Native Amazonian children forego egalitarianism in merit-based tasks when they learn to count.

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Research Highlights

- In the Tsimane', children who can count are more likely to produce merit-based distributions than children who cannot count.
- This behavioral difference is more strongly related to children's ability to count than their age or years in school.
- These findings suggest that learning the logic of natural numbers and counting can influence social cognition.

Abstract

Cooperation often results in a final material resource that must be shared, but deciding how to distribute that resource is not straightforward. A distribution could count as fair if all members receive an equal reward (*egalitarian distributions*), or if each member's reward is proportional to their merit (*merit-based distributions*). Here, we propose that the acquisition of numerical concepts influences how we reason about fairness. We explore this possibility in the Tsimane', a farming-foraging group who live in the Bolivian rainforest. The Tsimane' learn to count in the same way children from industrialized countries do, but at a delayed and more variable timeline, allowing us to de-confound number knowledge from age and years in school. We find that Tsimane' children who can count produce merit-based distributions, while children who cannot count produce both merit-based and egalitarian distributions. Our show establish that the ability to count—a non-universal, language-dependent, cultural invention—can influence social cognition.

Introduction

Fair distribution of resources is important in many aspects of human life, including cooperative tasks. However, deciding what counts as fair is not straightforward. Very young children prefer *egalitarian distributions*, in which all members get an equal share of the resources (e.g., Schmidt & Sommerville, 2011; Sommerville, Schmidt, Yun, & Burns, 2012). In doing so, they frequently ignore merit (Damon, 1975), need (Huntsman, 1984), and group membership (Fehr, Bernhard, & Rockenbach, 2008; Olson & Spelke, 2008). As they grow older, children consistently start producing and preferring more complex distribution methods based on effort and other factors (e.g., Alma, Cappelen, Sorensen, & Tungodden, 2010; Huntsman, 1984; Nelson & Dweck, 1977; Damon, 1975, 1980; Sigelman & Waitzman, 1991; McGillicuddy-de Lisi, Watkins, & Vinchur, 1994).[1] This developmental change may be driven by children's increased experience in cooperative contexts, by explicit pedagogy, or by a mixture of both.

Here we propose an additional dimension that may influence how children reason about resource distributions: the acquisition of the logic of natural numbers (i.e., the logic that sets have an exact size that can be counted, and the words and mechanisms for calculating these sizes via counting). Knowing how to count and understanding its logic can affect how people distribute resources in several ways. Most obviously, if a child wants to give someone an exact number of objects, he or she needs to be able to count up to that number first. However, children not only learn how to count to calculate a set's exact size; they also learn that sets *have* an exact size. For example, young children do not realize that substituting one element in a set (removing one element and putting in another) leaves the set's exact size constant, nor that adding or taking one element away doesn't (Izard, Streri, & Spelke, 2014). Although learning to count and learning the underlying concepts that counting captures are likely separate processes (Davidson, Eng, & Barner, 2012), they nevertheless emerge at around the same time (Jara-Ettinger, Piantadosi, Spelke, Levy, & Gibson, *under review*).

In light of what children learn, mastering the logic of natural numbers may affect both how we think about fairness and how we act upon these beliefs. To illustrate this, consider a simple scenario: A child has to distribute a set of cookies between two people, one of whom worked harder than the other. Despite the simplicity of the scenario, the ability to take merit into account is not trivial. First, the child needs to translate a work or effort difference into a merit difference (i.e., the person that worked harder deserves a bigger reward). Next, the child needs to transform the abstract merit difference into a concrete reward difference (i.e., based on the merit difference, how many more cookies does the harder-working person deserve?). Lastly, the child needs to be able to distribute the cookies based on these earlier judgments. Pre-numerical children may succeed in the first step and believe that the harder working person deserves a bigger reward, but they may nevertheless have trouble with the last two steps. Specifically, not understanding that sets have an exact size may affect how children transform a merit difference into a

[1] Although the literature does not converge on an exact developmental milestone when children forego egalitarianism, the studies consistently report that younger children are more likely to behave as egalitarians in the presence of merit, need, and social affiliation differences.

reward difference. At an even broader level, learning that sets have an exact size that can be calculated may lead children to focus more on the idea that almost anything can be exactly or approximately quantified (including merit). This is in fact crucial for *utilitarianism* (e.g., Bentham, 1879; Mill, 1906), one of the most influential theories on fairness, which relies on the assumption that anything can be quantified even when *how* to quantify it is unclear. In the face of these impediments, children may default to a fairness rule that they can comprehend and consistently produce: *egalitarianism*.

Exploring the effect of numerical competency on fairness judgments is difficult in industrialized cultures because the ability to count and the ability to understand the logic of counting are tightly linked with age, emerging in the third year of age (Piantadosi et al., 2014). However, this is not true in non-industrialized cultures like the Tsimane'. The Tsimane' are a farming-foraging group living in the Bolivian Amazon (Huanca, 2008). The Tsimane' are an ideal population for testing how learning the logic of the natural numbers may influence fairness judgments. They learn to count in the same manner as children in industrialized countries do, but on a delayed and more variable timeline (Piantadosi, Jara-Ettinger, & Gibson, 2014). Thus, this population allows us to disentangle the role of natural number understanding from other maturational skills that correlate tightly with age in industrialized cultures. To discover how mastery of the logic of natural numbers and counting affects merit-based fairness judgments, we ran a simple resource distribution task with the Tsimane'.

Experiment

Methods

Participants. We recruited 70 children (mean age: 6.53 years; SD: 1.93 years; range 3-12; 38 males, 32 females) from six Tsimane' communities near San Borja, Bolivia. All work was done in collaboration with the *Centro Boliviano de Investigación y de Desarrollo Socio Integral* (CBIDSI), which provided interpreters, logistical coordination, and expertise in Tsimane' culture.

Procedure. Children's ages and years of education were gathered through parental reports and, when available, school records. Children's ability to count was assessed through the *Give-N* task (e.g., Wynn, 1990; 1992) using the procedure from Jara-Ettinger et al. (*under review*). In this task, one sheet of paper with 10 chips was placed next to a second sheet of paper. Children were first asked to move 4 out of the 10 chips from one sheet to the other. We next followed a staircased procedure in which a higher number was requested whenever the child moved the correct number of chips and a lower number was requested whenever the child moved an incorrect number of chips. This procedure continued until either *(1)* the child successfully moved eight chips from one sheet to the other (thus having shown that he or she could produce the appropriate number of objects when asked for four, five, six, seven, and eight objects), *(2)* the child's ability to count could be determined after the first eight queries using the classification rules from Piantadosi, Jara-Ettinger, & Gibson (2014), or *(3)* the child wanted to stop. Occasionally, participants' performance made it impossible for us to assess the knower-level stage through the pre-determined staircasing procedure (for example, if a participant *always* moved three chips, the staircasing procedure would oscillate between requesting four chips and three chips). When this happened the experimenter would temporarily break the staircasing procedure and restart the staircasing at a smaller query, thus allowing us to test if the participant could count up to lower numbers.

The first and last author, blind to the participant's demographic information (age and years of education) and to their performance in the fairness task (described below), independently coded each participant as *pre-numerical* or as a *full counter* based on their performance on the Give-N task.[2] That is, each coder independently determined if each participant's errors were more likely due to performance and distraction errors (in which case they were coded as *full counters*) or if their errors were consistent enough to believe the child did not understand counting (in which case they were coded as *pre-numerical*). Overall, the two coders agreed on 98.5% of the trials (Cohen's Kappa inter-rater agreement = 0.968; $p < 0.0001$).[3]

Next, children completed a fairness task. Participants saw two cutout drawings of two identical children, differentiable only by their shirt color, placed on opposite sides of the table. The interpreter explained that one day, the two children had been sent to pick bananas. The first child worked very hard and brought back many bananas. The second child did not work very hard and only brought back a few bananas. As the interpreter described their performance, the experimenter placed a picture of 18 bananas (arranged in a 6 by 3 matrix) next to the hard-working child and a picture of four bananas (arranged in a 2 by 2 matrix) next to the non-hard-working child. The position of the two children relative to the participant and the order in which they were introduced were randomized across children.

To ensure that the scenario was clear, the interpreter asked participants to point to the child who had worked the hardest. The interpreter then told the participants that the children would receive some cookies as a prize for collecting the bananas. Two conditions varied the number of cookies that each participant distributed: Children were given either *four* cutout pictures of cookies (*small-set condition*, $N = 35$) or *ten* cutout pictures of cookies (*large-set condition*, $N = 35$). The interpreter asked each participant to distribute the cookies across the two children. All participants distributed their entire set of cookies across the two children, and the experimenter recorded the number of cookies that each participant gave to the harder-working child. Participants completed only a single trial to keep the experiment simple because the Tsimane' participants were unaccustomed to experiments.

Results. Participants who failed to identify the harder-working child in the inclusion question were excluded from further analysis ($N = 9$ of 70 participants, 12.86%). We categorized the remaining participants as *merit users* if they gave more cookies to the

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[2] In the number literature, pre-numerical children are often called subset-knowers and full counters are called CP-knowers. Subset-knowers can be further divided into a sequence of ordered stages (0- to 4-knowers; Piantadosi, Jara-Ettinger, & Gibson, 2014). However, our interest here is on what happens when children master numerical concepts, so there was no need to determine the exact stage of the pre-numerical children.

[3] Cases in which the first two coders disagreed were resolved by the second author following the methodology of Solomon, Johnson, Zaitchik, & Carey (1996).

harder-working child, or as *egalitarians* if they gave an equal amount of cookies to each child. Because our goal was to compare egalitarians to merit-users, we excluded five participants who gave fewer cookies to the harder-working child and thus fit into neither category (*N*=5, 7.14%).[4] The remaining dataset contained 56 participants; 29 in the four-cookie condition and 27 in the ten-cookie condition. Table 1 shows the full data from the experiment.

To test our main prediction—that children's ability to count affects whether their distributions reflect an appreciation of merit—we divided participants into children who could count (*full counters*; $N = 23$) and children who could not (*pre-numerical*; $N = 33$). Figure 1 shows the pattern of responses. Consistent with our predictions, the proportion of merit-using participants was higher among full counters. 42.42% of pre-numerical children produced egalitarian distributions (14 out of 33 participants) and 57.58% produced merit-based distributions (19 out of 33 participants). In contrast 26.09% of full counters produced egalitarian distributions (6 out of 23 participants) and 73.91% produced merit-based distributions (17 out of 23 participants). Consistent with this, a non-parametric permutation test revealed that the proportion of merit-based distributions was significantly higher among full counters, compared to pre-numerical children ($p<0.05$).

Next, we tested if the difference between children who produced egalitarian and merit-based distributions could be explained by differences in their ages or years in school. Figure 2 shows each participant's distribution type as a function of their age and education. If merit-usage were determined purely by age (or another factor tightly correlating with age), then merit-based distributions should be clustered on the right of the figure and egalitarian distributions should be clustered on the left of the figure. If merit-usage were determined by years in school, or any experience tightly correlating with years in school, then merit-based distributions should be clustered on the top of the figure and egalitarian distributions should be clustered on the bottom of the figure. Last, if the distribution type could be fully explained by some interaction between age and years in school, then merit-based distributions should be clustered in one (or more) of the corners of the figure. However, Figure 2 reveals none of these patterns. Instead, merit-based distributions are interspersed among egalitarian distributions, suggesting that the difference between egalitarian and merit-using children is not due to age, years in school, or a combination of these two. Consistent with this, results from a multiple logistic regression found no significant effect of age, years in school, or their interaction ($p>0.69$ in all cases).[5]

Next, to disentangle how age, counting ability, and set size affect children's use of merit, we performed a logistic multiple regression with merit-vs-egalitarian as the binary

[4] Four of these five participants were pre-numerical children in the large-set condition and one participant was a full counter in the small-set condition. See Table 1 for demographic information. Including these participants as merit users, egalitarians, or members of their own separate category does not affect the reported results.

[5] To ensure this null result was not because age and years of education correlate, we next performed two separate logistic regressions predicting distribution type from years of education and age. Neither revealed a significant effect—β=0.27 ($p=0.20$) per year of education and β=0.09 ($p=0.54$) per year in age.

dependent variable. Age (z-scored), children's understanding of number (*pre-numerical* or *full counter*), set size (as a sum-coded factor), and the interaction of the latter two, were input as predictors (independent variables). Table 2 shows the results from the regression. Consistent with our main finding, only children's ability to count yielded a significant influence on fairness, controlling for the other factors, suggesting that children's use of merit is strongly guided by their ability to count and not their age.

In the regression, set size also showed no effect and the overall qualitative pattern appeared in both conditions. In the small-set condition (distributing four cookies), only 25% of full counters produced an egalitarian distribution (3 out of 12 participants) compared to 47.06% of pre-numerical children (8 out of 17 participants). Similarly, in the large-set condition (distributing ten cookies), 27.28% of full counters produced an egalitarian distribution (3 out of 11 participants) compared to 68.75% of pre-numerical children (11 out of 16 participants). However, it is important to note that an analysis looking at each condition separately revealed a significant effect in the large-set condition (p=0.048 by permutation test) but not in the small-set condition (p=0.2764 by permutation test). Together with the overall analyses, these findings suggest that children's acquisition of number may have a stronger influence when the set is large.

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Discussion

Here we have shown that in the Tsimane', a farming-foraging group living in the Amazonian region of Bolivia, a child's ability to count is a strong predictor of whether their distribution of resources reflects an appreciation of merit. Full counters were significantly more likely to produce a merit-based distribution compared to pre-numerical children. Our results show that mastery of number—a non-universal, cultural invention (Frank, Everett, Fedorenko, & Gibson, 2008)—can have an important influence on merit-based fairness judgments.

Critically, our findings could not be explained by age or years of education. Thus, it is unlikely that our findings could be due to children foregoing egalitarianism as a function of exposure to social activities (which increases with age and occurs during school). Nevertheless, the ability to produce merit-based distributions may not be related to the acquisition of number concepts, but simply guided by some underlying factor that correlates with counting ability, but not age or school attendance.

In principle, children could have relied on approximate magnitudes and distributed the cookies by estimating the size of different piles. Thus, children should have been able to give more cookies to the harder working child without counting, especially in the small set condition. One possible explanation for why this did not occur is that children have a strong preference for exact, justifiable methods in scenarios that involve fairness. That is, children may prefer reproducible rules in which they can exactly determine how many more cookies the harder-working agent received.[6]

Why do pre-numerical children produce egalitarian distributions more often than full counters do? Is it because they do not understand merit (not believing that the child who worked harder deserves more)? Three recent studies suggest this is not the case. Baumard, Mascaro, and Chevallier (2012) found that if a task makes it impossible to produce an egalitarian distribution (for example, by having a small and a big cookie, or an odd number of cookies), three-year-old children (who may understand counting, but are likely too young to fully understand the logic of natural numbers; Davidson, Eng, & Barner, 2012) give more resources to whomever contributed more towards completion of the task. Similarly, Kanngiesser and Warneken (2012) found that three- and five-year-olds take merit into account even in first-party contexts. Along the same lines, Sloane, Baillargeon, and Premack (2012) showed that, before their second birthday, toddlers expect rewards to be distributed only between people who participated in the task for which they are being rewarded (i.e., they behave as believing that those who did nothing deserve nothing). Thus, although pre-numerical children tend to produce egalitarian distributions, they nevertheless understand merit.

Given the evidence that pre-numerical children understand merit, why do only full counters consistently produce merit-based distributions? Is it because it's easier for them to decide how to transform an abstract merit difference into a concrete reward difference? Is it because they have less trouble producing the distribution they believe is the most fair? Or is it a combination of both? Intuitively, learning to count should influence children's ability to produce the distributions they believe are fair. More fundamentally, learning the underlying logic of counting—specifically, that sets have exact sizes—may influence how children reason about transforming a merit difference into an exact reward difference. Here, we used a single measure, the *Give-N* task, which roughly separates children into those who cannot count nor understand the logic of natural numbers, and those who can and do. Because these two acquisitions are tightly correlated (Jara-Ettinger et al., *under review*), it is difficult to know how learning numerical concepts and learning to count may independently influence children's performance in merit-based fairness tasks. Further work would be needed to disentangle their roles.

Interestingly, the acquisition of counting and number concepts may extend beyond merit-based fairness tasks, as many tasks where fairness intuitions come into play involve transforming an abstract measure (such as need, or social entitlement) into a concrete reward difference, which the child must then produce. Learning that sets can be quantified may lead children to focus on the idea that differences in merit, need, or need can also be quantified and mapped onto material reward differences.

In conclusion, by testing a population in which age, years in school, and counting ability are less tightly related than in industrialized cultures, we were able to isolate an effect of

[6] Note that pre-numerical children should have trouble even if the reward difference is a small number (e.g., "One more cookie for the harder-working child.") because they do not understand that adding one element to a set changes its size (Izard et al., 2014).

number knowledge in how children distribute resources in merit-based fairness tasks. Our results show that numerical concepts can influence how we reason about fairness and they demonstrate a case in which children may possess the same fairness intuitions as adults, but may fail to exhibit those fairness preferences behaviorally until later in life (e.g., Damon, 1975).

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Figures and Tables

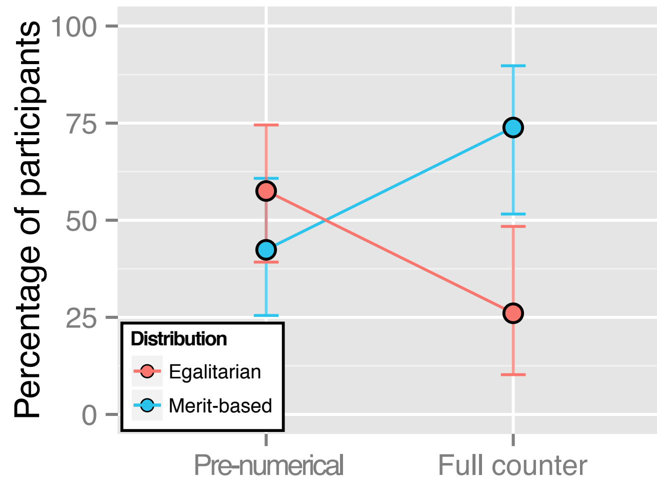

Figure 1: Children who cannot count (*pre-numerical*) show no overall bias between egalitarian and merit-based distributions. In contrast, children who can count (*full counters*) are biased towards producing merit-based distributions, giving more cookies to the harder working child. Each point shows the proportion of children making each choice and the vertical bars show 95% confidence intervals on the estimate.

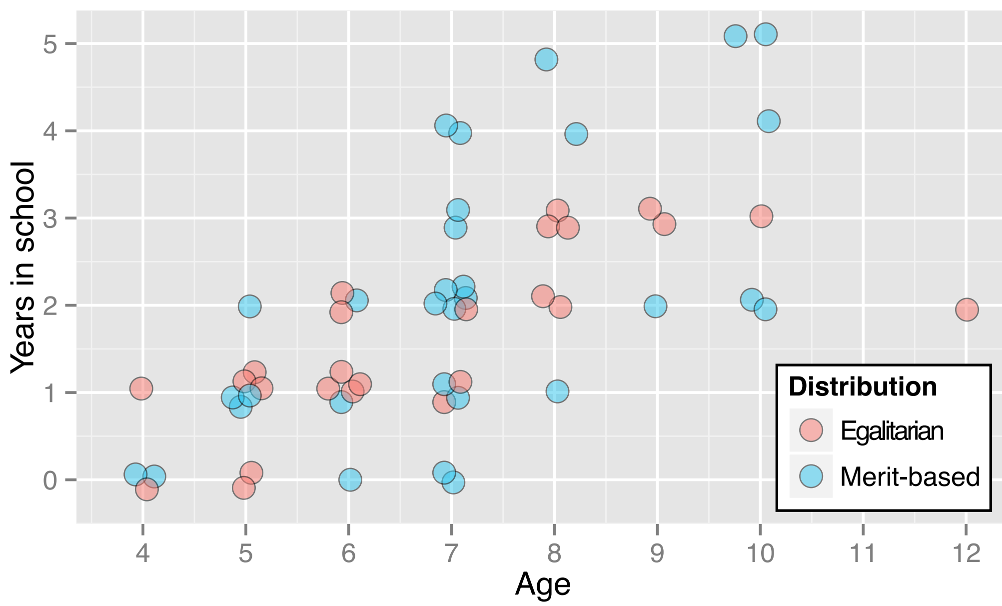

Figure 2: Participants' choice of distribution as a function of their age (x-axis) and their years in school (y-axis). Red circles represent participants who produced an egalitarian distribution and blue circles represent participants who produced a merit-based distribution. Merit-based distributions are not biased towards the right (implying age matters), to the top (implying education matters), or clustered on the top right (implying a combination of age and education matters). Instead, they are intermixed with egalitarian based distributions, suggesting that, in the Tsimane', foregoing egalitarianism in merit-based tasks is not the result of age or exposure to school.

Age	School	Set size	Full counter	Answer		Age	School	Set size	Full counter	Answer
4	0	4	N	2		8	5	4	Y	4
6	1	4	N	2		4	1	10	N	5
6	1	4	N	2		5	0	10	N	5
6	1	4	N	2		5	0	10	N	5
6	2	4	N	2		5	1	10	N	5
7	1	4	N	2		5	1	10	N	5
8	3	4	N	2		6	1	10	N	5
8	3	4	N	2		6	2	10	N	5
4	0	4	N	3		7	1	10	N	5
5	1	4	N	3		7	2	10	N	5
5	1	4	N	3		8	3	10	N	5
5	2	4	N	3		9	3	10	N	5
6	0	4	N	3		7	0	10	N	6
7	1	4	N	3		7	0	10	N	6
7	1	4	N	3		7	2	10	N	6
4	0	4	N	4		7	3	10	N	6
7	2	4	N	4		10	2	10	N	7
5	1	4	Y	2		9	3	10	Y	5
8	2	4	Y	2		10	3	10	Y	5
8	2	4	Y	2		12	2	10	Y	5
6	1	4	Y	3		10	4	10	Y	6
6	2	4	Y	3		10	5	10	Y	6
7	2	4	Y	3		7	2	10	Y	7
7	3	4	Y	3		8	1	10	Y	7
7	4	4	Y	3		9	2	10	Y	7
7	4	4	Y	3		10	2	10	Y	7
8	4	4	Y	3		10	5	10	Y	7
7	2	4	Y	4		5	1	10	Y	10
7	1	4	Y	0		6	1	10	N	4
3	0	10	N	0		6	1	10	N	4
5	0	10	N	4						

Table 1: Results from the experiment. Each row shows a participant's performance. The table shows each participant's age (*Age* column), years in school (*School*), the set-size they were given to distribute (Set-size column), whether they could count or not (*Full counter* column), and the number of cookies they gave to the harder-working child (*Answer* column). Children who took merit into account (i.e., when the answer is higher than half the set-size) are color-coded in light gray. The bottom part of the table (dark gray) shows the demographics and the condition of participants who gave *fewer* cookies to the harder-working child and were thus unclassifiable.

	Estimate	Std. Error	z-value	Pr(>|z|)	
Intercept	-0.3873	0.3860	-1.003	0.316	
age	*-0.1579*	0.3826	-0.413	0.680	
Set-size	0.4281	0.3679	1.164	0.245	
Full counter	1.5350	0.7200	2.132	0.033	*
set-size:Full counter	-0.4615	0.6231	-0.741	0.459	

Table 2: Results from a multiple logistic regression with children's use of merit as the dependent variable. Children's age (z-scored), their ability to count, set-size condition (as a sum-coded factor), and the interaction of set-size with counting ability were input as predictors (independent variables).

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