Solving the knowledge-behavior gap: Numerical cognition explains age-related changes in fairness

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Abstract

Young children share fairly and expect others to do the same. Yet little is known about the underlying cognitive mechanisms that support fairness. Across two experiments, we investigated whether children's numerical competencies are linked with their sharing behavior. Preschoolers (aged 2.5-5.5) participated in either third-party (Experiment 1) or first-party (Experiment 2) resource allocation tasks. Children's numerical competence was then 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 in both the third- and first-party contexts. These results suggest that an understanding of the cardinal principle serves as an important mechanism for fair sharing behavior.

Keywords: fairness; numerical cognition; preschoolers; knowledge-behavior gap

Introduction

By the preschool age, young children show a remarkable concern for fairness. This concern appears in their explicit endorsements of fairness as a social norm (Damon, 1977; Smith, Blake, & Harris, 2013), in their affective responses towards inequalities (LoBue, Nishida, Chiong, DeLoache, & Haidt, 2011), and in their own distribution of resources (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 show sufficient motivation to share at an early age – they recognize what fairness is and understand why it is important.

In spite of their interest in fairness, it is remarkable that many children do not typically behave fairly themselves (Blake, McAuliffe, & Warneken, 2014; Sheskin, Chevallier, Lambert, & Baumard, 2014). Prior work has consistently documented that fair sharing emerges late in the preschool period and into middle childhood (e.g., Fehr, Ernst, & Rockenbach, 2008). As such, researchers have recently begun to become interested in what is now termed the "knowledge-behavior gap": although young children recognize situations that are fair or unfair (Schmidt & Sommerville, 2012; Sloane, Baillargeon, & Premack, 2011), they do not always behave fairly themselves (see Smith et al., 2013). Why children show a knowledge-behavior gap has been of recent theoretical interest (e.g., Blake et al., 2014). In our work, we explore one possibility: the extent to which children's understanding of number underpins their abilities to share fairly with others.

Sharing is inherently a number-based problem. In order to understand how six candies should be shared between three people, one should understand that 6 divided by 3 results in 2 candies each. Similarly, a division is unfair if it does not show cardinal equivalence – if, for example, one person had 3 candies, and another received 1. 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 has 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 (e.g., "How many candies are in each box?") than when the end goal is to figure out the number of recipients present during fair sharing (e.g., "How many boxes did we use?"). Second, as compared with older children, younger children, with presumably limited numeracy skills, have a harder time splitting resources fairly and fail to recognize the connection between sharing and cardinal equivalence (e.g., don't recall correctly that each recipient has the same amount; Frydman & Bryant, 1988; see also Pepper & Hunting, 1998).

The converging evidence suggests that numerical competencies might be one cognitive prerequisite to fair sharing. Thus, although children may be able to recognize fair sharing from a young age, they do not yet possess the requisite numerical skills to produce fair shares. In our studies, we looked at the relationship between children's sharing behavior and numerical cognition.

In our first experiment, we began by looking at young children's sharing behavior in a third-party context (i.e., sharing between two recipients when there is no cost to the self). In the second, we looked at a more stringent test of fair sharing: sharing in a first-party context, in which children shared between themselves and another recipient. Across both experiments, we also assessed children's numerical understanding using a version of the Give-N task (Sarnecka & Carey, 2008; Wynn, 1992), used to classify young children according to whether they know and understand the cardinal principle (i.e., that the purpose of counting is to determine to cardinality of a set).

Experiment 1

Participants

Seventy-three children (28 male, 45 female) were tested at a local children's museum or during a laboratory visit (Mean age=3y;8m, Range = 2y;6m–5y;6m). Nineteen additional children were excluded due to experimenter error (n = 5), parental/sibling interference (n = 7), 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).

Procedure

Materials In the resource distribution tasks, we used 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 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.

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 or six). 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 re-prompted ("And what do you want to do with these?") until all toys were placed into the boxes. Children were asked additional follow-up questions regarding their memory of the number of resources they shared and sharing justifications (not further discussed or analyzed here).

Give-N Task Following the two resource sharing tasks, each child completed a version of the Give-N task (Sarnecka & Carey, 2008; Wynn, 1990, 1992) to determine whether the child understood the cardinal principle (that the purpose of counting is to determine the number of items in a set). Children were given a set (approximately 10 ducks) and a blue basket (a "pond"). They were then asked to place N ducks "into the pond" (basket), 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 for 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 (LeCorre & Carey, 2007), children were classified as either Subset Knowers (children who could count properly up to a specific subset of under 6 items but no more, and thus failed to understand that the purpose of counting is to determine cardinality; n = 42) or Cardinal Principle (CP) Knowers (proficient counters; n = 31).

Results

Our first question concerned whether there were age-related differences in fair sharing (defined as an equal split between the two animals). 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 1). There was a significant effect of Age, B = 0.92, SE(B) = 0.30, 95%CI = 0.34–1.50, Wald(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(1) = 8.18, p = .004, and no effect of Trial Type, p = 0.83. Therefore, as children aged, they became more likely to share fairly.

Table 1: Parameter Estimates (and Standard Errors) for Models Used in Experiment 1

	Model 1	Model 2	Model 3
Gender (1=Female)	**1.27 (0.44)****	**1.13 (0.44)****	**1.26 (0.44)****
Age	**0.92 (0.30)****	--	0.51 (0.35)
Trial Type (1=6 Resources)	-0.07 (0.34)	-0.07 (0.34)	-0.07 (0.35)
CP Knowledge (1=CP Knower)	--	**1.57 (0.48)****	**1.10 (0.56)***

Note: Response = likelihood of sharing fairly. Significant effects are in bold. *$p \leq 0.05$; **$p \leq 0.01$.

Our next – and focal – research question was whether children's acquisition of cardinal principle (CP knowledge) might explain age-related differences in fair sharing. We first tested whether CP knowledge related to fair sharing. To investigate whether CP knowledge predicted fair sharing, we re-ran 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(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(1) = 6.62, p = .01, and no effect of Trial Type, p = 0.83. Therefore, understanding of the cardinal principle predicted children's abilities to share fairly.

We then confirmed that Age was significantly associated with CP Knowledge, B = 2.29, SE(B) = 0.54, Wald(1) = 18.15, p = 0.00002.

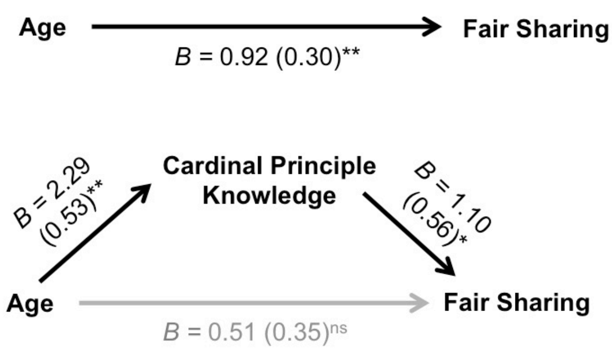

Figure 1: Mediation analysis in Experiment 1

As a last step, we tested whether CP knowledge mediated the effect of age on fair sharing. Here we combined Models 1 and 2 and 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(1) = 3.79, p = .05, and no longer any significant effect of Age, p = 0.15. 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(1) = 8.00, p = .005 and no significant effect of Trial Type, p = 0.83. A formal mediation test suggested that CP Knowledge mediated age-related differences in fair sharing, Sobel test z = 1.79, p = 0.07 (see Figure 1). Therefore, knowledge of the cardinal principle, and not age, predicted children's abilities to share fairly across both trials.

Discussion

Our results show that understanding the cardinal principle explained age-related changes in third-party sharing, suggesting that numerical cognition serves as an important mechanism for fairness as children age. As children acquire cardinality, they become more adept at social skills such as dividing resources equally between two recipients.

Because third-party sharing involves a situation in which there is no cost to the self and because third-party sharing is something that even infants expect others to do (Schmidt & Sommerville, 2012), our task was able to look at sharing ability in a context unconfounded with potential motivational concerns. That is, our results suggest that even in a context in which prior has found that children are likely motivated to share equally (e.g., Olson & Spelke, 2008), only children who had acquired cardinality had the requisite skills are able to do so.

In Experiment 2, we looked at a more stringent test of fair sharing: first-party sharing. Prior work has consistently documented age-related differences in first-party fairness (e.g., Fehr, Bernard, Rockenbach, 2008; Smith et al., 2013), but as with third-party fairness, the mechanism driving this increase is not yet clear. Moreover, unlike third-party fairness, first-party fairness requires additional cognitive skills (e.g., inhibitory control), which develop with age during the preschool period. We were interested in whether numerical cognition would continue to predict fair sharing behavior, even in a context in which fairness is costly to the child.

Experiment 2

Participants

Ninety-two children (37 male, 55 female) were tested at a local children's museum or during a laboratory visit (Mean age = 3y;10m, Range = 2y;6m – 5y;4m)[1]. Eighteen additional children were excluded due to either protocol error (n = 2), failure to complete the task (n = 9), missing video (either equipment failure or lack of parental consent to video record (n = 4)), or being outside the a priori targeted age range (n = 3).

Procedure

Materials Materials were the same as Experiment 1, with the following modifications: (a) only one stuffed animal recipient was used in each resource distribution trial (the second recipient was the child), and (b) stickers instead of dinosaur toys were used as resources.

Resource Distribution Tasks Because first-party sharing with anonymous recipients has been shown to be particularly difficult for preschool-aged children, we contextualized the situation and used a modified procedure that has been shown to successfully induce sharing in preschoolers (Chernyak & Kushnir, 2013). Children were introduced to a puppet that was described as feeling "very sad", and told that they could give him/her some stickers to make the puppet feel better. The distribution phase

[1] Three children's parents did not provide a date of birth but identified them as being within the proper age range for the study. Their ages are not recorded in final calculations. They are by necessity excluded from any analyses with age.

proceeded in exactly the same manner as in Experiment 1. Children were then shown a set of linearly arranged stickers (either four in the Four Resource Trial or six in the Six Resource Trial; order counterbalanced) arranged linearly between two boxes (one labeled as the puppet's box which had pictures of the puppet on the top and inside; and the other labeled as the child's box which had no pictures), and told they could split the stickers however they wished between themselves and the puppet.

Give-N Task After the two resource distribution tasks, children completed a Give-N task, which proceeded in exactly the same manner as in Experiment 1. Children were classified as either Subset Knowers (48 children) or CP knowers (44 children).

Results

Overall, the rates of fair sharing were lower in Experiment 2 (first-party sharing) than in Experiment 1 (third-party sharing). A direct comparison of the proportion of fair sharing trials across the two experiments revealed that children were more likely to be fair in Experiment 1 (n = 99 of 146) than in Experiment 2 (n = 103 of 184), Fisher's exact test, p = 0.03. Therefore, children were less likely to be fair when sharing in a first-party context. We then asked whether CP knowledge nonetheless continued to predict children's fair sharing.

As with Experiment 1, 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). There was a significant effect of Age, B = 0.84, SE(B) = 0.25, 95%CI = 0.35 – 1.34, Wald(1) = 11.07, p = .001, a significant effect of Trial Type (with children being more likely to share fairly in the Four Resource trial), B = -0.88, SE(B) = 0.27, 95%CI = -1.41 - -0.35, Wald(1) = 10.72, p = .001, and no effect of Gender, p = .26. Therefore, as children aged, they became more likely to share fairly in a first-party context.

Table 2: Parameter Estimates (and Standard Errors) for Models Used in Experiment 2

	Model 1	Model 2	Model 3
Gender (1=Female)	0.44 (0.39)	0.74 (0.39)	0.51 (.40)
Age	**0.84 (0.25)****	--	0.19 (.32)
Trial Type (1=6 Resources)	**-0.88 (0.27)****	**-0.88 (0.27)****	**-0.95 (.29)****
CP Knowledge (1=CP Knower)	--	**1.54 (0.39)****	**1.58 (0.52)****

Note: Response = likelihood of sharing fairly. Significant effects are in bold. *$p \leq 0.05$; **$p \leq 0.01$.

Our next – and focal – research question was whether children's CP knowledge might explain age-related differences in fair sharing. To investigate whether CP knowledge predicted fair sharing, we re-ran Model 1, but used CP knowledge instead of Age as a predictor (Model 2). Confirming the idea that acquiring cardinality predicts first-party fairness, there was a significant effect of CP Knowledge, B = 1.54, SE(B) = 0.39, 95%CI = 0.77 – 2.30, Wald(1) = 15.42, p = .00008. As with the first Model, there was a significant effect of Trial Type (with children being more likely to share fairly in the Four Resource trial), B = -0.88, SE(B) = 0.27, 95%CI = 0.35 – 1.40, Wald(1) = 10.75, p = .001, and a marginally significant effect of Gender (with females being more likely to share fairly than males), p = 0.06. There were no interactions with CP knowledge or trial type (p = .64). Therefore, understanding the cardinal principle predicted children's abilities to share fairly even in a first-party context.

We then confirmed that as in Experiment 1, age was significantly associated with CP Knowledge, B = 2.51, SE(B) = 0.50, Wald(1) = 25.62, p = 0.0000004.

As a last step, we tested whether CP knowledge mediated the effect of age on fair sharing. As with Experiment 1, we combined Models 1 and 2 and used both age and CP knowledge as predictors (Model 3). There was a continued significant effect of CP knowledge (such that CP knowers were more likely to share fairly than subset knowers), B = 1.58, SE(B) = 0.52, 95%CI = 0.57 – 2.60, Wald(1) = 9.36, p = .002, and no longer any significant effect of Age, p = 0.55. As with the previous models, there was also a significant effect of Trial Type, B = -0.95, SE(B) = 0.29, 95%CI = -1.53 – -0.38, Wald(1) = 10.55, p = .001 and no significant effect of Gender, p = 0.20. A formal mediation test confirmed that CP knowledge fully mediated age-related differences in fair sharing, Sobel test z = 2.60, p = 0.009 (see Figure 2). Therefore, knowledge of the cardinal principle, and not age, predicted children's abilities to share fairly in our first-party context.

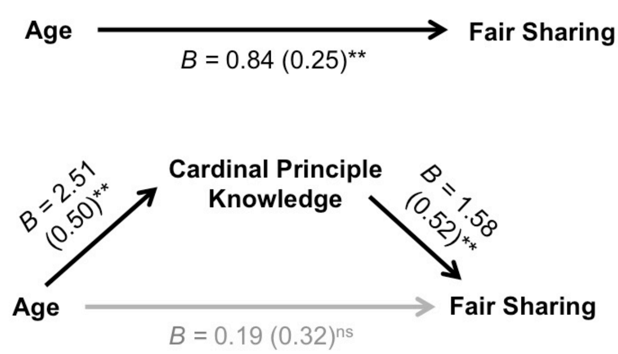

Figure 2: Mediation analysis in Experiment 2

We were also interested in the types of errors children make when they failed to share fairly. We looked at trials during which children had *not* shared fairly (n = 81 of a total of 184 trials). One possibility is that young children tend to default to selfishness. If this is the case, we might expect that younger children will consistently behave selfishly and keep most resources for themselves. Another possibility, however, is that children are motivated to share fairly, but do not always have the cognitive skills (i.e., numerical cognition) in order to do so. If this is the case, children should be just as likely to make either fair sharing error (either generous sharing or selfish sharing).

Confirming the latter possibility, children did not strategically default to selfishness: Of the trials during which they did not share fairly, approximately half were generous (n = 42 of 81; 52%) and the other half were selfish (n = 39, 48%).

We also tested whether CP knowledge predicted how close children's errors were to fair sharing behavior. We computed a "Difference from Fairness" score (DFS) reflecting the magnitude of the deviation of the child's sharing behavior from perfect fair sharing behavior. The DFS reflected the absolute value of the difference between the number of resources the child gave to the puppet (child's sharing behavior) and the number reflecting fair sharing (i.e., 3 in the six resource trial and 2 in the four resource trial). Thus, children who made "greater" errors and deviated more from fair sharing received higher DFS scores.

We ran a Poisson model using DFS score as the response and CP knowledge, Age, Trial Type (entered as a within-subjects effect), and Gender as the predictors. The results revealed a significant effect of CP knowledge, B = -.33, SE(B) = .17, 95%CI = -0.66 - -0.002, Wald(1) = 3.69, p = .05, and no other significant effects, all p's > .25. Therefore, CP knowers had lower DFS scores, suggesting that children with limited numerical cognition also deviated to a greater extent from fair sharing behavior.[2]

To make sure that this result could not be explained by children simply becoming more generous as they aged (and thus becoming more fair in the selfish subsample), we also ran this model using number of stickers donated to the puppet as a response. There were no significant effects in either the subsample of kids who had not shared fairly, or in the full dataset. This rules out the possibility that as children age and gain numeracy skills, they simply become less interested in the resources or more generous with them. Instead, this supports the idea that as children acquire cardinality, their behavior approaches fairness.

Discussion

As in Experiment 1, numerical cognition predicted and explained age-related differences in children's abilities to share fairly, even in a context in which children may be particularly motivated to share unfairly (be selfish). Children who did *not* share fairly did not strategically default to selfishness – instead, they were just as likely to be generous as they were to be selfish. CP knowers made errors that were smaller in magnitude (closer to fairness) than subset knowers. These results suggest that even in a context in which children may have been motivated to be unfair, numerical cognition continued to predict fair sharing behavior.

General Discussion

A body of recent work has documented the early development of our concern for others' welfare. We add to this work by showing that between the ages of 2.5 and 5.5, children develop the capacity to distribute resources fairly.. Importantly, our results highlight a key cognitive mechanism that enables such sharing behavior. Numerical cognition predicted young children's abilities to share fairly and their sharing strategies. Strikingly, numerical cognition also mediated age-related changes in fair sharing.

Recent work has found that young children recognize fairness before age two (e.g., Schmidt & Sommerville, 2012), but do not necessarily act fairly themselves (e.g., Fehr et al., 2008; Posid, Fazio, & Cordes, 2015; Smith et al., 2013). Our findings have two important implications for fairness. First, we find that sufficient motivation is *not* enough to enable fairness in young children. Even in a third-party context, in which children are motivated to share equally (Olson & Spelke, 2008), children were not always able to do so. This suggests that fairness involves not only sufficient motivation, but also the coordination of later-developing socio-cognitive abilities.

Second, we find that nonsymbolic numerical abilities are also not enough to enable fair distribution behavior. One possibility could have been that sharing 4 stickers would require only the ability to discriminate between 1 vs. 3 items, or between a 2/2 distribution and a 1/3 distribution - a problem that even infants are capable of solving (Feigenson & Carey, 2003; Schmidt & Sommerville, 2012). Instead, however, our results found that knowledge of cardinality and explicit understanding of counting was critical to children's abilities to act fairly. This suggests that while nonsymbolic numerical abilities may be implied in children's passive and implicit understanding of fairness, active manipulation of resources requires the later-developing ability of counting proficiency.

Future work might focus on the mechanism by which the acquisition of cardinality scaffolds sharing decisions. One possibility is that children already have a rudimentary understanding of equality as a social norm (Schmidt & Sommerville, 2011; Geraci & Surian, 2011; Sloan, Baillargeon, & Premack, 2012), and that acquiring the cardinal principle simply helps children realize that norm in their own behavior.

Our work focused on how knowledge of the cardinal principle is related to third-party and first-party resource distribution. However, both fairness and numerical cognition involve a host of other sub-component competencies that follow distinct developmental pathways. For example, fairness involves the ability to engage in third-party moral evaluation of others (thought to be an early-developing capacity; Schmidt & Sommerville, 2012) as well as the ability to engage in altruistic sharing (e.g., Svetlova,

[2] We did not find any relationship between DFS scores and CP knowledge in Experiment 1.

Nichols, & Brownell, 2010). Similarly, numerical cognition includes the approximate number system (ANS; e.g., Xu & Spelke, 2000), knowledge of the cardinal principle (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.

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 help 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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