child had given both puppets the same amount. All other responses (e.g., “so many”) were coded as incorrect.

**Qualitative recall check.** To check that children believed they had shared fairly, we asked children to recall which puppet had more resources or whether they had the same. Of children who provided a response to this question, most stated that they believed they gave the puppets the same amount (45/59 in the four-resource trial; and 47/63 in the six-resource trial; both Binomial  $ps < .001$  assuming chance levels of 33%).<sup>1</sup> There were no significant effects of age, gender, trial type, or number knowledge on the likelihood of stating one had shared fairly (all  $ps > 0.05$ ).

**Sharing justification.** For each sharing justification question, children’s answers were coded as either referencing fairness (e.g., “So that they’d both have the same”) and/or number (e.g., “Because it’s two and two”). The two categories were not mutually exclusive and children’s responses could be coded as referencing both (e.g., “so they both have two and it’s fair”).

## Results

### Does Age Relate to Fair Sharing in a Third-Party Sharing Task?

Our first question concerned whether there were age-related differences in fair sharing. We ran a binary logistic regression using age, gender, and trial type (four vs. six; entered as a within-subjects effect) as the predictors and likelihood of fair sharing as the response (Model 1; see Table 2). All models were estimated using generalized estimating equations procedure assuming an exchangeable correlation structure. All reported tests are two-tailed. There was a significant effect of age,  $B = 0.92$ ,  $SE(B) = 0.30$ , 95% confidence interval (CI) [0.34, 1.50], Wald  $\chi^2(1) = 9.60$ ,  $p = .002$ , with older children being more likely to share fairly. Additionally, there was also a significant effect of gender (with females sharing more fairly than males),  $B = 1.27$ ,  $SE(B) = 0.44$ , 95% CI [0.40, 2.13], Wald  $\chi^2(1) = 8.18$ ,  $p = .004$ , and no effect of trial type,  $p = .83$ .<sup>2</sup> Therefore, as children aged, they became more likely to share fairly on both trials.

### Does Numerical Cognition Relate to Fair Sharing?

Our next—and focal—research question was whether children’s numerical cognition might explain age-related differences in fair

Table 1  
Mean Ages (Standard Errors in Parentheses) for Each Classification Level

Give- $N$ classification	No. of children	$M$ age ( $SE$ )
Subset knower	42	3.26 (.09)
CP-knower	31	4.27 (.12)

Note. CP = cardinal principle.

<sup>1</sup> We obtain a consistent pattern when analyzing only the subsample of trials on which children stated they had shared fairly. See the online supplemental materials for details.

<sup>2</sup> We did not find any gender differences in numerical cognition or age (all  $ps > .15$ ), but did find gender differences in rates of fair sharing. We therefore included gender in all of our models. For all models, we also checked for any interactions with CP knowledge and with age. Unless otherwise noted, none reached significance (all  $ps > 0.05$ ).

Table 2  
Parameter Estimates (Standard Errors in Parentheses)

Predictor	Model 1	Model 2	Model 3
Gender (1 = female)	<b>1.27 (0.44)**</b>	<b>1.13 (0.44)**</b>	<b>1.26 (0.44)**</b>
Age	<b>0.92 (0.30)**</b>		0.51 (0.35)
Trial type (1 = six-resource trial)	-0.07 (0.34)	-0.07 (0.34)	-0.07 (0.35)
CP knowledge (1 = CP knower)		<b>1.57 (0.48)**</b>	<b>1.10 (0.56)*</b>

Note. Significant effects are in boldface. CP = cardinal principle; Response = likelihood of fair sharing.  
\*  $p \leq .05$ . \*\*  $p \leq .01$ .

sharing. We first tested whether numerical cognition related to fair sharing (see Figure 2). To investigate whether CP knowledge predicted fair sharing, we reran Model 1, but used CP knowledge (CP knowers vs. subset knowers, coded as 1 and 0, respectively) instead of age as a predictor (Model 2). There was a significant effect of CP knowledge,  $B = 1.57$ ,  $SE(B) = 0.48$ , 95% CI [0.64, 2.50], Wald  $\chi^2(1) = 10.92$ ,  $p = .001$ . As with the first model, there was a significant effect of gender,  $B = 1.13$ ,  $SE(B) = 0.44$ , 95% CI [0.27, 1.98], Wald  $\chi^2(1) = 6.62$ ,  $p = .01$ , and no effect of trial type,  $p = .83$ . Our main analysis did not show differences between subset knowers when controlling for age (all  $ps > 0.05$ ); however, see the online supplemental materials for other analyses on number knowledge matters. Therefore, understanding of the CP predicted children's abilities to share fairly. We then confirmed that age was significantly associated with CP knowledge,  $B = 2.29$ ,  $SE(B) = 0.53$ , Wald  $\chi^2(1) = 18.15$ ,  $p = .00002$ .

Next, we tested whether CP knowledge explained the effect of age on fair sharing. We reran Model 1 but used both age and CP knowledge as predictors (Model 3). With CP knowledge added to the model, there was a significant effect of CP knowledge (such that CP knowers were more likely to share fairly than subset knowers),  $B = 1.10$ ,  $SE(B) = 0.56$ , 95% CI [-0.007, 2.20], Wald  $\chi^2(1) = 3.79$ ,  $p = .05$ , and no longer any significant effect of age,  $p = .15$ . As with the previous models, there was also a significant effect of gender,  $B = 1.26$ ,  $SE(B) = 0.44$ , 95% CI [0.39, 2.13], Wald  $\chi^2(1) = 8.00$ ,  $p = .005$  and no significant effect of trial type,  $p = .83$ . A formal test suggested that CP knowledge mediated age-related differences in fair sharing, showing a marginally significant trend toward full mediation, Sobel test  $z = 1.79$ ,  $p = .07$ . Therefore, knowledge of the CP, and not age, predicted children's abilities to share fairly across both trials.

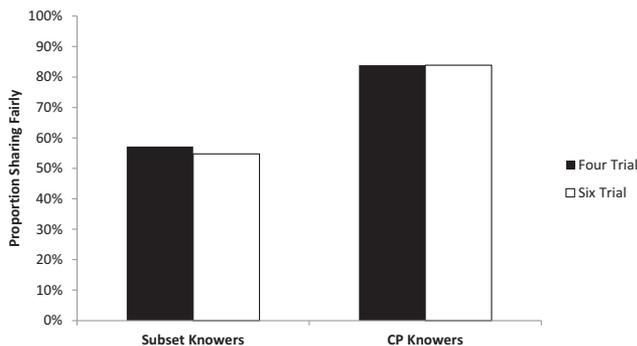


Figure 2. Proportion of trials on which children shared fairly as a function of trial type and cardinal principle (CP) knowledge.

### Additional Analyses: Does Numerical Cognition Predict Children's Sharing Strategies?

We then looked at the types of strategies that children used to accomplish fair sharing. Recall that children could use either turn-taking (lower-level strategies in which children took turns giving each recipient one resource at a time), division (making immediate splits without turn-taking), or a combination strategy. Because we were interested in how children accomplish fairness, we restricted this analysis solely to the trials in which children shared fairly (99 of the 146 total trials). For detailed analyses of sharing strategy and fair sharing, please see the online supplementary analyses. We first explored whether CP knowledge predicted the advanced (division) sharing strategy (see Figure 3 for raw frequencies). An ordinal logistic regression using age, gender, trial type, and CP knowledge as the predictors and likelihood of sharing via division as a response (coded as 2 for division, 1 for combination, and 0 for turn-taking; Model 4; see Table 3) revealed a significant effect of CP knowledge,  $B = 1.12$ ,  $SE(B) = 0.55$ , 95% CI [-0.05, 2.19], Wald  $\chi^2(1) = 4.18$ ,  $p = .04$ , such that CP-knowers were more likely to share via division (and not via turn-taking or combination), and no other significant effects (trial type:  $p = .12$ ; age:  $p = .22$ ; gender,  $p = .18$ ). Follow-up analyses also revealed a significant CP-Knowledge  $\times$  Trial Type interaction,  $B = 2.11$ ,  $SE(B) = 0.82$ , 95% CI [0.51, 3.71], Wald  $\chi^2(1) = 6.62$ ,  $p = .01$ : CP knowledge predicted sharing strategies in the four trial,  $B = 2.40$ ,  $SE(B) = 0.92$ , 95% CI [0.60, 4.21], but not in the six trial,  $p = .89$ . Therefore, CP-knowers and subset knowers accomplished sharing in qualitatively different ways such that CP-knowers were more likely than subset knowers to accomplish fair sharing by using advanced strategies such as division, rather than the simpler strategy of turn-taking when distributing resources. This difference did not occur in the six trial.

### Additional Analyses: Does Numerical Cognition Relate to Children's Memory and Sharing Justifications?

We next investigated whether children's numerical cognition predicted their verbal references to fairness and number. Once again, this analysis was restricted to data from the fair sharers to assess whether children who shared fairly were, in fact, aware of doing so. Overall, excluded quantifiers and words like "none", children provided number words in the majority of their responses (209 of 292 (72%) of responses; Note that each child was asked a total of four "how many did you give to X?" questions, one for each animal). We specifically looked at children's accurate recall scores (i.e., the number of times they correctly recalled how many toys they had given to each puppet). We ran a Poisson regression

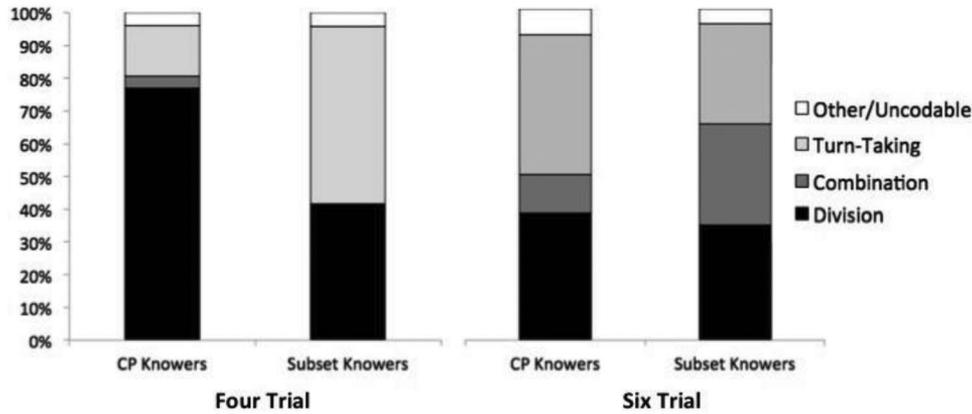


Figure 3. Proportion of sharing types as a function of cardinal principle (CP) knowledge and trial type.

using age, gender, CP knowledge, and trial type (entered as a within-subjects effect) as predictors, and accurate recall score (0–2) as a response (Model 5). There was a significant effect of trial type (with children displaying lower accurate recall during the six trial),  $B = -0.49$ ,  $SE(B) = 0.18$ , 95% CI  $[-0.84, -0.14]$ , Wald  $\chi^2(1) = 7.53$ ,  $p = .006$ , but no significant effects of CP knowledge ( $p = .17$ ), gender ( $p = .96$ ), or age ( $p = .68$ ). Therefore, children found it easier to accurately recall the number of resources shared when there were fewer resources, but their recall scores were unrelated to age or numerical cognition.

We also investigated children’s likelihood of referencing fairness or number in their sharing explanations (see Figure 4 for raw proportions). Here again, we were interested in whether numerical cognition or age predicted how children explained their sharing decisions. We therefore restricted our analysis to the fair sharers. Once again, we ran a binary logistic regression using age, gender, CP knowledge, and trial type (entered as a within-subjects effect) as predictors, and likelihood of referencing fairness as a response (Model 6). Results showed a significant effect of age,  $B = 1.80$ ,  $SE(B) = 0.67$ , 95% CI  $[0.50, 3.11]$ , Wald  $\chi^2(1) = 7.30$ ,  $p = .007$ , such that older children were more likely to reference fairness in their explanations, and no other significant effects (gender:  $p = .68$ ; CP knowledge:  $p = .74$ ; trial type:  $p = .97$ ). We also ran the same binary logistic regression using the likelihood of referencing number as a response (Model 7). Results showed no significant effects (CP-knowledge:  $p = .23$ ; gender:  $p = .12$ ; age:  $p = .86$ ; trial type:  $p = .71$ ). Therefore, among children who shared fairly,

age predicted the likelihood that they would explain their actions with appeals to fairness.

Discussion

Recent work has found that young children understand and expect equal distributions before age two (e.g., Schmidt & Sommerville, 2011), but do not necessarily act fairly themselves (e.g., Fehr et al., 2008; Posid et al., 2015; Smith et al., 2013). Our work points to one important cognitive mechanism that may help explain this knowledge-behavior gap: our numerical cognition. Even in a context in which children were sufficiently motivated to act fairly and could do so at no cost to themselves, children who had failed to acquire the CP were less likely to act fairly. This suggests that young children’s inability to share fairly may involve not only self-serving errors (e.g., selfishness), but also numerical errors (caused by a lack of ability to manipulate and create two equivalent sets). Thus, even third-party (rather than first-party) distribution tasks undergo important developmental changes.

Our results have several implications for our understanding of the knowledge-behavior gap, as well as our understanding of numerical cognition. We found that acquiring an understanding of the CP has important consequences for children’s social behavior—CP knowledge predicted children’s fairness. Future work might focus on the mechanism by which the acquisition of cardinality scaffolds sharing decisions, and thus explains children’s early emerging knowledge of equality and its relatively late be-

Table 3  
Parameter Estimates (Standard Errors in Parentheses)

Variable	Model 4 (Response = likelihood of sharing via division)	Model 5 (Response = accurate recall score)	Model 6 (Response = likelihood of referencing fairness)	Model 7 (Response = likelihood of referencing number)
Gender (1 = female)	-0.63 (0.48)	-0.005 (0.21)	0.34 (0.82)	-0.98 (0.63)
Age	-0.45 (0.37)	0.06 (0.16)	<b>1.80 (0.68)**</b>	-0.10 (0.52)
Trial type (1 = six-resource trial)	-0.64 (0.41)	<b>-0.49 (0.18)**</b>	-0.007 (0.21)	-0.13 (0.34)
CP knowledge (1 = CP knower)	<b>1.12 (0.55)*</b>	0.34 (0.24)	0.34 (1.02)	0.98 (0.82)

Note. Significant effects are in bold. Only trials during which children had shared fairly are included. CP = cardinal principle.  
\*  $p \leq .05$ . \*\*  $p \leq .01$ .

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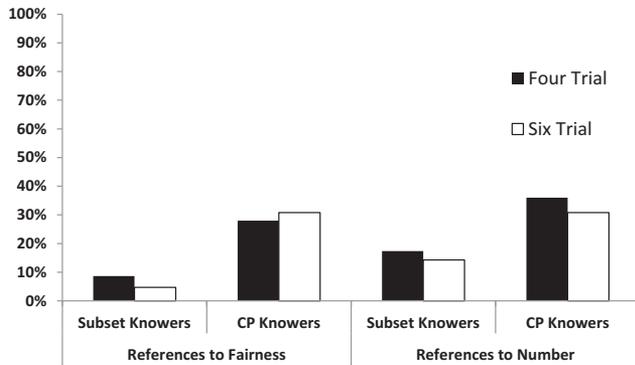


Figure 4. Proportion of references to fairness and number as a function of cardinal principle (CP) knowledge and trial type.

havioral emergence. One possibility is that children already have a rudimentary understanding of equality as a social norm (Geraci & Surian, 2011; Schmidt & Sommerville, 2011; Sloane et al., 2012), as well as sufficient motivation to share equally, but that acquiring the CP simply helps children act on their motivation.

Another possibility, however, is that acquiring the CP does not simply manifest itself in equal sharing behavior but also refines children's explicit concept of fairness, thereby increasing their motivation to share equally. Although our data cannot directly speak to this possibility, we found several suggestive pieces of evidence: For example, although subset knowers can accomplish fair sharing in some instances, they do so through different means than CP knowers; they turn-take between recipients. Such turn-taking strategies might reflect either an attempt to be numerically fair without knowing how to do the proper numerical calculation, or a different schema for fairness, in which fairness consists not of giving two recipients cardinally equivalent amounts, but rather taking turns such that everyone gets at least something (Frydman & Bryant, 1988). In support of the latter possibility, prior work suggests that young children do have different schemas of fairness than adults (e.g., Berg & Mussen, 1975; Chernyak & Sobel, 2016). Moreover, although age predicted children's references to fairness, it did not predict references to number, suggesting that the two schemas of sharing (one with reference to fairness and one with reference to number) may be qualitatively different and/or follow distinct developmental pathways. Together, these findings point to the possibility that acquiring the CP might also change children's early concepts of fairness. That possibility, however, warrants further investigation.

We did not find differences between the two sharing trials (four resources vs. six resources) on most measures, although notably, we did find a difference in the use of strategy type on the four trial. One implication is that cardinality helps manifest the ability to behave fairly regardless of the size of the set that children manipulate. Such a possibility is consistent with work showing that cardinality helps children understand set equivalence (Muldoon et al., 2009; Sarnecka & Wright, 2013). However, given prior work showing important changes in numerical cognition after children become CP-knowers as classified by the Give-*N* task (Davidson, Eng, & Barner, 2012), it is important for future work to delineate the boundaries of what CP knowledge does and does not do for children's sharing. Future work may focus on children's sharing of

large sets, or how children's abilities to recognize equal sharing relates to their abilities to coordinate it themselves.

Overall, girls were more likely to share fairly than boys, even when controlling for number knowledge. This finding may suggest that girls are more averse to inequity than boys, or develop inequity aversion at earlier ages (see McAuliffe, Blake, Kim, Wrangham, & Warneken, 2013 for a consistent finding), but further work is needed to better understand the relationship between gender and fairness.

Our work attempts to resolve the knowledge-behavior gap by focusing on how knowledge of the CP is related to third-party resource distribution. However, both fairness and numerical cognition involve a host of other subcomponent competencies that follow distinct developmental pathways. For example, fairness can involve not only costless sharing, but also the ability to engage in third-party moral evaluation of others (thought to be an early developing capacity; Schmidt & Sommerville, 2011) as well as costly sharing which is relatively later-developing (e.g., Svetlova, Nichols, & Brownell, 2010). Similarly, numerical cognition includes the approximate number system (ANS; e.g., Xu & Spelke, 2000), knowledge of the CP (e.g., Wynn, 1990), the ability to map symbols onto their respective magnitudes (e.g., Mundy & Gilmore, 2009), and other related competencies (e.g., school-based arithmetic). Future work is warranted to explore the specific numerical competencies (and cognitive systems) that underlie each type of social behavior. Most critically, it is important for future work to detail how numerical cognition might interact with other known influences on sharing, such as children's own motivations.

More generally, our work points to important links between social and cognitive development in early childhood. This link is important to consider from the perspective of developing young children's number knowledge and their sharing behavior: For example, it is important to keep in mind the child's individual cognitive competencies (e.g., number knowledge) when studying social behavior. Similarly, giving children experiences with sharing may promote their numerical understanding. More generally, bridging social and cognitive development may help us gain better insights into the developmental processes of each.

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