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Modeling Fairness Judgments of Splits Between Multiple Parties

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Abstract

Fair divisions are a fundamental problem for moral cognition. Past experimental work has provided evidence in support of three principles of fairness in divisions between two parties: proportional splits, equal splits, and splits that equalize net gains (the Nash bargaining solution). When the number of parties increases, so does the complexity of such decisions, potentially influencing people's cognitive strategies and their reliance on precise explicit heuristics vs intuitive approximations. We design a novel task in which participants can easily and intuitively sample and select among various distributions of resources between multiple people (2 to 18) by adjusting a continuous slider that updates divisions in real time. In two preregistered experiments (n = 378; 2,268 choices), we quantitatively model participants' fairness judgments at the individual level. We find that participants can be categorized into three main groups. Overall, around 50% are best fitted by proportionality, 40% by the Nash bargaining solution, and fewer than 10% by equality. At the aggregate level, proportionality and the Nash bargaining solution perform best. Fairness judgments remain stable as the number of involved parties increases. When they only have access to the slider (Experiment 1), participants best fitted by the Nash bargaining solution seem to intuitively approximate it, but in an imprecise way. By contrast, they tend to precisely select it when three buttons (one for each model, Experiment 2) are available to automatically adjust the slider. These results suggest that a substantial proportion of participants rely on intuitive approximations for the Nash bargaining solution, consistent with bargaining-based (contractualist) theories of fairness.

Keywords: fairness; moral cognition; judgment and decision making; contractualism; cognitive modeling

Introduction

Fair divisions are a fundamental problem for moral cognition (Curry, 2016; Graham et al., 2013; Rai & Fiske, 2011; Tomasello & Vaish, 2013). Human cooperation routinely raises distributive questions: how to share common resources, such as food and tools; how to divide the gains from joint production, such as the spoils of a hunt; how to apportion effort and other contributions to collective action; and how to allocate rewards and punishments (Cushman, 2015; Ostrom, 1990; Warneken et al., 2011). These distributive decisions create conflicts of interest that must be resolved appropriately to ensure mutually beneficial long-term cooperation, and avoid violent conflicts (Tooby & Cosmides, 2025). What is the fair way to divide the proceeds of a collective endeavor between people who differ from each other? Experimental work usually focuses either on divisions between two asymmetric parties or on splits between multiple parties in symmetric positions. Past research shows the importance of a proportionality principle (Aristotle, c. 350 BC/2009; Selten, 1988). Yet a vast literature on inequality aversion emphasizes the attractiveness of equal splits (Blake & McAuliffe, 2011; Dawes et al., 2007; Fehr et al., 2008; Shaw & Olson, 2012). Recently, contractualist models of moral cognition have proposed that fairness judgments should reflect what rational agents in search of mutual benefit would agree to (Le Pargneux et al., 2024) and approximate the outcome of rational bargaining models, the most prominent being the Nash bargaining solution (NBS) (André et al., 2023; Binmore, 1994a, 1994b; Levine et al., 2024).

Previous work finds support for all three principles—proportionality, equality, and bargaining—in two-party contexts (Bediou et al., 2012; Gächter & Riedl, 2006; Le Pargneux et al., 2025; Luhan et al., 2019; Takeuchi et al., 2022). However, much less is known about fairness judgments of splits between more than two parties. This matters because the fairness principles people favor may depend on the number of involved parties.

One reason the number of parties may matter is computational cost (Levine et al., 2024). As groups get larger, every fairness principle becomes harder to implement, but this seems especially true for the NBS (see Models). If people aim to apply principles exactly, this could lead them to abandon the NBS for simpler alternatives. However, people may instead rely on intuitive approximations, in which case the effect of group size is not straightforward.

Beyond computational costs, group size may matter because it can change both the mental models people apply and the ecological features they implicitly assume. On one view, larger groups may cue a more transactional frame—e.g., market pricing rather than equality matching (Rai & Fiske, 2011)—making proportionality or bargaining-based splits seem fair. Relatedly, larger groups may make such inegalitarian splits seem appropriate because they evoke higher outside options or distrust (André et al., 2023). On another view, larger groups may instead cue impersonal fairness norms—capable of sustaining cooperation among strangers (Henrich et al., 2010; Singer, 1981)—making egalitarian principles seem preferable.

We next outline several hypotheses. Given the lack of preexisting data and the methodological novelty of our studies, we did not favor any of these *ex ante*. We therefore preregistered an analysis plan but not a predicted outcome.

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The Egalitarian hypothesis predicts that people will become more egalitarian as the number of involved parties increases. The Market hypothesis instead predicts that people will become less egalitarian. The Consistency hypothesis predicts that choices will remain consistent. Which principles of fairness do people favor in splits between multiple parties? Do these principles, or people's cognitive strategies, change as the number of involved parties increases?

Here we design a novel task in which participants can select their favorite distribution among multiple parties. To accomplish this, we implement a continuous slider which updates in real time the amount of money that each party receives. This makes it intuitive for participants to propose fair divisions of money, without requiring the use of explicit complex math (i.e., only the math required to ensure appropriate allocations, no matter the distributive principle).

Models

The structure of our scenario is that of a (simplified) multi-party Nash bargaining problem (see Method, (Nash, 1950)). Several collectors can either sell their items on their own or decide to put their items in common and sell them at a larger price to a large buyer. The common sale only happens if they all agree in advance on how to split the proceeds. Otherwise, each collector sells his items on his own at a certain price—his "disagreement payoff" (i.e., obtained in the absence of agreement). Based on previous work in a two-party context (Le Pargneux et al., 2025; Takeuchi et al., 2022), we consider three models: Equality, Proportionality, and the NBS.

Models

$$P_i = \frac{S \cdot c}{n} \qquad S = \sum_{i=1}^{I} d_i$$

Equality This model splits the total amount of money equally among all n collectors. Here P_i is the payoff and d_i is the disagreement payoff for collector i. c is a constant scalar (≥ 1) that determines the total amount of value created if the collectors put their items in common. Collectors can collectively sell for $S \cdot c$ where S is the sum of all collectors' disagreement payoffs. In our scenario below, collectors can sell for twice the sum of all disagreement payoffs if they can agree about how to split the proceeds, so c equals 2. As groups get larger, Equality seems harder to compute (e.g., dividing by 8 or 12 is harder than dividing by 2). In practice, participants can simply search for the slider location that provides the same payoff to each collector.

$$P_i = d_i \cdot c$$

Proportionality This model allocates proceeds proportionally to the size of the collector's disagreement payoff (Konow, 2000; Selten, 1988). A simple explicit heuristic for Proportionality in our scenario is to "multiply each party's disagreement payoff by 2". This exact rule-of-thumb does not get much harder to apply with the number of parties. In fact, people simply need to search for the location of the slider that doubles each collector's payoff.

$$\max \prod_{i=1}^{n} (P_i - d_i) \qquad P_i = d_i + \frac{(c-1) \cdot S}{n}$$

Nash bargaining solution This model maximizes the product of each collector's payoff over his disagreement payoff. Here, this corresponds to giving each collector his disagreement payoff and then splitting the surplus (total price minus sum of disagreement payoffs) equally among all n collectors (Nash, 1950, 1953). As groups get larger, the number of terms in the product increases, and computing the exact Nash bargaining solution may become increasingly difficult. This may not be an issue if this computation remains largely implicit, intuitive, and approximate. Interestingly a simple explicit heuristic of "equalizing each party's net gains over their disagreement payoffs" is also available to participants to determine the exact NBS. However, unlike for Proportionality and Equality—which are likely to be more widespread and consciously available—, for most people, such a rule-of-thumb may be unlikely to come to mind.

Other fairness principles are of course possible (e.g., a redistributive model favorable to low disagreement payoff parties or a "super-proportional" model maximally favorable to high disagreement payoff parties). In practice, these are rarely observed, both in previous research (Le Pargneux et al., 2025) and in pilot data, and so we do not discuss them.

Experiment 1

Method

Participants The design, sample size, and main hypotheses were preregistered. Data, materials and code are available on an OSF repository. 208 US participants were recruited from Prolific and asked to complete the study on a computer. As per our preregistration, 28 participants were excluded for failing comprehension checks, or not adjusting the slider for all trials (final sample size: 180; 46.7% female, 50.0% male, 3.3% other; age range: 20-81 years, mean = 44.7 years). Our studies received ethics approval (Harvard #IRB14-2016).

Materials The task was conducted on Qualtrics. The scenario was: *"Consider a group of collectors: Each collector has items to sell. Each collector can either sell his items on his own or put them in common with other collectors to be sold to a large buyer. If all collectors put all their items in common then they can be sold for a much higher price to a large buyer. The common sale to the large buyer can only happen if all collectors agree about how to split the proceeds of the common sale. Each collector has a veto. If any collector uses his veto then the common sale does not happen and each collector sells his items on his own. This corresponds to the amount of coins indicated under "Own money" on the slider below. If all collectors agree, then they put all their items in common. The items are sold to a large buyer for a higher price. Each collector gets the amount of coins indicated* *under "Common sale" on the slider below. Click on the slider below and move it around to visualize all the possible ways of splitting the proceeds of the common sale."*

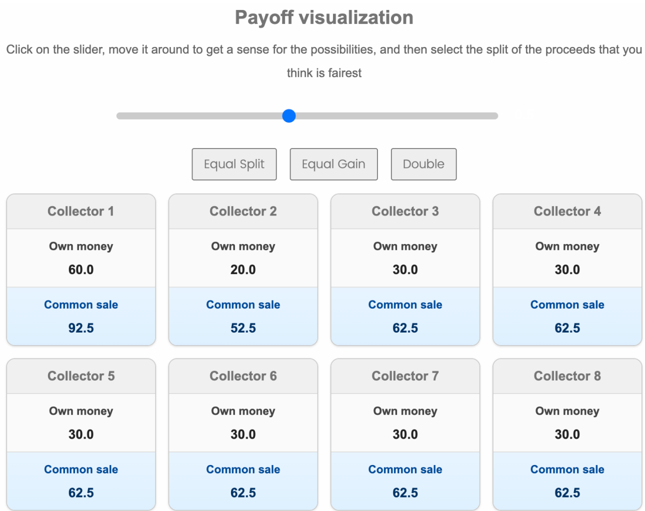

Figure 1: Visualization of the slider for a trial with 8 collectors. The blue dot only appeared when and where the participant clicked on the slider. The blue dot could then be dragged left or right. For each collector, the number of coins under "Common sale" was updated in real time as participants moved the slider. The three buttons ("Equal Split", "Equal Gain", "Double") were only present in Experiment 2, not in Experiment 1. In Experiment 2, buttons could be clicked as many times as necessary. The slider could be adjusted after clicking a button. Participants did not have to click on any of the buttons to move the slider. The image shows the NBS allocation (Proportionality: 120 to collector 1, 40 to collector 2, and 60 to others; Equality: 65 to all).

Procedure Participants were presented with a consent form and entered their Prolific IDs. They read the scenario, which was presented sequentially over multiple pages. Then they were once again presented with the full scenario on one page and had two attempts to correctly answer a set of three comprehension questions. After that, they completed six trials presented in randomized order (within subjects). Finally, they answered "Please briefly explain (2-3 sentences) how and why you made your choices in this study." Then, they provided their age, gender, and any comments they had, and were debriefed.

Design The trials corresponded to groups of respectively 2, 4, 8, 12, 15 and 18 collectors. For each trial collector 1 had a disagreement payoff of 60, collector 2 had a disagreement payoff of 20, and any additional collector had a disagreement payoff of 30. At each trial, participants were asked: "*Consider a new group of investors. Please select the split of the proceeds that you think is fairest. (A reminder about the instructions is available at the bottom of the page.)*" The full scenario was present at the bottom of the page for reference and was identical for all trials. Above the slider was the instruction: "*Click on the slider, move it around to get a sense for the possibilities, and then select the split of the proceeds that you think is fairest*". Participants had to click on the slider in order for the blue dot to appear, see Figure 1. Trials were chosen to cover a range of group sizes between 2 and 18 (maximum number of boxes for which all boxes and the slider can be seen concurrently on a standard laptop computer screen without having to scroll), while limiting the study's length (median time: 9 minutes).

Slider We coded the slider according to the following principles. First, for all trials Proportionality, the NBS, and Equality are always achievable. Second, neither of these solutions is located at one extreme of the slider (leftmost or rightmost point). Third, distributions that go beyond Equality (disproportionally advantageous to the collector with the lowest disagreement payoff) or proportionality (disproportionally advantageous to the collector with the highest disagreement payoff), and a wide range of distributions between these two are also possible. Fourth, all distributions correspond to a split of a total sum of money of constant size $S \cdot c$ and are thus Pareto efficient. Fifth, collectors with the same disagreement payoffs always receive the same payoff (they don't differ on any dimension).

Payoffs for each collector are updated in real time as participants moved the slider. This is to make the task less cognitively demanding than having to input specific numbers for each collector while ensuring that all numbers add up to the size of the total sum of money. The slider was coded according to the following two main equations:

$$(1)\ P_i = w \cdot \frac{d_i}{S} \cdot c \cdot S + (1-w) \cdot \frac{1-\frac{d_i}{S}}{\sum_j (1 - d_j/S)} \cdot c \cdot S \quad if\ w \le 1$$

$$(2)\ P_i = s \cdot \frac{\left(\frac{d_i}{S}\right)^2}{\sum_j \left(\frac{d_j}{S}\right)^2} \cdot c \cdot S + (1-s) \cdot \frac{d_i}{S} \cdot c \cdot S\ if\ w > 1$$

This corresponds to two main segments (the slider appeared continuous to participants). From the participant's perspective the zone from 0.0 (leftmost point) to 0.8 determines payoffs via Equation (1), which is a weighted sum between "anti-proportionality" (the collector with the lowest disagreement payoff receives the highest proportion of the split) and proportionality (collectors receive twice their disagreement payoff). The zone from 0.8 to 1.0 determines payoffs via Equation (2), which is a weighted sum between proportionality and "super-proportionality", in which the collector with the largest disagreement payoff gets more, in proportion to the size of his disagreement payoff compared to other disagreement payoffs. This ensures Proportionality is not located at one end of the slider. $slider_{value}$ is the slider value (from 0 to 1) selected by the participant on the screen. When this value is below or equal to 0.8, the payoff is determined by Equation (1). When this value is above 0.8 the payoff is determined by Equation (2). This is achieved with:

$$(3)\ w = \frac{slider_{value}}{0.8}\ if\ slider_{value} \leq 0.8$$

$$w = 1 + \frac{slider_{value} - 0.8}{1 - 0.8}\ if\ slider_{value} > 0.8$$

$$s = w - 1\ if\ w > 1$$

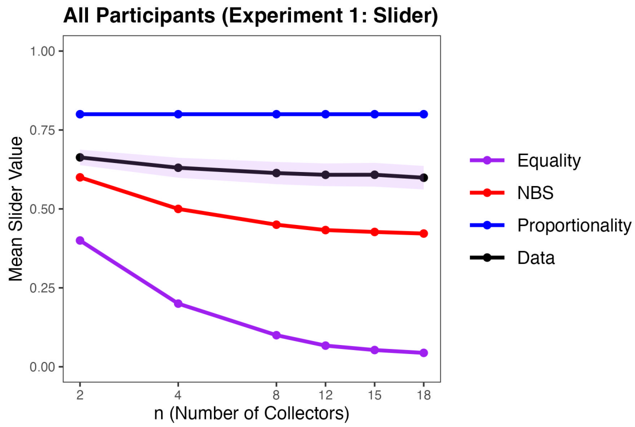

Figure 2: Experiment 1: Average slider value for each trial. Data are in black. Shaded pink region corresponds to 95% CI.

Results

Preregistered Analyses Which model best accounts for the data, on aggregate? We compute the RMSE for each model (across all trials and participants). We find that Proportionality (RMSE: 0.21) best fits the data, closely followed by the NBS (0.26), with these two models fitting the data much better than Equality (0.50). Visually, the mean slider value is in between Proportionality and the NBS for all trials, and shows a moderate downward trend, as predicted by the NBS and Equality, but not Proportionality, see Figure 2.

What is the proportion of participants best fitted by each model? For each participant, we compute the RMSE for each model (across all six trials of a participant) and select the model that minimizes this metric. We find that 53.3% of participants are best fitted by Proportionality, 37.8% are best fitted by the NBS, and 8.9% are best fitted by Equality. We split participants into three groups according to the model that best fits their choices and plot the mean slider value for each trial, see Figure 4. Visually, for each group, we observe a good fit between model predictions and data. Quantitatively, we find that Proportionality, the NBS and Equality are on average 0.05, 0.15, and 0.09 away, respectively, from the slider value of participants best fitted by each model. This suggests that for each category of participants, the corresponding model provides a reasonably good approximation of judgments made by participants.

Do fairness judgments depend on the type of trial (and thus the number of collectors)? For each participant's choice, we compute the squared error of that choice according to each model. We categorize each choice according to its best fitting model (Proportionality, NBS, Equality). Visually, we observe remarkable stability across trials in the proportion of choices best fitted by each model, see Figure 3. To test whether participants' choices depend on the trial (and thus on the number of collectors) we perform a permutation test (approximative general independence test) stratified by participant id (thus controlling for dependencies in the data). The null hypothesis of this test is that, within participants, the distribution of best models is the same across trials. We fail to reject the null hypothesis (maximum standardized test statistic = 2.9549, p = 0.0512), though the p-value is low. For the two most extreme trials (2 and 18 collectors), we also perform a complementary Chi-squared test of independence between the distribution of best models and find no statistically significant difference (χ^2 = 3.5087, df = 2, p = 0.173), though this analysis does not take dependencies into account. Visual observation of individual level plots for each participant (all available on OSF) does not reveal a systematic pattern of change in fairness judgments as the number of collectors increases. On the contrary, most participants appear to make consistent choices across trials. Overall, these results suggest that there is little variation at most in fairness judgments depending on the type of trial.

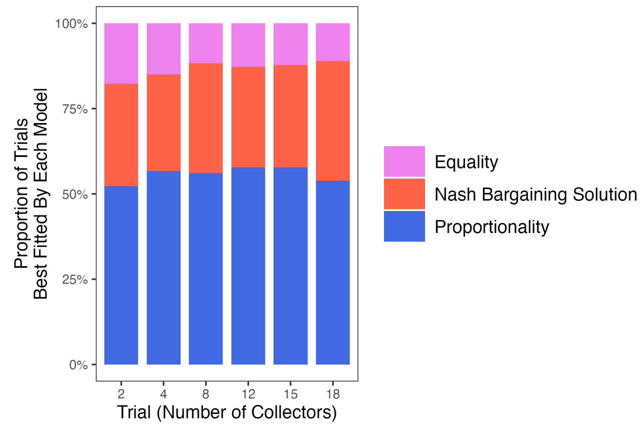

Figure 3: Experiment 1: Proportion of choices best fitted by each model for each trial.

Experiment 2

Method

Participants The design, sample size, and main hypotheses were preregistered. Data and code are available on an OSF repository. 207 US participants were recruited from Prolific. As per our preregistration, 9 participants were excluded for failing comprehension checks, or not adjusting the slider for all trials (final sample size: 198; 48.5% female, 50.0% male, 1.5% other; age range: 21-80 years, mean = 43.9 years).

Design The only difference with Experiment 1 was that, below the slider, participants had the option (but not the obligation) to click on one of three buttons labeled "Equal Split", "Equal Gain" and "Double", that automatically moved the slider to the locations corresponding to Equality, the NBS, and Proportionality, respectively. The slider could be adjusted before and after clicking on a button. Participants could click on each button as many times as needed.

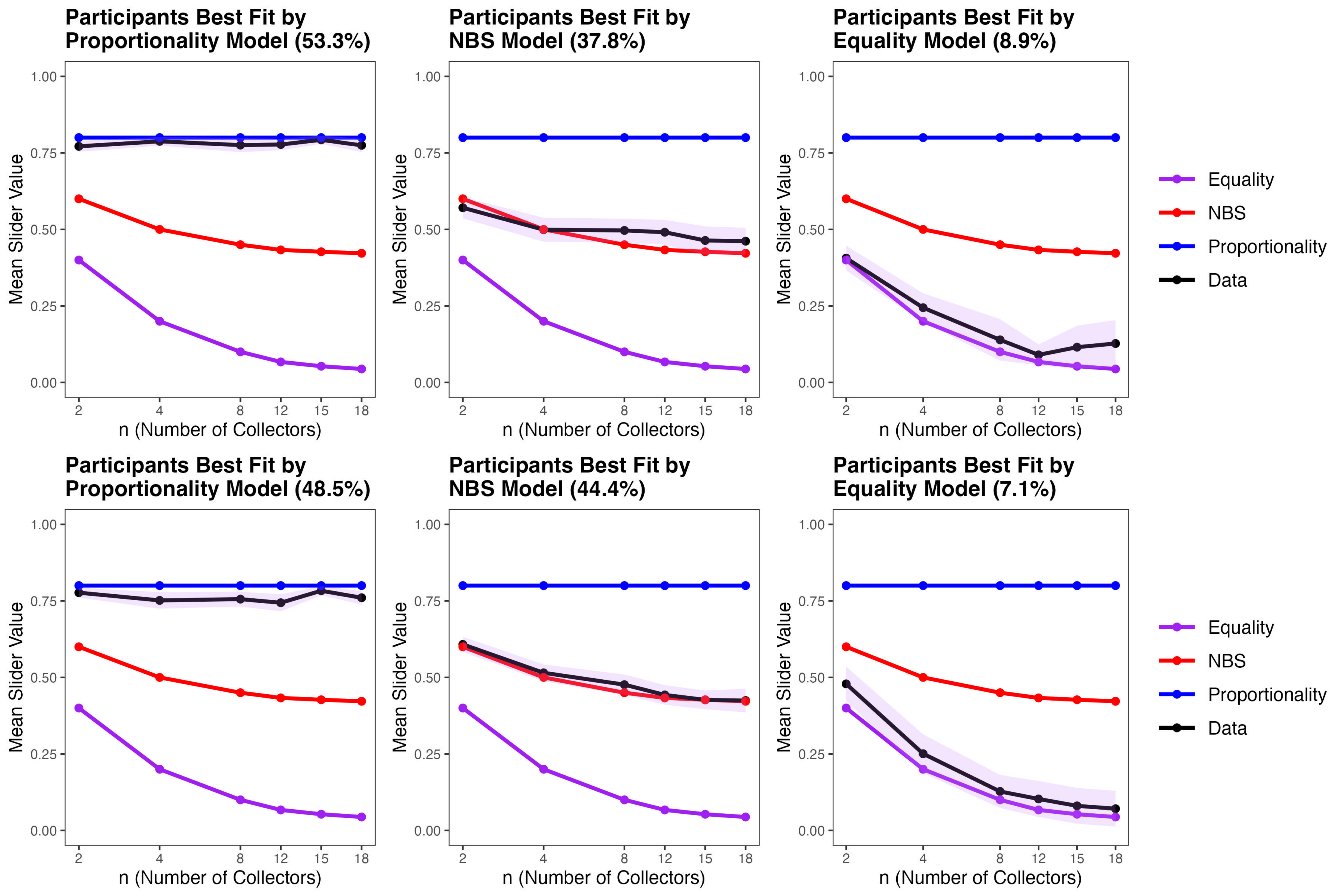

Figure 4: (Top row) Experiment 1: Average slider value for participants (n = 180) best fit by Proportionality (left, 53.3%), the NBS (center, 37.8%), and Equality (right, 8.9%). (Bottom row) Experiment 2: Average slider value for participants (n = 198) best fit by Proportionality (left, 48.5%), the NBS (center, 44.4%), and Equality (right, 7.1%). Shaded pink regions are 95% CI.

Results

Preregistered Analyses As in Experiment 1, we find that Proportionality (0.23) and the NBS (0.22) best fit the data at the aggregate level, with comparable RMSE values, far ahead of the Equality model (0.48). Visually, the mean slider value is in between Proportionality and the NBS for all trials, and shows a moderate downward trend, as predicted by the NBS and Equality, but not Proportionality, see Figure 5.

Next, for each participant, we compute the RMSE for each model (across all six trials of a participant). We find that 48.5% of participants are best fitted by Proportionality, 44.4% by the NBS, and 7.1% by Equality. This is very comparable to the results of Experiment 1. A Chi-squared test of independence (3 categories: Proportionality, NBS, Equality; 2 conditions: Slider (Experiment 1), Buttons (Experiment 2)) reveals no statistical difference in the distribution of best models between our two experiments (χ^2 = 1.8445, df = 2, p = 0.3976).

We split participants into three groups according to the model that best fits their choices, and plot the mean slider value for each trial, see Figure 4. Visually, for each group, we observe a good fit between model predictions and data. Quantitatively, we find that Proportionality, the NBS and Equality are on average 0.07, 0.11, and 0.07 away, respectively, from the slider value of participants best fitted by each model. This suggests that, for each category of participants, the corresponding model provides a reasonably good approximation of judgments made by participants.

Visually, we observe remarkable stability across trials in the proportion of choices best fitted by each model (not shown). As in Experiment 1, we do not find evidence that the distribution of best models is different across trials (approximative general independence test: maximum standardized test statistic = 1.4136, p = 0.892). We also do not find that the distribution of best models differs between trials $n = 2$ and $n = 18$ (χ^2 = 0.23948, df = 2, p = 0.8871).

Overall, it seems that participants are making their choices in a consistent way across trials, and we do not observe any systematic changes in choice of fairness principles as the number of collectors varies from 2 to 18. This conclusion is also supported by a visual inspection of choices for each participant (all plots available on OSF), which suggests that most participants make consistent choices across trials.

Exploratory Analyses Participants seem to make heavy use of the buttons: the mean number of button clicks per trial is 2.12, and 88.0% of trials involve at least one button click. In Experiment 1, of those participants best fitted by the NBS, only a few participants (6) very precisely locate the slider at or near the NBS on every single trial (Proportionality: 49; Equality: 5), while most participants seem to approximate it in an imprecise way. By contrast, in Experiment 2, many more participants (33) locate the slider at the precise location of the NBS (Proportionality: 51; Equality: 7) on every trial, likely making their choices using the "Equal Gain" button.

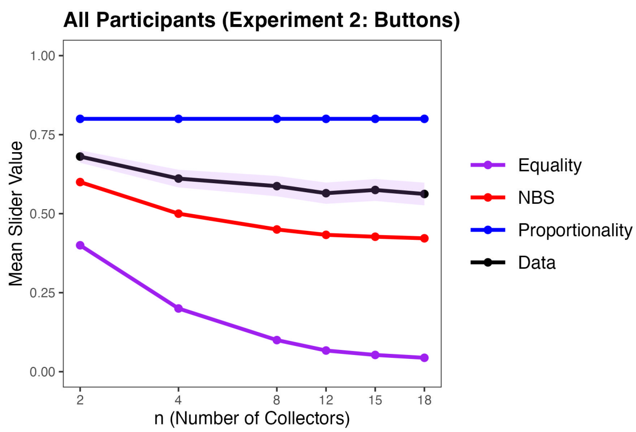

Figure 5: Experiment 2: Average slider value for each trial. Data is in black. Shaded pink region corresponds to 95% CI.

Discussion

Which fairness principles do people use to split the proceeds of a joint endeavor between multiple parties? On aggregate, proportionality and the NBS perform best. At the individual level, around 50% of participants are best fitted by proportionality, 40% by the NBS and fewer than 10% by equality. Does the size of the group influence participants' choices? Participants' judgments seem to remain consistent as the number of parties involved in the common sale varies between 2 and 18, in line with the Consistency hypothesis, but not the Egalitarian and Market hypotheses. Do participants attempt exact computations or make approximate judgments? Many participants best fitted by proportionality and equality seem to apply those principles precisely (and explicitly). Most participants best fitted by the NBS seem to rely on intuitive approximations. Nevertheless, we don't see evidence of strategy change as the number of parties goes up.

Insofar as a substantial proportion of participants make fairness judgments that, on average, approximate the NBS (despite its location changing at each trial), our findings provide some support for recently proposed contractualist models of moral cognition which posit an intuitive sense of fairness that tracks the NBS (André et al., 2023). Indeed, while very few of those participants find the precise NBS unaided (Experiment 1), many view the exact NBS as fairest when they can use a button to easily find it (Experiment 2).

Importantly, in both experiments, the best model at the individual level is Proportionality (note that this is the only model for which the slider location is fixed across trials, though the comparable results obtained in Experiment 1 and 2 seem to indicate that this may not matter much). In this regard, it is interesting to note that proportionality also occupies a central place in prominent contractualist accounts (Baumard et al., 2013; Binmore, 1994a, 1994b, 2005). In highly efficient markets in which the "surplus" approaches zero the predictions of bargaining solutions coincide with a split proportional to disagreement payoffs (Baumard et al., 2013). We speculate that some participants may interpret the scenario as one resembling a fairly efficient market in which proportionality constitutes a good (and/or cognitively efficient heuristic (Levine et al., 2024)) approximation of a contractualist logic, and should be applied. And indeed, a strength of contractualist approaches is that the NBS can prescribe both proportionality (in efficient markets) and also equality (e.g., when the bargaining agents are in symmetric starting positions) under certain conditions.

Our findings remain exploratory and should be taken with caution. This is due to a number of limitations of our design. The first is the size of the groups. To ensure that participants can see all boxes and the slider without scrolling, we limit the maximum number of collectors to 18. It is unknown whether the results presented here would hold for large groups of collectors (e.g., 100, 1000, 10,000 and more). Second, we only test one set of possible parameters in our experiments. In all our trials collectors have disagreement payoffs of 60 (collector 1), 20 (collector 2) and 30 (all other collectors) and the total to split is equal to twice the sum of the disagreement payoffs. This is to ensure comparability (by holding asymmetries constant) between trials and across participants. Because all collectors beyond collector 1 and 2 share the same disagreement payoff, strictly speaking participants only need to attend to 3 distinct payoffs as they make their choices, no matter the number of collectors. This limits the gradient of cognitively complexity as the number of collectors increases, potentially rendering the manipulation of group size less potent than it would be otherwise (e.g., an equal split gets harder to compute but remains cognitively easy; the NBS can explicitly be found with the same heuristic on all trials, though very few people seem to have explicit access to it; proportionality seems always relatively easy to apply). Finally, all our participants are from the US (though related cross-cultural research (Le Pargneux et al., 2025) finds remarkable levels of consistency in fairness judgments across countries). In future work, we plan to test different distributions of disagreement payoffs, and different value creation/production functions for the total to split (Takeuchi et al., 2022), and to assess the variability in preferred fairness principles depending on the context (e.g., investors investing in a common fund, lumberjacks joining forces etc.), and their generalizability to other countries and cultures.

Despite this, our studies provide early insights on the cognitive strategies involved in judgments of fair splits between multiple parties.

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