The “motive cocktail” in altruistic behaviors

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Abstract

Prosocial motives such as social equality and efficiency are key to altruistic behaviors. However, predicting the range of altruistic behaviors in varying contexts and among different individuals proves challenging if we limit ourselves to one or two motives, as most previous studies have done. Here we demonstrate the numerous, interdependent motives in altruistic behaviors and the possibility to disentangle them through behavioral experimental data and computational modeling. In one laboratory experiment (*N*=157) and one pre-registered online replication (*N*=1258) across 100 different situations, we found that both third-party punishment and helping behaviors aligned best with a model of seven socioeconomic motives, referred to as a "motive cocktail", including two compound motives. For instance, the "inequality inattention" motives imply that individuals, when confronted with costly interventions, behave as if the inequality between others barely exists. The motive cocktail model also provides a unified explanation for a range of phenomena in the literature.

Keywords: third-party punishment; third-party helping; inequality aversion; inequality inattention; computational models

Introduction

Many people voluntarily provide resources like shelter, food, and healthcare to refugees fleeing war-torn regions, while others advocate sanctioning responsible nations, even at the expense of personal cost. This altruistic behavior, known as third-party punishment (3PP) and helping (3PH), involves sacrificing personal interests to punish transgressors or help victims. Such behaviors have been observed both in laboratory (Fehr & Fischbacher, 2004; Henrich et al., 2006; Jordan et al., 2016; Marlowe et al., 2008) and field studies (Balafoutas et al., 2014, 2014; Singh & Garfield, 2022). What, then, motivates these actions?

The desire to reduce inequality is believed to underlie both altruistic punishment and helping behaviors (Darley & Pittman, 2003). Unlike other altruistic behaviors that potentially enhance reciprocity (Gintis, 2000) or signal trustworthiness (Jordan et al., 2016), most 3PP or 3PH actions do not yield any direct benefit to the third party (Balafoutas et al., 2014), thus highlighting humans' innate aversion to inequality. Indeed, by quantifying inequality as a kind of loss in a rational framework of utility maximization, the seminal work of Fehr and Schmidt (1999) provides a unified explanation for a range of social-economic phenomena (Fehr & Fischbacher, 2004), including altruistic punishment and helping behaviors (Blain et al., 2022; Ferguson, 2021; Paulus et al., 2013; Qu et al., 2018; Stallen et al., 2018; Zhong et al., 2016). There is also neural evidence (Hsu et al., 2008; Stallen et al., 2018; Tricomi et al., 2010) that the utility of (in)equality is computed in the human brain.

The power of this normative framework (Fehr & Fischbacher, 2004), lies in its potential to integrate different motives into one utility measure to address the complexity of human altruistic behaviors. However, its potential is far from thoroughly explored, because most previous studies only focused on one or two motives and modeled them as independent and additive terms in utility calculation. As a result, when trying to explain intricate behavioral patterns, researchers often resort to additional assumptions that are incompatible with utility maximization. For example, to explain why people may choose to punish the transgressor but not punishing enough to restore equality (Fehr & Fischbacher, 2004), a personal tendency, willingness to punish, is introduced (Stallen et al., 2018).

Here we aimed to extend the normative framework of utility maximization to provide a unified explanation for a wider range of phenomena in altruistic behaviors. We constructed a series of computational models that assume altruistic behaviors are driven jointly by multiple socioeconomic motives. These "cocktail motive" models cover a comprehensive set of socioeconomic motives established in the literature, such as self-centered inequality (Fehr & Fischbacher, 2004; Zhong et al., 2016), victim-centered inequality (Li et al., 2022; Qu et al., 2018; Xie et al., 2017; Zhong et al., 2016), and efficiency (Engelmann & Strobel,

2004; Hsu et al., 2008). While some of the established socioeconomic motives are qualitatively similar, they lead to different quantitative patterns and can thus be told apart through computational modeling. Furthermore, our models also consist of new “compound” motives that are non-linear combinations of more elementary motives.

To separate the effects of different socioeconomic motives, we need an experimental setup that can systematically vary all the motives in the same context. We thus designed a third-party intervention task—the Intervene-or-Watch task (Fig. 1a–b), which enables an unusually rich set of experimental conditions for testing this variety of motives that would otherwise be undistinguishable. On each trial (Fig. 1c–d), participants saw the outcomes from a dictator game, where the dictator (“transgressor”) allocated more to themselves than to the receiver (“victim”, e.g., 88 vs. 12 tokens). As the unaffected third-party, participants decided whether to accept a specific intervention offer (e.g., spending 10 tokens of their own payoff to reduce the transgressor’s payoff by 15 tokens). Each participant completed 300 trials in 100 different conditions that varied in the transgressor-victim inequality as well as the scenario (punishment vs. helping), the cost and the impact-to-cost ratio of the intervention offer.

We performed one laboratory experiment (N=157) and a pre-registered online experiment (N=1258), with all major findings of the former replicated in the latter. A three-way interaction of inequality × cost × impact ratio found in participants’ intervention decisions suggests utility calculations that go beyond linear combinations of different motives. Indeed, participants’ behavioral patterns were best fit by a “motive cocktail” model whose utility calculation involves seven socioeconomic motives, including two compound motives. We called the compound motives “inequality inattention”, as if people are increasingly inattentive to the inequality between others when the intervention cost rises. Individuals’ cocktail motives fall into three groups: *justice warriors* who have a strong intention to intervene whenever there is inequality, *pragmatic helpers* who are sensitive to the impact of their intervention to help the victim, and *rational moralists* who seek to achieve an acceptable standard of morality at the lowest cost to self-interest. Our model provides a unified explanation not only for 3PP and 3PH, but also for a wider range of phenomena in the literature, such as why the third party often but not always prefers helping than punishment, and why the harmed second party punishes more intensely than the third party does.

Results

On each trial of our Intervene-or-Watch task (Fig. 1c–d), participants saw the results of a dictator game, where an anonymous dictator ("transgressor") allocated more amounts to themselves than to an anonymous receiver ("victim"), such as 88 vs. 12 tokens. As the third-party, participants received 50 tokens in each trial and were offered an opportunity to intervene, such as spending 10 tokens (intervention cost) to reduce the transgressor's payoff by 15 tokens (impact ratio = 15/10 = 1.5). The task was to decide whether to accept this intervention offer to intervene or to keep all 50 tokens to themselves. Each trial was either in a punishment scenario (as the example above, Fig. 1a & 1c) or in a helping scenario (to increase the victim's payoff, Fig. 1b & 1d). Across trials, we varied the inequality between the transgressor and the victim (50:50, 60:40, 70:30, 80:20, or 90:10, with ±2 jitters), the intervention cost (10, 20, 30, 40, or 50), and the impact ratio (1.5 or 3.0). Each participant completed 300 trials (5 inequality levels × 5 cost levels × 2 impact ratios × 2 scenarios × 3 repetitions) of intervention decisions.

Behavioral patterns in third-party punishment and helping

In Experiment 1, there were 157 participants. We first performed a generalized linear mixed model analysis (GLMM1, see Table S1) on participants' decisions (to intervene or not) to assess the effects of each independent variable and their interactions.

Preference for helping over punishment. Consistent with most previous studies, participants had a higher probability to help the victim (M = 0.25) than to punish the transgressor (M = 0.18, *b* of scenario = –1.22, 95% CI [–1.64, –0.80], $p < 0.001$; Figure 1e).

Inequality aversion and rationality. As one would expect from inequality aversion, participants were more willing to intervene when the transgressor-victim inequality was more extreme (*b* = 1.61, 95% CI [1.40, 1.81], $p < 0.001$; Figure 1f) and when the impact-to-cost ratio was higher, that is, when the same cost yielded a higher reduction in inequality (*b* = 0.82, 95% CI [0.62, 1.01], $p < 0.001$; Figure 1g). Meanwhile, participants were also rational decision makers who cared about their own interest, being less willing to intervene under a higher cost of intervention (*b* = –2.12, 95% CI [–2.37, –1.86], $p < 0.001$; Fig. 1h).

Interaction effects. Thanks to our factorial experimental design with 4 dimensions and 100 conditions, we also identified three two-way and one three-way interaction effects that were seldom documented before. Under a higher impact-to-cost ratio, the preference for helping over punishment was stronger (scenario × ratio interaction: *b* = –0.39, 95% CI [–0.47, –0.30], $p < 0.001$; Fig. 1j), and the probability of intervention changed more

dramatically with the transgressor-victim inequality (inequality × ratio interaction: $b = -0.08$, 95% CI [–0.14, –0.02], $p = 0.017$; Fig. 1k) and with cost (cost × ratio interaction: $b = -0.08$, 95% CI [–0.14, –0.02], $p = 0.015$; Fig. 1l). According to the three-way interaction of inequality × cost × ratio ($b = -0.21$, 95% CI [–0.27, –0.15], $p < 0.001$), a higher ratio also led to a stronger modulation of the intervention cost to participants' sensitivity to inequality (Fig. 1i).

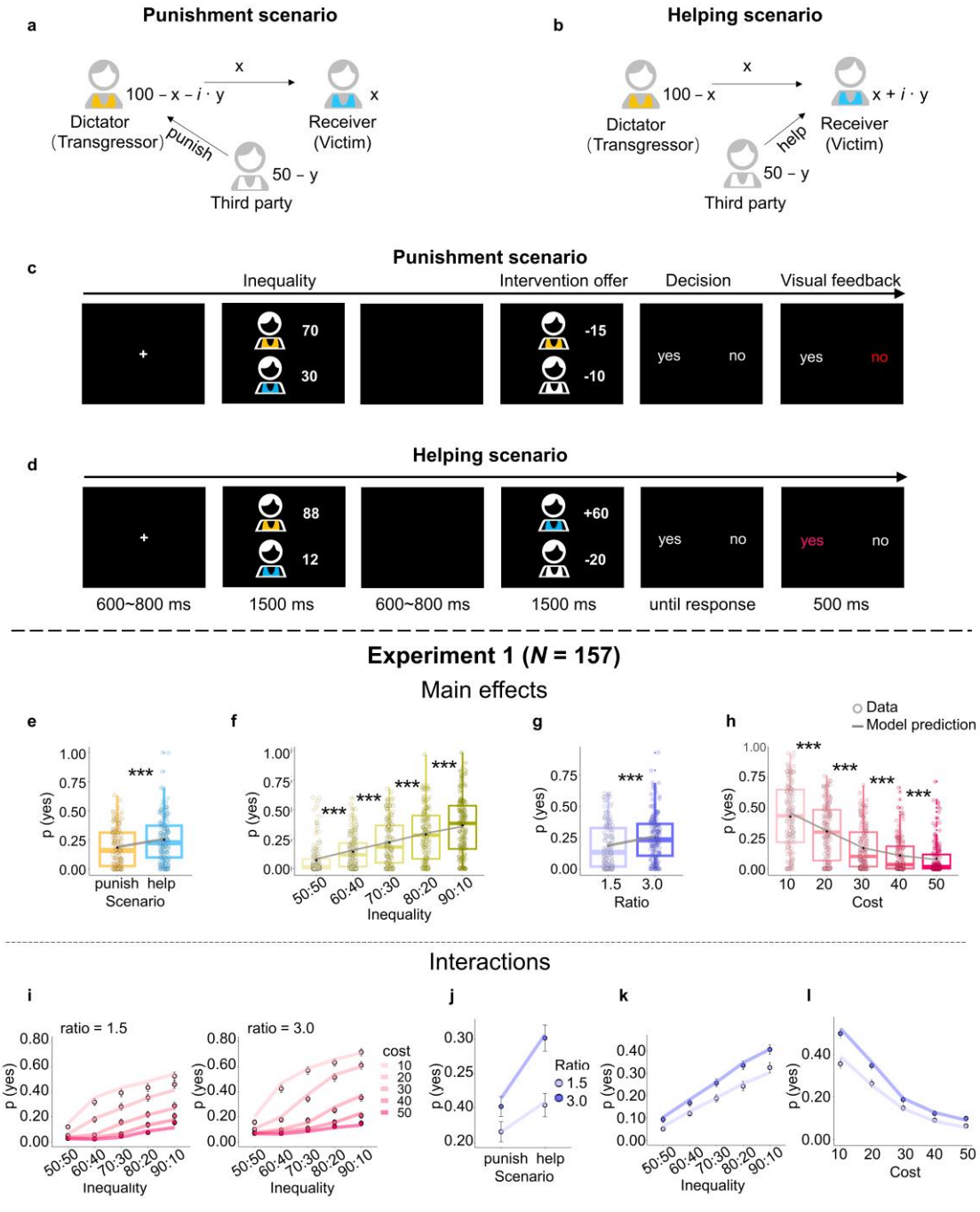

Fig. 1 | The Intervene-or-Watch task and participants' behavioral patterns.

a–**b**, Schema of the Intervene-or-Watch task for the punishment scenario (**a**) and the helping scenario (**b**).

c–**d**, Time course of a trial for the punishment (**c**) and helping (**d**) scenarios. On each trial, participants first saw the outcome of a dictator game—out of 100 tokens how much the dictator ("transgressor", cartoon figure in orange shirt) allocated to themselves and to the receiver ("victim", blue shirt), such as 70 vs. 30 (**c**) or 88 vs. 12 (**d**). As a third party starting with 50 tokens, participants (white shirt) were provided with an intervention offer, such as spending their own 10 tokens to reduce the transgressor's payoff by 15 tokens (**c**), or spending their own 20 tokens to increase the victim's payoff by 60 tokens (**d**). Participants' task was to decide whether to accept the intervention offer (press "yes") or do nothing (press "no").

e–**h**, Main effects of scenario (**e**), transgressor-victim inequality (**f**), impact-to-cost ratio (**g**), and intervention cost (**h**) on the probability of accepting the intervention offer, *p*(yes). Participants had a higher probability to help the victim than to punish the transgressor (**e**), were more willing to intervene when the transgressor-victim inequality was more extreme (**f**), when the impact-to-cost ratio was higher (**g**), and when the intervention cost was lower (**h**). For each box plot, the bottom, middle, and top lines of the box respectively indicate the first quartile, the median, and the third quartile; the whiskers represent 1.5 times the interquartile range (IQR), which is the distance between the third quartile (Q3) and the first quartile (Q1). Data points beyond 1.5 times the IQR from the upper and lower quartiles are considered outliers and are represented by the color points. Each filled circle denotes one participant. The *** denotes $p < 0.001$ for the difference between adjacent conditions from the post hoc comparison, and *p*-values were corrected using the Bonferroni method. The black dot inside each box denotes the group mean. The gray line superimposed on the boxes denotes the prediction of the best-fitting model (i.e., the seven-motive "motive cocktail" model, described later).

i–**l**, Interaction effects on *p*(yes). The inequality × cost × ratio three-way interaction (**i**) shows that participants' probability of intervention increased more slowly with the transgressor-victim inequality when the intervention cost was higher, with this modulation effect more pronounced under a higher impact-to-cost ratio. The two-way interactions involving the impact ratio show that under a higher ratio, the preference for helping over punishment was stronger (**j**), and the probability of intervention changed more dramatically with inequality (**k**) and with cost (**l**). Each dot denotes the mean across participants. Error bars denote SEM. As in **e**–**h**, the lines denote the predictions of the best-fitting model.

In sum, the behavioral patterns in our Intervene-or-Watch task not only agree with classic effects about altruistic punishment and helping, but also reveal intriguing interaction effects. These interactions pose challenges for previous decision models that assume a linear combination of simple motives.

Seven socioeconomic motives and their hypothetical effects

What socioeconomic motives may have driven the observed 3PP and 3PH behaviors? Besides self-interest (the core of classical economic models), we considered five classes of computationally well-defined socioeconomic motives (Fig. 2a), which expand into seven

motive terms in utility calculation. Five of these motives are adapted from the literature, including three variants of inequality aversion (Fehr & Fischbacher, 2004; Zhong et al., 2016), efficiency (Engelmann & Strobel, 2004; Hsu et al., 2008), and reversal preference (Li et al., 2022; Xie et al., 2017). The remaining two motives under the class of "*inequality inattention*" are newly defined here to capture the interaction between self-interest and inequality aversion. As unfolded below, each motive affects the utility gain from intervention relative to non-intervention (thus the tendency to intervene) in a different way (Fig. 2b).

Self-centered inequality refers to the payoff difference between self and others (Fehr & Fischbacher, 2004). Depending on whether it favors self or other, it can be further divided into disadvantageous inequality (self < other) and advantageous inequality (self > other), which lead to two variants of inequality aversion motives that are respectively controlled by parameters α and β. α implies a stronger aversion to receiving lower payoff than others (e.g., self 50 vs. transgressor 88). β implies a stronger aversion to receiving higher payoff than others (e.g., self 50 vs. victim 12). In our experimental setting, before intervention, the participant always had lower payoff than the transgressor but higher payoff than the victim. As the result, α, participants would be more motivated to penalize the transgressor to reduce their disadvantageous inequality, but less motivated to help the victim because helping would increase their disadvantageous inequality with the transgressor and even create a disadvantageous inequality with the victim (Fig. 2b, row 1 left pair). In contrast, the larger β, participants would be more motivated to intervene in both the punishment and helping scenarios, unless the larger punishment leads to an undesirable advantageous inequality over the transgressor (Fig. 2b, row 2 left pair).

Victim-centered inequality refers to the payoff difference between the transgressor and the victim (Zhong et al., 2016). This variant of inequality aversion implies that participants have a distaste for the higher payoff of the transgressor over the victim. Participants with larger γ would intervene more in almost all punishment and helping scenarios (Fig. 2b, row 3 left pair), unless the victim-centered disadvantageous inequality is too small (e.g., transgressor 51 vs. victim 49) to compensate for the cost of intervention.

Efficiency concern is a motive frequently used for modeling economic games (Engelmann & Strobel, 2004; Hsu et al., 2008) but seldom for 3PP or 3PH before assumes that people care about the overall welfare of others, that is, the sum of the transgressor's and the victim's payoffs in our case. Participants with larger ω would be more likely to help the victim to increase the overall welfare, but less likely to penalize the transgressor to avoid reducing the overall welfare, regardless of the inequality between others (Fig. 2b, row 4 left pair).

Reversal preference refers to the motive that participants intend to reverse the payoff

difference between the transgressor and the victim, rewarded by their payoff difference in the opposite direction (i.e., after intervention the victim would be more well-off than the transgressor). The parameter κ controlling reversal preference is allowed to be either positive or negative, respectively implying a willingness or reluctance to reverse the economic status of others, thus making the term a generalized form of rank reversal aversion (Li et al., 2022; Xie et al., 2017). Individuals with more positive κ would be more willing to punish or help when the impact (i.e., cost × ratio) is large enough (relative to the inequality) to yield a rank reversal between the transgressor and the victim (Fig. 2b, row 1 right pair).

Inequality inattention refers to people's tendency to underestimate the inequality between others as the intervention cost increases. We defined two types of inequality inattention motives: *inaction inequality inattention* (controlled by η_{no}) and *action inequality inattention* (controlled by η_{yes}), which represent a diminished awareness of inequality when choosing not to intervene and when opting to intervene, respectively. Inequality inattention motives are "compounds" that reflect the modulation of self-interest to victim-centered inequality aversion. Participants with larger η_{no} would be less likely to intervene which differs from that of smaller γ (victim-centered inequality aversion) in that it may cause no intervention even when the transgressor-victim inequality is high (Fig. 2b, row 2 right pair). Conversely, participants with larger η_{yes} would be more likely to intervene when the transgressor-victim inequality grows, irrespective of the scenario, as if they have an optimistic belief in the minimization of inequality following intervention (Fig. 2b, row 3 right pair).

Many of these motives would remain unidentifiable in a task involving only two parties, testing exclusively either punishment or helping scenarios, or lacking variation in cost or impact ratio. However, in our Intervene-or-Watch task, the seven motives forecast unique effects on intervention decisions, thus making them distinguishable in behavioral data. Subsequent modeling analysis validated the discernibility of each parameter, even under simultaneous modeling (see Methods and Fig. S1).

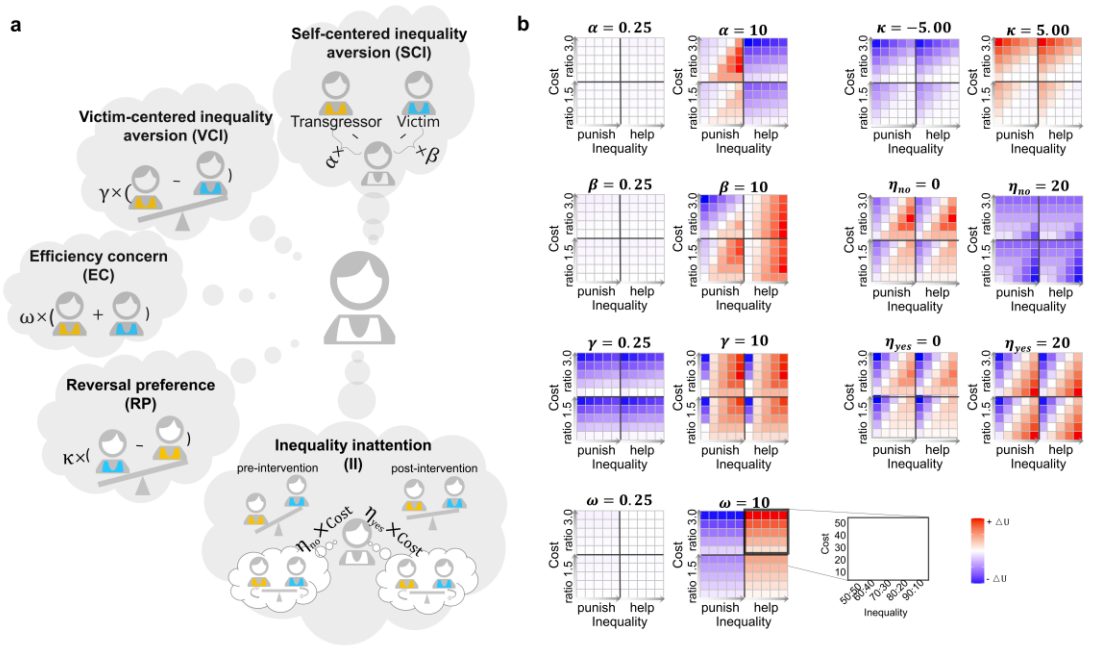

Fig. 2 | The seven socioeconomic motives and their hypothetical effects on the third-party's utility gain to intervene relative to not to intervene. **a**, Five classes of computationally well-defined socioeconomic motives that expand into seven motive terms in utility calculation. The parameters α and β respectively control the motives of disadvantageous (self < other) and advantageous (self > other) inequality aversion. The parameter γ controls the motive of victim-centered disadvantageous (victim < transgressor) inequality aversion. The parameter κ (could be positive or negative) controls the direction and strength of the reversal preference motive (victim > transgressor after intervention). The parameter ω controls the strength of efficiency concern (maximizing the total payoff of others). The parameters η_{no} and η_{yes} respectively control the motives of inaction and action inequality inattention (attenuated perception of inequality under higher intervention cost). **b**, How the strength of each motive would influence the △U (utility of choosing yes – utility of choosing no) of the third-party intervention decision. The effect of each motive is illustrated by a pair of panels, with the small and large parameters controlling the motive's magnitude differently. For simplicity, when examining the effects of one single parameter, we set all other parameters to zero. The parameters η_{no} and η_{yes} are exceptions, where the parameter γ is set to 1, because their utility terms are multiplied by γ. Each heatmap contains four submaps, horizontally divided by scenario (left for punishment, right for helping) and vertically by impact ratio (bottom for 1.5, top for 3.0). The x-axis of each submap denotes the severity of inequality, running from near equality (left: 50:50) to extreme inequality (right: 90:10). The y-axis of each submap denotes the intervention cost, from low cost (bottom: 10) to high cost (top: 50). Colors code △U, where more reddish (more positive △U) corresponds to a stronger preference for choosing yes while more bluish (more negative △U) a stronger preference for choosing no. For illustration purposes, the values of △U were scaled separately for each column and separately for positive and negative values. Each motive shows a distinct influence on △U and would thus lead to distinguishable effects on third-party intervention decision behaviors.

The “motive cocktail” model with all seven motives best predicts human behaviors

We assessed the seven socioeconomic motives' contribution to altruistic behavior by incrementally incorporating them into utility calculations, creating a series of increasingly complex computational models. We then compared these models' predictive power for the behavioral patterns observed in Experiment 1. Starting from a baseline coin-flipping model, which intervened at a fixed probability, and a self-interest (SI) model, we introduced five motive classes as utility terms in the following order: self-centered inequality (SCI), victim-centered inequality (VCI), efficiency concern (EC), reversal preference (RP), and inequality inattention (II). This process yielded seven different models (see Methods) with different predictions (Fig. 3). We used maximum likelihood estimation to fit each model to individual participants’ decisions, and the corrected Akaike Information Criterion (AICc, Hurvich & Tsai, 1989) to evaluate each model's relative goodness-of-fit, accounting for complexity. We also computed the protected exceedance probability (PEP, Rigoux et al., 2014) to provide a group-level measure of each model's potential superiority.

The full “motive cocktail” model that includes all the motives best predicted participants’ decisions (lowest AICc, PEP > 99.99% among the seven models). A model recovery analysis (see Methods) further confirmed that the superiority of the full model was real and could not attribute to model misidentification: Among the 700 synthetic datasets generated by the six alternative models, none was misidentified as the full model (Fig. 3a). Integrating each motive class (SI, SCI, VCI, EC, RP, & II) into our models led to considerable improvements in their fits (as indicated by lower AICc values in Fig. 3b).

The full model closely mirrored changes in participants' intervention probabilities across the 100 experimental conditions (Fig. 3c), successfully predicting the main and interaction effects of different variables (lines in Fig. 1e–1l). In contrast, alternative models failed to replicate certain patterns within the data (Fig. 3d–3i). A supplementary analysis that compared more model variants further demonstrated the necessity of the inequality inattention assumption (the interaction items) in the full model as well as the nonlinear modulation of self-interest on the VCI (Fig. S2) in fitting the behavioral data. To conclude, participants’ third-party intervention decisions were jointly driven by self-interest and the seven socioeconomic motives, including the two inequality inattention terms.

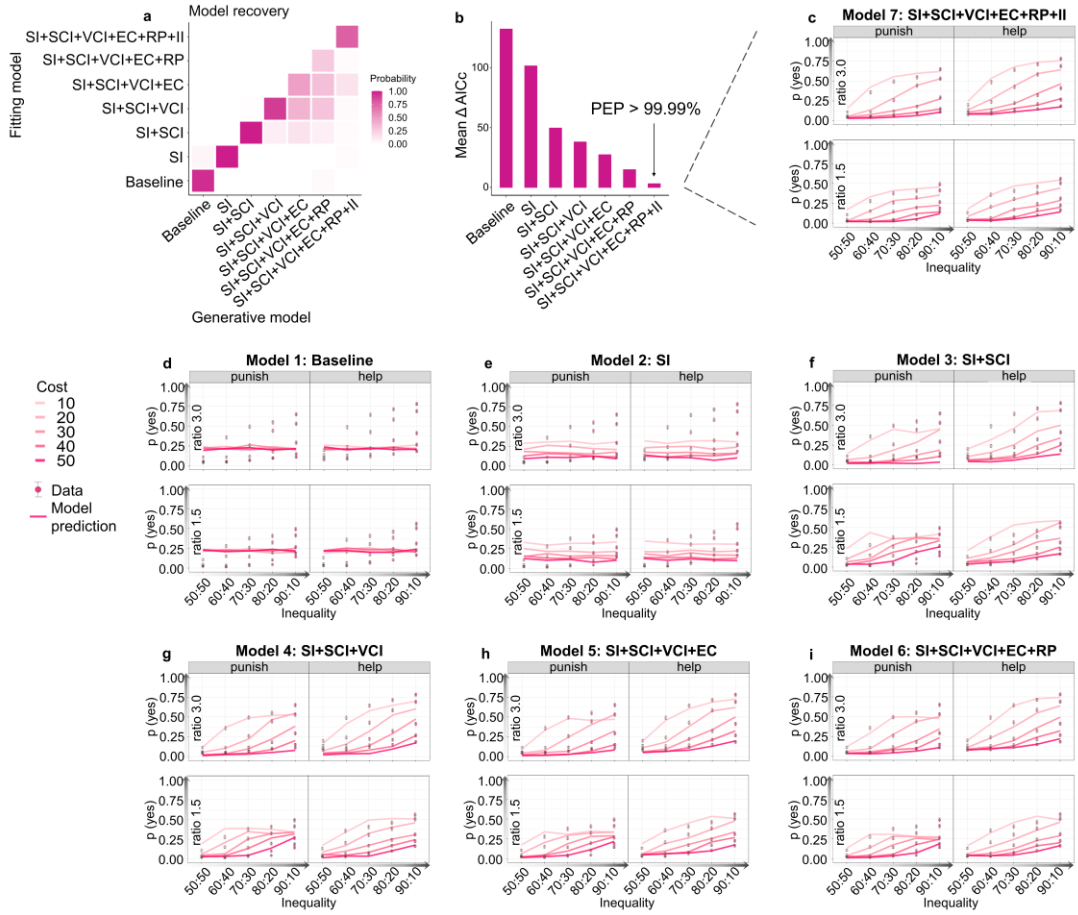

Fig. 3 | The "motive cocktail" model with all seven socioeconomic motives best predicts participants' behavioral patterns. a, Model recovery analysis. Each model was used to generate 100 synthetic datasets, for each of which model fitting and comparison were performed. Each column is for one generative model. Each row is for one fitting model. The color in each cell codes the probability that the synthetic datasets from the generative model in the column are best fit by the fitting model in the row, with darker color indicating higher probability. b, Model comparison results. For each participant, the model with the lowest AICc was used as a reference to compute ΔAICc by subtracting it from the AICc of the other models (ΔAICc = AICc – $AICc_{lowest}$). Lower ΔAIC indicates better fit. Protected exceedance probability (PEP) is a group-level measure of the likelihood of each model's superiority over others. The name of a model (e.g., SI+SCI) conveys the motives included in its utility calculation. SI: self-interest. SCI: self-centered inequality. VCI: victim-centered inequality. EC: efficiency concern. RP: reversal preference. II: inequality inattention. Both ΔAICc and PEP suggest that the full "motive cocktail" model best fits participants' decision behaviors. Panels **c–i** show data versus model predictions separately for the seven models compared in **b**. The title of each panel indicates its model name. The probability of intervention, *p*(yes), is plotted against the inequality (from 50:50 to 90:10). Different colors code different levels of intervention cost (from 10 to 50, darker color for higher cost). Each sub-panel corresponds to one scenario and impact ratio condition. The dots and error bars respectively denote the mean and SEM across participants. The solid lines denote the predictions of the models.

Individual differences: justice warriors, pragmatic helpers, and rational moralists

Our Intervene-or-Watch task, with its 100 factorially-designed conditions, yielded a rich, multifaceted profile that captured not only the collective behavioral tendencies but also the nuanced 3PP and 3PH behaviors of individual participants. A clustering analysis of the behavioral patterns of the 157 participants revealed that they were best summarized by three distinct clusters (see Methods and Fig. 4a-b). Among them, the "justice warriors" (35% of participants) had an overall high probability to intervene, especially when the transgressor-victim inequality was high, and the cost was relatively low (Fig. 4j). The "pragmatic helpers" (18%) also had a high probability to intervene, but were insensitive to inequality or cost, and preferred helping over punishment (Fig. 4k). The "rational moralists" (47%) barely intervened unless their intervention cost was minimal (Fig. 4l). The full "motive cocktail" model accurately predicted not only the average behavior (Fig. 4i) but also the behavioral patterns specific to each individual cluster (Fig. 4j–l).

These dramatic individual differences were associated with different combinations of motive parameters (Fig. 4c–e). Kruskal-Wallis tests and the following post-hoc tests revealed significant differences across the three clusters for three out of the seven motive parameters (Fig. 4f–h & Fig. S3): action inequality inattention η_{yes} ($H(2) = 22.18$, $p < 0.001$), reversal preference κ ($H(2) = 15.57$, $p < 0.001$) and inaction inequality inattention η_{no} ($H(2) = 9.71$, $p = 0.008$). The highest values of η_{yes}, κ and η_{no} respectively occurred at justice warriors, pragmatic helpers, and rational moralists. To unravel the relationship of these parameters to the observed individual differences, we carried out a series of correlation analyses between individuals' parameter value and their sensitivity to different variables in the group level (multiple comparisons corrected for each parameter using *FDR*; see Fig. S4), where participants' sensitivity to a variable was defined as the normalized intervention probability difference after the corresponding variable was dichotomized. The observed behavioral differences across clusters coincide with the correlational effects of these parameters (Fig. 4m–r) and agreed with the insights we obtained through simulation (Fig. 2). For example, higher η_{yes} implies increased tendency to perceive one's action as effective in reducing inequality, irrespective of the actual impact, when the intervention cost is high. Indeed, individuals with higher η_{yes} were less sensitive to the impact ratio. Justice warriors, those who had the highest η_{yes} among the three clusters, were least sensitive to the impact ratio (Fig. 4n).

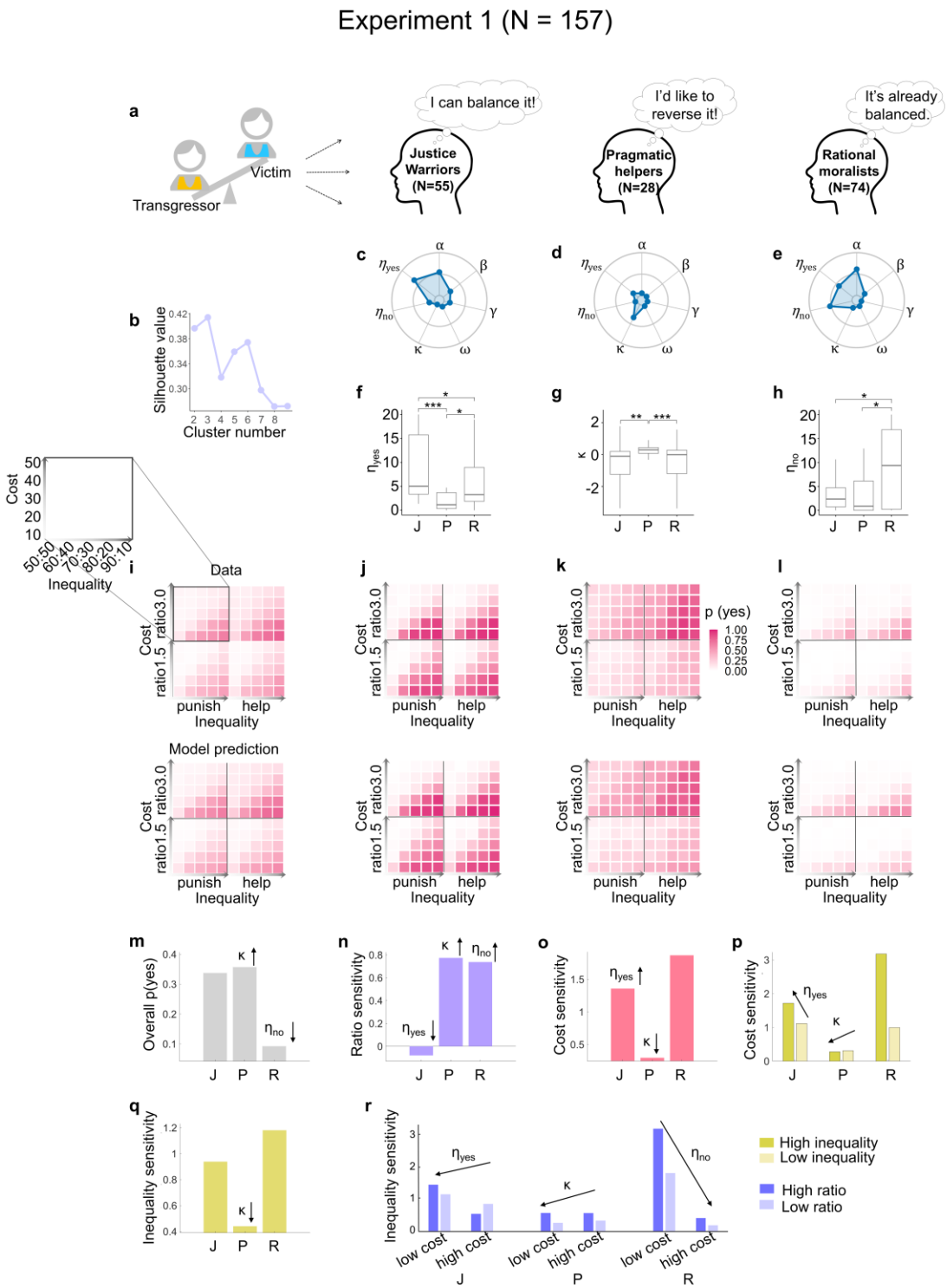

Fig. 4 | Three types of 3PP and 3PH behaviors: justice warriors, pragmatic helpers, and rational moralists. a, Illustration of the three types of behavioral patterns. **b**, The clustering performance of behavioral patterns was best for three clusters. To identify the distinct types of behaviors in the 157 participants of Experiment 1, we used *k*-means to classify participants' behavioral patterns into clusters and used the silhouette value as the metric for the goodness of clustering, where a higher value indicates a larger ratio of the between-cluster to within-cluster distance. **c–e,** The median value of the motive

parameters for each cluster. The outer contour of the spider plot indicates the highest median value for a specific parameter summarized across all clusters. **f–h,** The values of the action inequality inattention parameter η_{yes} (**f**), reversal preference parameter κ (**g**) and inaction inequality inattention parameter η_{no} (**h**) compared across the three clusters of participants. J: justice warriors. P: pragmatic helpers. R: rational moralists. The highest values of η_{yes}, κ and η_{no} respectively occurred at justice warriors (J), pragmatic helpers (P), and rational moralists (R). For each box plot, the bottom, middle, and top lines of the box respectively indicate the first quartile, the median, and the third quartile; the whiskers represent 1.5 times the IQR, which is the distance between the Q3 and the Q1. **i–l**, The intervention probability *p*(yes) in the 100 different conditions for all participants (**i**) and for each cluster (**j–l**), with data (top panels) contrasted with the prediction of the full motive cocktail model (bottom panels). Similar to **Fig. 2b**, each heatmap contains four submaps, horizontally divided by scenario (left for punishment, right for helping) and vertically by impact ratio (bottom for 1.5, top for 3.0). The x-axis of each submap denotes the severity of inequality, running from near equality (left: 50:50) to extreme inequality (right: 90:10). The y-axis of each submap denotes the intervention cost, from low cost (bottom: 10) to high cost (top: 50). Colors code *p*(yes), where darker colors correspond to higher probabilities to choose intervention. **m–r**, How the three parameters (η_{yes}, κ and η_{no}) may contribute to the behavioral differences across the three clusters of participants. Each panel is for one main or interaction effect that was detected across individuals (as in Fig. 1), with the bar height denoting the corresponding effect size in each cluster. The arrow accompanying a parameter in a specific panel indicates the significant correlation between parameters and behavioral measures, and how the parameter modulates the plotted behavioral measure (the orientation of the arrow) in the group level (Fig. S4). For example, panel **m** shows that higher κ was associated with higher overall *p*(yes) and higher η_{no} with lower overall *p*(yes), which coincide with the observed high *p*(yes) in pragmatic helpers (**k**) and low *p*(yes) in rational moralists (**l**). The sensitivity for a specific variable was calculated as the normalized intervention probability difference between the high and low manipulated conditions. Specifically, “low inequality” refers to trials with inequality levels of 60:40 and 50:50, whereas “high inequality” refers to inequality levels of 90:10, 80:20, and 70:30. “Low cost” and “high cost” respectively refer to trials with cost ≤ 20 and cost > 20. “Low ratio” and “high ratio” respectively refer to trials with impact ratio of 1.5 and 3.

Replication in a pre-registered, large-scale online experiment

To test whether our findings can be generalized to a large population with different cultural backgrounds, we performed a pre-registered, large-scale online experiment using the same experimental procedures, with 1258 participants (sample size pre-determined based on a model-based power analysis, Fig. S5) from over 60 countries (or regions, see Table S2). As summarized below, all major findings of Experiment 1 were replicated in Experiment 2.

Both the main and interaction effects of the independent variables on intervention

decisions (as in Fig. 1e–l) were replicated (Fig. S6a–m and Table S3). In particular, participants preferred helping over punishment (scenario b = –1.19, 95% CI [–1.32, –1.06], p < 0.001; Fig. S6a), and they intervened more often under higher inequality (b = 0.59, 95% CI [0.53, 0.64], p < 0.001; Fig. S6b), higher impact ratio (b = 0.71, 95% CI [0.65, 0.76], p < 0.001, Fig. S6c), and lower cost (b = –0.78, 95% CI [–0.84, –0.72], p < 0.001, Fig. S6d). We also found similar three-way interactions of cost × inequality × ratio (b = –0.02, 95% CI [–0.02 –0.01], p = 0.021; Fig. S6e–f), and two-way interactions of scenario × ratio (b = –0.31, 95% CI [-0.32, -0.29], p < 0.001; Fig. S6g) and cost × ratio (b = 0.04, 95% CI [0.03, 0.05], p < 0.001; Fig. S6i). The inequality × ratio interaction was marginally significant (b = –0.01, 95% CI [–0.03, 0.00], p = 0.064; Fig. S6h).

As in Experiment 1, the full motive cocktail model outperformed the other models and accurately captured the behavioral patterns in Experiment 2 (Fig. 5a–b, see Fig. S7 for model recovery analysis). The behavioral patterns of the 1258 participants were best captured by six clusters (Fig. S6j), in which the first three clusters agreed with those in Experiment 1—justice warriors (16.60%, Fig. 5c), pragmatic helpers (17.30%, Fig. 5d), and rational moralists (27.00%, Fig. 5e). As in Experiment 1, each of these three clusters were best fit by the full motive cocktail model (or its derivatives; Fig. S8). The remaining 3 clusters of participants (39.10%, Fig. S6n-q) were best described by a heuristic model that linearly combines different independent variables (see Methods and Fig. S8b), accounting for phenomena, for example, always helping but seldom punishment. These participants probably have less engaging participation, which is more common in online settings.

Upon completion of the experiment, participants were asked to fill out personality questionnaires that assessed their prosocial inclinations in everyday life, including the social value orientation scale (SVO, Murphy et al., 2011) to measure selfishness, the interpersonal reactivity index (IRI) (Davis, 1983) for empathy concern. We computed Pearson's correlation coefficients (r) between each participant's model parameters (from the motive cocktail model (Davis, 1983)) and the participant's personality measures (Fig. S9 and Fig. S10). In both Experiments 1 and 2, we found that stronger self-centered disadvantageous inequality aversion (α) or inaction inequality inattention (η_{no}) was associated with more selfishness. When one of these two parameters was controlled, the correlations between η_{no} and selfishness (Experiment 1: ρ = –0.22, p = 0.006; Experiment 2: ρ = –0.16, p < 0.001) was still significant, but the correlation between α and selfishness was significant only in Experiment 2 (Experiment 1: ρ = –0.11, p = 0.16; Experiment 2: ρ = –0.12, p < 0.001). We also found that both inaction inequality inattention (η_{no}) and action inequality inattention (η_{yes}) was associated with empathy in the opposite direction. When one of these two parameters was controlled, the correlation between η_{no} and empathy was still significant in both experiments (Experiment 1: ρ = –0.25, p = 0.002; Experiment 2:

ρ = –0.12, p < 0.001), the correlation between η_{yes} and empathy was significant only in Experiment 2 (Experiment 1: ρ = 0.12, p = 0.13; Experiment 2: ρ = 0.12, p < 0.001).

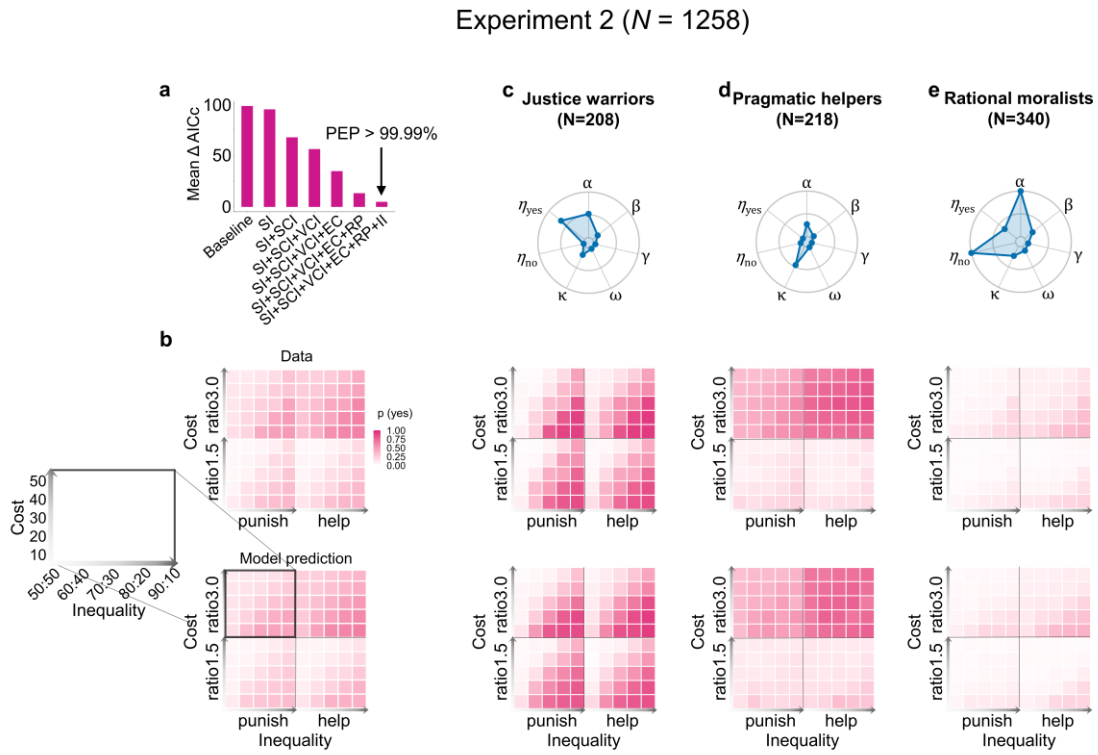

Fig. 5 | All major findings were replicated in the pre-registered, large-scale online Experiment 2. **a**, Model comparison results. As in Experiment 1, the full motive cocktail model best fit participants' decision behaviors, as indicated by the lowest △AICc and a PEP over 99.9%. **b**, Data versus model prediction. As in Experiment 1, the full model can accurately predict not only participants' average behaviors, but also that of individual clusters. **c–e**, The median value of the motive parameters for the first three clusters. The three clusters had similar behavioral patterns and parameter combinations to those of the justice warriors, pragmatic helpers, and rational moralists identified in Experiment 1. Conventions follow Fig. 4.

The motive cocktail model reproduces a broader range of puzzling phenomena

One may wonder whether the motive cocktail estimated in participants' Intervene-or-Watch decisions is specific to this specific third-party intervention task. To demonstrate that such motive cocktail underlies human responses to inequality in general, we performed an out-of-sample prediction, using the motive cocktail model (with slight adaptations) to simulate the behavioral patterns in published studies with different experimental settings (Fehr & Fischbacher, 2004; Stallen et al., 2018). Indeed, we found that the motive cocktail model can predict behavioral patterns in second-party punishment (2PP) as well as 3PP and 3PH (Fig. 6), including phenomena that were puzzling to previous theoretical models.

One such phenomenon is that the intervener would spend a greater amount to penalize the transgressor when they themselves are the victim instead of the unaffected third party (i.e., 2PP > 3PP). We assume that the second-party intervener has all the motives a third-party intervener would have except for efficiency concern (see Methods for details), that is, the victim cares less about the welfare of the transgressor than the third party does. We found that the motive cocktail model, with parameters estimated from participants of our Experiment 1, can reproduce the 2PP>3PP phenomenon as well as the increase of punishment with increasing inequality observed in previous laboratory experiments (Fehr & Fischbacher, 2004; Stallen et al., 2018). For both experiments, simulations with the justice warriors' parameters best matched the data.

The task scenario of Stallen et al. (2018) differed from that of Fehr & Fischbacher (2004) and ours in that the first party robs from the second party, which violates social norms in a more aggressive way. In such case we assume that even the unaffected third party would have no efficiency concern. With this modification, our model reproduces the 3PP>3PH phenomenon in Stallen et al. (2018), in contrast to the helping-over-punishment preference found in most previous studies and our two experiments.

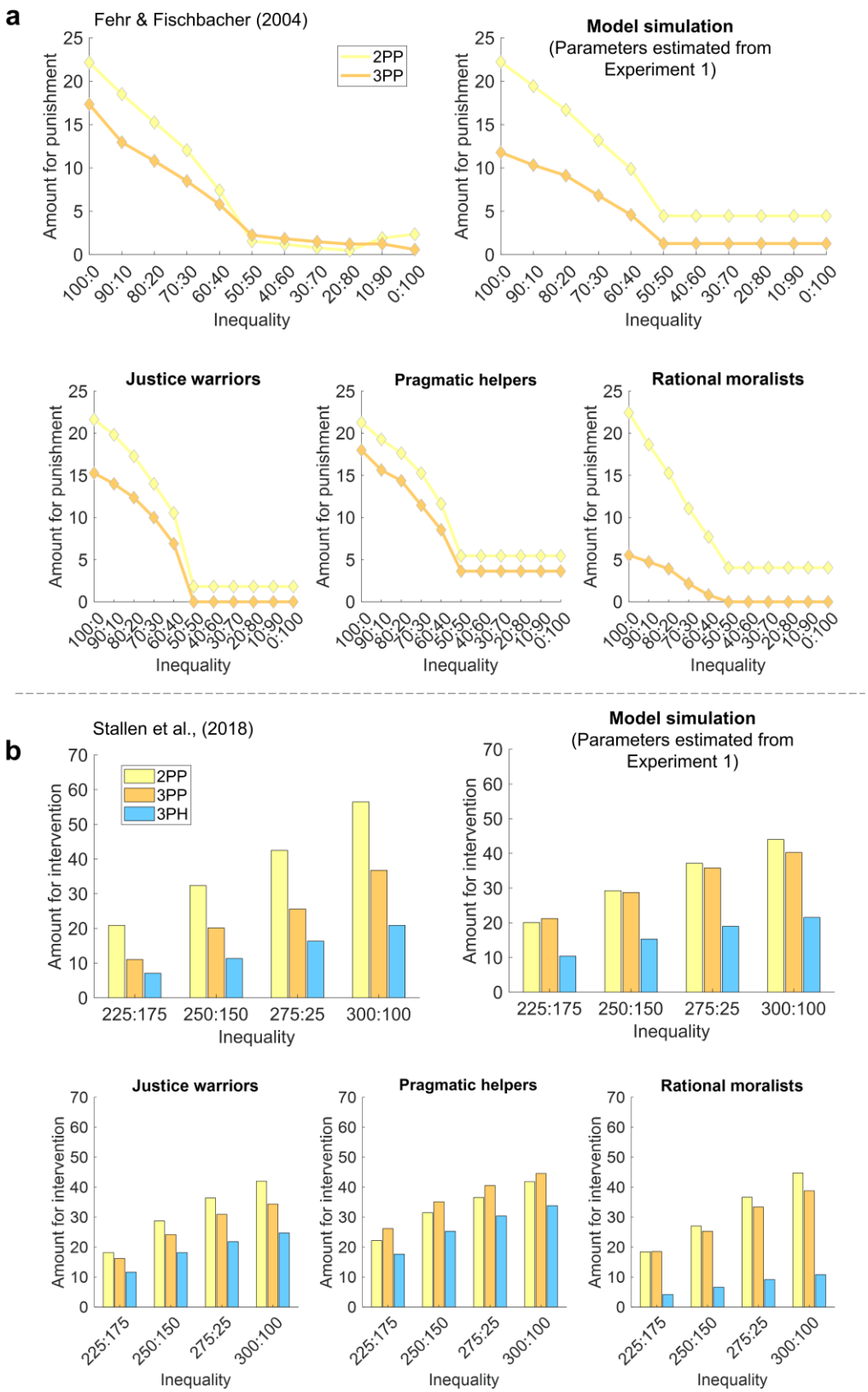

Fig. 6 | The motive cocktail model successfully reproduces a broader range of puzzling phenomena. We used the full motive cocktail model estimated from the Intervene-or-Watch task (3PP and 3PH) to simulate the second-party punishment (2PP) as well as the 3PP and 3PH behaviors in

previous publications. In each sub-plot (**a** or **b**), the top-left panel is the data; the upper-right and three lower panels are model simulations respectively based on the estimated parameters of all participants and the three clusters of our Experiment 1. **a,** Reproduction of the 2PP and 3PP behaviors in Figure 5 of (Fehr & Fischbacher, 2004)Fehr & Fischbacher (2004). The amount participants would use to punish the allocator in a dictator game is plotted as a function of the level of inequality favoring the allocator. In simulating 2PP behaviors, participants—as the second party (the receiver)—were treated as a third party who had all the motives of third parties except for efficiency concern. Our model simulation (with no free parameters) reproduced two effects in the data: (1) the amount participants use for punishment decreases almost linearly with the decrease of inequality when the inequality favors the allocator and is nearly zero when the inequality favors the receiver, and (2) 2PP is larger than 3PP. The simulation based on justice warriors' parameters best matched the data. **b,** Reproduction of the 2PP, 3PP, and 3PH behaviors in Stallen et al. (2018). The amount participants would use to intervene is plotted as a function of the level of inequality. The task scenario of Stallen et al. (2018) differed from that of Fehr & Fischbacher (2004) in that the first party robs from the second party, causing a more severe violation of social norms. In this case we assume the efficiency concern is excluded from the motive cocktail for all intervention behaviors, which leads to larger amounts for punishment than helping. As in **a**, the simulation based on justice warriors' parameters best matches the data.

Discussion

It has been widely known that people have an innate aversion for inequality, willing to change others' payoffs at the expense of their own, even when the action does not augment their reputation or encourage future cooperation (Dawes et al., 2007). What we have demonstrated here, through 100 different experimental conditions and a total of 1415 participants, is that such altruistic behaviors may result from a trade-off among as many as seven socioeconomic motives. Moreover, we have shown the plausibility to disentangle the effects of these different motives via computational modeling. The motive cocktail model we constructed here can explain a wide range of phenomena observed in the literature as well as in our two experiments.

Part of the phenomena found in our experiments and the literature, such as the increased third-party intervention with the increased inequality between the transgressor and the victim (Bernhard et al., 2020; Ciaramidaro et al., 2018; Civai et al., 2019; Cui et al., 2019; Egas & Riedl, 2008; Gummerum & Chu, 2014; Guo et al., 2020; Jordan et al., 2014; Mothes et al., 2016; Ouyang et al., 2021; Stallen et al., 2018; Q. Yang et al., 2021; Zhong et al., 2016) and with the increased impact-to-cost ratio of the intervention (Bone & Raihani, 2015; Egas & Riedl, 2008), can be readily explained by previous models of inequality aversion as well as by the three different inequality aversion terms in our model.

However, inequality aversion alone cannot explain why participants in our experiments were more likely to help the victim than to punish the transgressor, a finding in line with many previous studies (Batistoni et al., 2022; FeldmanHall et al., 2014, 2018; Lotz et al., 2011; Singh & Garfield, 2022; van Doorn et al., 2018; Wiessner, 2020). Helping and punishment are equally efficient in reducing victim-centered inequality but differ in their influences on self-centered inequality, which would lead to a preference of punishment over helping, unless one is more uneasy about their advantage over others than the reverse. What enables our motive cocktail model to explain the preference for helping over punishment is the inclusion of efficiency concern as a utility term, that is, people also care about the overall payoff of the transgressor and the victim.

With an additional assumption that the motive of efficiency concern is weakened when oneself is the victim or when the transgressor violates social norms in a more aggressive way such as robbing or stealing from the victim (Stallen et al., 2018; van Prooijen, 2009), we can also explain why people spend more resources for 2PP than for 3PP (Fehr & Fischbacher, 2004; Stallen et al., 2018) and why a preference for punishment than helping is found in some studies (Stallen et al., 2018; van Prooijen, 2009), as our simulation shows (Fig. 6). The simulation also reveals that the proportional increase of punishment with

inequality can be the consequence of the joint effect of the motive cocktail, without any "willingness to punish" to be assumed. Our motive cocktail model thus provides a unified account for 2PP, 3PP and 3PH behaviors.

One motive documented in previous studies, which seems to go against inequality aversion, is rank reversal aversion (Li et al., 2022; Xie et al., 2017). Our motive cocktail model includes a generalized form of this motive and found that participants in our experiment prefer to reverse the initial inequality so that the victim has an advantage over the transgressor, similar to what happens in Shakespeare's The Merchant of Venice. This reversal preference motive is opposite to rank reversal aversion and our finding suggests that the latter may only apply to situations where the inequality is not caused by the benefited party (Li et al., 2022; Xie et al., 2017).

The sixth and seventh motive terms—the inequality inattention terms—distinguished our model from all previous models in that they assume interactions between cost and inequality aversion. In other words, different motives are not necessarily independent; the perceived inequality between others may be modulated by one's self-interest. In line with the joint functioning of multiple motives identified in our modeling analysis, we found a three-way interaction between cost, impact ratio, and the inequality between the transgressor and the victim. Such interaction was not found in previous studies, probably because most studies used cost as a dependent variable, measuring the amount of money participants were willing to spend on the intervention, rather than as an independent variable to manipulate. In contrast, the cost is manipulated by the experimenter in our task, resembling real-world scenarios where individuals are confronted with limited options when it comes to addressing others' inequalities.

The two forms of inequality inattention—inaction inequality inattention and action inequality inattention—have distinct psychological implications. The former assumes that people are increasingly likely to ignore the inequality imposed on the victim due to the increasing cost of intervention. Consequently, they may be reluctant to engage in altruistic actions that pose potential harm to their own interests. The latter form of inequality inattention assumes that people tend to ignore the remaining inequality faced by the victim after their intervention. As a result, they may be willing to intervene even when their intervention hardly improves equality. The co-existence of these two types of inequality inattention demonstrates the motive diversity in altruistic behaviors across various social contexts. In particular, our observations of the action inequality inattention agree with the warm glow theory (Andreoni, 1989, 1990) that individuals are motivated to intervene by "impurely altruistic", a positive feeling of helping others irrespective of the actual impact.

In both the laboratory experiment (N=157) and the large-scale online replication

(N=1258), we found diverse behavior patterns across individuals. Three types of interveners—justice warriors, pragmatic helpers, and rational moralists—differed in their probability of intervention, their sensitivity to variables such as cost and inequality, and their preference for helping over punishment. The motive parameters estimated from the motive cocktail model provides a multi-facet measure of such individual differences, opening questions such as how individuals' motives may depend on their personal experiences, cultural background, or genetic makeup.

The motive cocktail model we developed here extends the economic modeling of altruistic behaviors and may be applied to a broader range of socioeconomic tasks than second-party and third-party interventions. The new motives and individual differences we identified may also shed light on future research that aims to uncover the neural basis of human morality and its disorders, one of the most important scientific questions (Sanders, 2021).

Following a common practice of previous studies (Blain et al., 2022; Dawes et al., 2007; Fehr & Fischbacher, 2004; Fehr & Gächter, 2002; FeldmanHall et al., 2014; Leliveld et al., 2012; Rockenbach & Milinski, 2006; Stallen et al., 2018; van Baar et al., 2019; Zhong et al., 2016), we used a one-shot anonymous interaction setting to minimize participants' concern for their own reputation, a motive that is instrumental to the long-term reciprocity in human society. Therefore, the motive cocktail model tested here, which provided a satisfactory explanation for our data, did not include reputation concerns as a motive. Integrating the reputation concern into the motive cocktail model to explain TPP and TPH behaviors in contexts with more interaction opportunities would be a topic for future research.

Methods

Experiment 1

Participants

Experiment 1 was conducted in a laboratory room at Beijing Normal University and 157 university students (59 males, mean age ± SD: 21.24 ± 2.56) were recruited. Participants completed the screening form before the task to confirm that they had normal or corrected-to-normal vision and no history of psychiatric or neurological illness. All participants provided informed consent. This study was approved by the ethics committee of Beijing Normal University.

Experimental procedure

Participants were self-paced to read the instructions of the task. A quiz followed the completion of each sub-section of the instruction. Participants proceeded to the next section of the instruction only if they gave the correct answer to the quiz. Before the formal task, participants underwent several practice trials to ensure that they fully understood the rules of the game. The Intervene-or-Watch task (detailed below) lasted approximately 45 minutes. After completing the task, participants were asked whether they had any doubts or questions during the task in an open-ended question. In Experiment 1, four participants reported doubts about whether all the players were real people. To examine whether participants who reported doubts used different strategies compared to those who did not have doubts during the task, we conducted a generalized linear mixed model similar to GLMM1 but added “doubt” as an additional predictor (a categorical variable) in the model. We found that the predictor “doubt” couldn’t predict participants’ choice (b = –2.74, 95% CI [–7.19, 2.24], p = 0.304). Thus, we concluded that participants who reported doubts did not employ different strategies in the task. Therefore, all participants were included in the following analysis. In the final section, participants were asked to fill out a few personality questionnaires (detailed below), including measures of social value orientation (SVO), Machiavellianism Scale (MACH–IV), and interpersonal reactivity index (IRI), to assess their prosocial personalities.

The Intervene-or-Watch task and experimental design

The Intervene-or-Watch task was a paradigm adapted from a third-party punishment task (Fehr & Fischbacher, 2004). In the task, participants played the role of an unaffected third party who watched an anonymous dictator (“transgressor”) allocated amounts between himself/herself and an anonymous receiver (“victim”), and then decided whether to intervene. On each trial, the transgressor allocated the 100 game tokens between himself/herself and the victim, while the victim had to accept the offer without any other options. Participants were told that all offers between a transgressor and a victim were made by other real participants, and that their decisions would affect their own payoffs as well as those of the victims and the transgressors. In reality, the offers between the transgressors and the victims were generated by a custom code and were designed to disentangle different hypotheses. To give the participants a more realistic experience and to familiarize them with the roles in the game, they were instructed to play two trials of the dictator game, in which they played the role of transgressor and victim respectively. In the Intervene-or-Watch task, participants had 50 game tokens in each trial which could be used to reduce the payoff of the transgressor in the punishment scenario or increase the payoff of the victim in the helping scenario. To avoid serial or accumulative effects, participants

were instructed that their payoff was independent across trials and would not be accumulated through the task. They were also informed that 10% of the trials would be randomly selected and implemented at the end of the study to determine the payoffs of all players (or roles). Additionally, participants were explicitly informed that the roles of the transgressor and the victim were played by different participants in each trial, hence encouraging them to make decisions based solely on the current situation. We are aware that our experimental setting included deception, in the sense that participants' intervention to the players in the dictator game was not real implemented. Nevertheless, all of the offers we used in the Intervene-or-Watch task were what real human players may make in the dictator game (Doñate-Buendía et al., 2022; Engel, 2011). Such use of deception is a common practice of previous studies (Blain et al., 2022; FeldmanHall et al., 2014; Leliveld et al., 2012; McAuliffe et al., 2015; Qu et al., 2018; Stallen et al., 2018; J. Yang et al., 2022; Ying et al., 2022). Since all players in the task were anonymous, no reputation concern was involved in this task. The players also had no opportunities for interaction, thus reciprocity could be excluded. Therefore, participants' decisions to help and to punish in the Intervene-or-Watch task were altruistic.

Each trial (Fig. 1c & 1d) began with a fixation cross (600–800 ms), followed by an inequality window (1500 ms) displaying the allocation between the transgressor and the victim, and an intervention offer window (1500 ms) showing the intervention cost for the participant and the consequence of the intervention (impact ratio × intervention cost) to the transgressor or victim. Subsequently, in the decision window, participants were asked whether they would like to accept the intervention offer: Yes (to intervene) or No (not to intervene). The intervention would only be implemented if participants chose Yes. For example, if the intervention offer window displays an intervention cost of x in a trial, a decision of intervention would result in the transgressor losing (or the victim gaining) 1.5x or 3.0x in the punishment (or helping) scenario. There was no time limit for the decision. A visual feedback window after the decision highlighted the selected choice in red. Four independent variables were varied across trials: scenario (punishment and helping), inequality (transgressor vs victim, 50:50, 60:40, 70:30, 80:20, 90:10, jitter ± 2), cost (10, 20, 30, 40, 50), and impact ratio (1.5 and 3.0). This led to 100 unique conditions, with each condition repeated 3 times for each participant. The scenario variable varied between blocks and the other three variables were randomly interleaved within blocks. Before each block, participants were told whether the following section was the "increase" condition (the helping scenario) or the "reduce" condition (the punishment scenario). In total, each participant completed 300 trials in 6 blocks, with 3 blocks each for the punishment and helping scenarios.

Personality questionnaires

Following the Intervene-or-Watch task, participants completed several personality questionnaires that allowed us to access their prosocial tendencies in daily life. Specifically, a Social Value Orientation (SVO, Murphy et al., 2011) was used to measure individual preference about how to allocate financial resources between themselves and others. A higher score on the SVO scale reflects a greater degree of concern for others' payoffs and, therefore, indicates a more prosocial personality. A Machiavellianism Scale (MACH–IV, Rauthmann, 2013) was used to assess an individual's level of Machiavellianism, related to manipulative, exploitative, deceitful, and distrustful attitudes. Individuals with higher scores on the MACH–IV scale are indicative of a more pronounced degree of Machiavellian traits. An Interpersonal Reactivity Index (IRI, Davis, 1983) was used to measure the multi-dimensional assessment of empathy, including (1) perspective-taking, assessing an individual's tendency to consider a situation from others' perspective; (2) fantasy, evaluating an individual's inclination to identify with the situation and emotions of characters in books, movies, or theatrical performances; (3) empathy concern, measuring an individual's inclination to care about the feelings and needs of others; (4) personal distress, assessing an individual's tendency to experience distress and discomfort in challenging social situations.

Model-free analysis

All statistical analyses (except for group-level Bayesian model comparisons) were conducted in R 4.2.1 (R Core Team, 2013). Generalized linear mixed models (GLMM) assuming binomial distributed responses were used to model the probability of intervention, given various predictors (e.g., scenario, inequality) and their interactions. The GLMMs were implemented by "lme4" package (Bates et al., 2015), with the fixed-effect coefficients output from the binomial GLMM on the logit scale and the significance of each coefficient determined by the z-statistics. The standard linear mixed-effect models (LMM), which assume the error term is normally distributed, were estimated using the "afex" package to model participants' decision times. For the estimation of marginal effects and the post hoc analysis, the "emmeans" package was used (Lenth et al., 2018). Interaction contrasts were performed for significant interactions and, when higher-order interactions were not significant, pairwise or sequential contrasts were performed for significant main effects.

GLMM1: participants' choices of all trials in Experiment 1 are the dependent variable; fixed effects include an intercept, the main effects of the scenario, inequality, cost, ratio, trial number, and all possible interaction effects of the independent variables; random effects include correlated random slopes of scenario, inequality, cost, ratio and trial number within participants and random intercept for participants. The scenario is a category variable. Trial

number, inequality, cost, and ratio are continuous variables that were normalized to Z-score prior to model estimation. See Table S1 for the statistical results of GLMM1.

GLMM2: participants' choices of all trials in Experiment 2 are the dependent variable. The fixed and random effects remain the same as GLMM1. See Table S3 for the statistical results of GLMM2.

LMM1: participants' decision times of all trials in Experiment 1 are the dependent variable. In addition to the fixed and random effects included in GLMM1, participants' intervention decisions (choice) are added as well. See Table S4 and Fig. S11 for the statistical results of LMM1.

We found an inverted U-shaped relationship between the intervention probability (*p*(yes)) and decision time (Fig. S11j), which implies that participants made decisions with more difficulty when the decision uncertainty (or entropy) was higher. This result is in line with prior research demonstrating an inverted U-shaped relationship between confidence levels and decision times (Lee & Dry, 2006; Ratcliff & Starns, 2013).

LMM2: participant's decision times of all trials in Experiment 2 are the dependent variable. The fixed and random effects remain the same as LMM1. See Table S5 for the statistical results of LMM2. The inverted U-shaped relationship between the probability of intervention (*p*(yes)) and decision time was replicated in Experiment 2 (Fig. S12).

The sensitivity analysis to different variables. We measured participants' intervention sensitivity to different variables, which was defined as the normalized intervention probability difference after the corresponding variable was dichotomized (Fig. 4n-r and Fig.S4). Specifically, participants' sensitivity to the main effects, including scenario, ratio, cost and inequality, was calculated as the intervention probability difference in the helping trials compared with the punishment trials, the high-impact ratio trials (i.e., 3.0) compared with the low-impact ratio trials (i.e., 1.5), the low-cost trials (i.e., cost<=20) compared with high-cost trials (cost>20), and the high-inequality trials (i.e., the inequality level between the transgressor and the victim is 80:20 and 90:10) compared with the low-inequality trials (i.e., 70:30, 60:40 and 50:50), divided by their overall *p*(yes), respectively. For the interaction effects, the sensitivity (i.e., the normalized intervention probability difference) was calculated in a similar way as the main effect, that is, marginalizing over the other variables (see Fig.S4 for details).

Behavioral modeling

We assumed that participants would make decisions on each trial by calculating the utility of the two options (yes and no) and choosing the option with the higher utility. In the

Intervene-or-Watch task, participants were given the context regarding inequality between a transgressor and a victim as well as other related variables (e.g., cost, impact ratio) from the perspective of a third-party and afterwards made a decision between two alternatives, yes (to intervene) and no (not to intervene). In general, participants calculated the utilities of the choices by estimating the reduction in inequality for others through their intervention and considering the associated cost to themselves. Specifically, if they chose "yes" (decide to intervene), they could reduce the inequality between the transgressor and the victim to some extent but at a cost. On the contrary, by choosing "no" (decide not to intervene), they could keep the inequality between the transgressor and the victim without incurring any cost. To investigate how individuals make decisions in the Intervene-or-Watch task, we constructed a series of computational models with different utility calculation hypotheses (i.e., combinations of multiple socioeconomic motives) and compared their goodness of fit.

Participants' choices were then modelled using the Softmax function (Eq. 1, Luce, 1959), with the utilities of not intervention (U_{no}) and intervention (U_{yes}) from different models as the inputs:

$$p(yes) = \frac{1}{1 + e^{\lambda(U_{no} - U_{yes})}} \tag{1}$$

where the inverse temperature, parameter $\lambda \in [0, 10]$, controls the stochasticity of participants' choices, with a larger λ corresponding to less noisy choices.

In the following descriptions, we will use x_1, x_2 and x_3 to denote the payoffs of the transgressor, the victim, and the third-party (participant) if the third-party does not intervene (choose 'no'), and use x_1', x_2' and x_3' to denote the counterpart payoffs if the third-party intervenes (choose 'yes'). In particular, x_3' is equal to $x_3 - cost$ in both scenarios. In the punishment scenario, $x_1' = x_1 - impact\ ratio \times cost$ and $x_2' = x_2$. While in the helping scenario, $x_1' = x_1$ and $x_2' = x_2 - impact\ ratio \times cost$.

Model 1: The baseline model. We modeled each participant's choices of intervention in each trial (i.e., whether to choose the yes option) as outcomes from a Bernoulli distribution, where the intervention probability is controlled by a parameter, $q \in [0, 1]$. For each participant, the probabilities of choosing the intervention (*p*(yes)) and not choosing the intervention (*p*(no)) are denoted as follows:

$$p(yes) = q \tag{2}$$

$$p(no) = 1 - q \tag{3}$$

Model 2: Self-interest model (SI). The models based on socioeconomic motives started

with SI, where participants only consider self-interest when making decisions and thus, always leading to a reduced utility of the intervention. Participants' choices were then modeled using the Softmax function (Eq.1).

$$U_{no} = x_3 \tag{4}$$

$$U_{yes} = x'_3 \tag{5}$$

where x_3 denotes the payoff of the third-party when choosing “no” (without intervention), which is always 50 tokens in each trial. x'_3 denotes the payoff of the third-party after choosing “yes” (with intervention), equaling to $50 - cost$.

Building upon the SI model, the following hypothetical socioeconomic components were progressively introduced into the utility calculation and participants’ choices were modeled using the Softmax function. The necessity of each component to explain participants’ decisions was determined through model comparisons.

Model 3: SI and self-centered inequality aversion model (SI+SCI). Based on SI model, we added a self-centered inequality aversion component, which assumes that participants are averse to the inequality between themselves and others in both directions (Fehr & Schmidt, 1999). The self-centered Disadvantageous Inequality (DI) aversion corresponds to that participants are averse to others having more payoffs than themselves, while the self-centered Advantageous Inequality (AI) aversion denotes participants are averse to themselves having more payoffs than others. The contributions of self-centered disadvantageous and advantageous inequality are controlled (Fehr & Schmidt, 1999)separately by the parameters $\alpha\ (\alpha \in [0, 10])$ and $\beta\ (\beta \in [0, 10])$ and are subtracted from the self-interest. Under the assumption of the SI+SCI model, participants are motivated to maximize their self-interest and meanwhile, minimize the inequality between themselves and others and then make a choice between no intervention and intervention based on their respective utilities:

$$U_{no} = x_3 - \alpha \sum_{j=1}^{2} \max(x_j - x_3, 0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) \tag{6}$$

$$U_{yes} = x'_3 - \alpha \sum_{j=1}^{2} \max(x'_j - x'_3, 0) - \beta \sum_{j=1}^{2} \max(x'_3 - x'_j, 0) \tag{7}$$

where *j* denotes the index of the transgressor and victim; x_1 and x_2 represent the payoffs of the transgressor and the victim when participants (the third-party) choose “no”; x'_1 and x'_2 represent the payoffs of the transgressor and the victim after the intervention of the third party.

Model 4: SI+SCI and victim-centered disadvantageous inequality aversion model (SI+SCI+VCI). Based on the SI + SCI model, we introduced another previously proposed inequality component, the victim-centered disadvantageous inequality aversion (VCI). The VCI assumes that participants are averse to the transgressor having more payoff than the victim (Zhong et al., 2016), with its contribution to the utility calculation determined by a parameter γ ($\gamma \in [0,10]$). Participants with larger γ will be more willing to intervene in almost all punishment and helping scenarios. Within this model, participants were motivated to maximize self-interest and simultaneously, minimize the two kinds of inequality aversions (SCI and VCI):

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0) - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) \tag{8}$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0) - \alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) - \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0) \tag{9}$$

Model 5: SI+SCI+VCI and efficiency concern model (SI+SCI+VCI+EC). Based on the SI+SCI+VCI model, efficiency concern (Engelmann & Strobel, 2004) component was added into the model. The efficiency concern (EC) assumes that participants are motivated to maximize the total payoff of others, which is weighted by parameter ω ($\omega \in [0,10]$). Participants with larger ω will more likely intervene in the helping scenario, but not in the punishment scenario:

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0) - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) + \omega(x_1 + x_2) \tag{10}$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0) - \alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) - \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0) + \omega(x_1' + x_2') \tag{11}$$

Model 6: SI+SCI+VCI+EC and reversal preference for victim-centered advantageous inequality model (SI+SCI+VCI+EC+RP). Based on the SI+SCI+VCI+EC model, we introduced another component, the reversal preference for victim-centered advantageous inequality (RP), into the model. RP is mutually exclusive to VCI and assumes that participants prefer to reverse the economic status of the victim. That is, RP motivates participants to make the victim have more payoff than the transgressor by punishing the transgressor or helping the victim. The reversal preference is controlled by the parameter κ ($\kappa \in [-10,10]$). A positive value of κ indicates that participants are in favor of the victim having more money than the transgressor, while a negative value indicates that they are

averse to the newly created reverse inequality. Participants with larger κ will more likely intervene when the initial victim-centered disadvantageous inequality is small enough or the impact is large enough to guarantee an inequality reversal:

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0) - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) + \omega(x_1 + x_2) + \kappa \max(x_2 - x_{1,}0) \quad (12)$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0) - \alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) - \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0) + \omega(x_1' + x_2') + \kappa \max(x_2' - x_1', 0) \quad (13)$$

Model 7: SI+SCI+VCI+EC+RP and inequality inattention model (the motive cocktail model, SI+SCI+VCI+EC+RP+II). Based on the SI+SCI+VCI+EC+RP model, we included a newly proposed inequality inattention (II) component. Thus, the motive cocktail model includes seven socioeconomic motives. II is derived from the rational framework of economic decisions and is implemented to capture the interaction between self-interest and VCI. Specifically, II assumes that people will systematically disregard the victim-centered disadvantageous inequality as costs increase. We proposed two types of inequality inattention: inaction inequality inattention (III, controlled by parameter η_{no}) and action inequality inattention (AII, controlled by η_{yes}), which are respectively blind to the initial and residual disadvantageous inequalities between the transgressor and the victim under no intervention and intervention with rising costs, respectively. In the model fitting, the range of parameters η_{no} and η_{yes} is restricted to between 0 and 20.

Participants with larger η_{no} would have a lower probability to intervene. The effect differs from victim-centered disadvantageous inequality aversion (small γ) in that at large η_{no} the tendency to intervene would barely increase with inequality. Conversely, participants with larger η_{yes}, who subjectively exaggerate the reduction of inequality by intervention, would have a higher probability to intervene. Those with large η_{yes} would have similarly high probability to intervene regardless of the impact ratio, as if they optimistically believe that the inequality would be minimized by any of their intervention:

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0)\, \delta_{III} - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) + \omega(x_1 + x_2) + \kappa \max(x_2 - x_{1,}0) \quad (14)$$

$$\delta_{III} = \frac{2}{1 + e^{\eta_{no}(\cos t/50)}} \tag{15}$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0)\, \delta_{AII} - \alpha \sum_{j=1}^{2} \max\left(x_j' - x_3', 0\right) - \beta \sum_{j=1}^{2} \max\left(x_3' - x_j', 0\right) + \omega(x_1' + x_2') + \kappa \max(x_2' - x_1', 0) \tag{16}$$

$$\delta_{AII} = \frac{2}{1 + e^{\eta_{yes}(\cos t/50)}} \tag{17}$$

Redundancy checks on the parameter space for the motive cocktail model

In the estimated parameters, we observed three highly correlated pairs in the parameter space of the motive cocktail model: the value of parameter β (self-centered advantageous inequality aversion) and γ (victim-centered disadvantageous inequality aversion), α (self-centered disadvantageous inequality aversion) and ω (efficiency concern), γ and η_{no} (inequality inaction inattention). To exclude the possibility that the correlation was due to parameter redundancy in the model, we performed redundancy checks as follows. We first randomly shuffled participants' labels for different parameters to eliminate correlations in the shuffled parameters. Based on these shuffled parameters, we generated 157 synthetic datasets and used them to estimate the model parameters. We found little correlations between the parameters estimated from these synthetic datasets, which indicates that the high correlations found in the data reflect the behavioral characteristics of human participants rather than redundancy in the model itself (Fig. S13).

Model fitting and model comparison

For each participant, we fit each model to their intervention decisions across all trials using maximum likelihood estimates. The likelihood function derived from the binomial distribution was used to describe the relationship between participants' choice and the model's prediction. The function *fmincon* in MATLAB (MathWorks) was used to search for the parameters that minimized negative log-likelihood. To increase the probability of finding the global minimum, we repeated the search process 500 times with different starting points. We compared the goodness of fit of each model based on two metrics: Akaike information criterion with a correction for sample size (AICc) (Hurvich & Tsai, 1989) and the protected exceedance probability of group-level Bayesian model selection (Rigoux et al., 2014).

Model identifiability and parameter recovery analyses

We further performed a model identifiability analysis to rule out the possibility of model mis-identification in model comparisons. For each model, the parameters estimated from the data of all participants were used to generate a synthetic dataset of 157 participants. Each synthetic dataset regarding a specific model was then used to fit each of the 7 alternative models and identify the best fitting model by model comparison. We repeated the above procedure 100 times to calculate the percentages that each model was identified as the best model based on all synthetic datasets from a specific generating model. The highest percentage assigned to the same fitting model as the generating model suggests that the model is identifiable. To assess parameter recovery in the motive cocktail model (model 7: SI+SCI+VCI+EC+RP+II), we computed the Pearson correlation between the parameters estimated from the 100 synthetic datasets (recovered parameters) and the parameters used to generate the synthetic datasets. The larger correlation coefficient between the recovered parameter and the estimated parameter indicates a non-redundancy in parameter space.

Clustering analysis

To gain further insight into whether the motive cocktail model (model 7: SI+SCI+VCI+EC+RP+II) could explain the varying behavioral patterns of individuals, we classified participants' intervention decisions using K-means clustering and then investigated the distributions of the estimated parameters across participants as well their unique contributions to behavioral patterns within each cluster. K-means clustering is an unsupervised machine learning algorithm relying on the Euclidean distance to classify each participant into a specific cluster with the nearest mean (Hartigan & Wong, 1979). The clustering evaluation criterion was based on silhouette value which denotes how well each participant was matched to its own cluster compared to other clusters, with a higher silhouette value indicating the clustering solution is more appropriate (Rousseeuw, 1987). The optimal cluster solution for 157 participants in Experiment 1 is 3 (Fig. 4a).

Correlation analysis between the estimated parameters and behavioral or personality measures

To further validate the psychological significance of the hypothetical socioeconomic motives in the motive cocktail model, we calculated Pearson's correlation between the estimated parameters and the scores on the personality measurements. A similar correlation analysis between individuals' motive parameters and their sensitivity to different variables was carried out to unravel the contributions of the parameters to behavioral differences. Partial correlation was conducted when multiple parameters correlated with

the same measurement to ensure that the observed relationships were not confounded by the potential influence of other variables. The partial correlation coefficient (ρ), ranging between –1 and 1, quantifies the strength and direction of linear links between parameters and measured variables. For multiple comparisons, the False Discovery Rate (FDR) was employed.

Reproducing puzzling phenomena with the motive cocktail model

We made slight modifications to the motive cocktail model and applied it to explain the intervention patterns in second-party punishment (2PP), third-party punishment (3PP), and third-party helping (3PP) models in the following two studies. The adapted model could also be used to explain puzzling phenomena in previous models.

In a sub-study conducted by Fehr & Fischbacher (2004), participants attended a dictator game, which contains both 2PP condition and 3PP condition. At the beginning of the experiments, participants were randomly assigned either the role of the transgressor (Player A) or the victim (Player B). In the 2PP condition, the victim also acted as an intervener who could punish his transgressor after observing the transfer from the transgressor accordingly. In the 3PP condition, the victim could only punish the dictator in another group (Player A' and Player B'), in which he/she served as an unaffected third party. A strategy method was implemented in the 3PP condition: the third-party (Player B) had to indicate how much he would punish the outgroup Player A' for every possible transfer of A' to Player B'. The results showed that the intervener as the victim exerted more punishment than the intervener as the third-party for all transfer levels below 50 (i.e., 2PP > 3PP), while the punishment was generally low and similar across transfer levels above 50 (Fig. 6a top left). In the study conducted by Stallen et al. (2018), participants played three conditions of the Justice Games. In the 2PP games, the participants played the role of the Partner (the victim), in which the Taker (the transgressor) had the opportunity to take or rob chips (or payoff) from the victim, and afterward, the victim was given the option of punishing the transgressor by spending chips of their own. In 3PP and 3PH games, participants played the role of an Observer (the third-party) to watch whether the transgressor robbed chips from the victim and then decided whether to intervene to punish the transgressor or to compensate the victim, at their own cost. Every time participants needed to make a choice, all intervention costs ranging from 0 to 100 with a step of 10 were displayed on the screen. The results indicated the intervener in the 2PP condition punished more on the transgressor than in the 3PP condition (i.e., 2PP > 3PP). In addition, the third-party was more likely to punish than to compensate (i.e., 3PP > 3PH, Fig. 6a left bottom). For both studies, we simulated participants' choices by calculating the utility of selecting "yes" and "no" for each inequality level using Eq.14-17. We assume that the second-party intervener

has all the motives a third-party intervener would have except for efficiency concern based on the belief that the victim is less concerned about the welfare of the transgressor than the third-party does. Therefore, we replaced x_3 in Eq. 14-17 with x_2, and set the efficiency concern ω to 0 in the second-party punishment condition. The same efficiency concern hypothesis (i.e., $\omega = 0$) was implemented during the simulation of third-party punishment and compensation games in Stallen et al., (2018) as we assume the unaffected third party would reasonably ignore others' welfare in a robbery situation.

Experiment 2

To further verify our findings and model specifications, we conducted Experiment 2 using the same experimental paradigm as Experiment 1 on an online participant platform (Prolific, https://www.prolific.co/) by recruiting a larger population with diverse cultural backgrounds.

Pre-registration

Experiment 2 was pre-registered on OSF (https://osf.io/gcsqp). Building on the results of the model-free analysis in Experiment 1, we hypothesized that the main effect of inequality, intervention cost, impact ratio and the interaction of inequality × cost × ratio would be statistically significant, and that participants' intervention decisions would follow the patterns we observed in Experiment 1. For the model-based analysis, we hypothesized that participants' decisions would be best described by the full motive cocktail model.

Participants

The criteria for participant recruitment were matched between Experiment 2 and 1, including the age ranges (18–30 years old), student status and the degree of education. In addition, the study was only accessible to participants with an approval rate of over 90% in Prolific. We received 1365 participants' submissions overall. One hundred and seven of them had an accuracy rate below 75% on the attention check task (see details below) and thus were rejected for further analysis. The final valid samples were 1258 (621 male, 631 female, 6 genders unknown, aged 23.30 ± 2.89). All participants provided informed consent before the task to confirm they voluntarily took part in the study, had a normal or corrected-to-normal vision, and did not have a history of psychiatric or neurological illness. This study was approved by the Ethics Committee of Beijing Normal University.

Determination of sample size

The sample size for Experiment 2 was pre-determined using a parametric simulation method (Kumle et al., 2021), derived from the motive cocktail model (the best-fitting model in Experiment 1). The effect we focused on is the three-way interaction of inequality × cost

× ratio (Fig. 1i). As a compensation for the higher randomness of online participants' decisions, we added another two parameters, p_{min} and p_{max} (lapse rates), in the motive cocktail model to capture participants' minimal and maximal $(1 - p_{max})$ intervention probability. An online pilot study based on 32 participants showed the motive cocktail model with lapse rates (see Model 8 for more details) fit participants' behavior better. We, therefore, used model 8 to generate synthetic datasets to determine the sample size for Experiment 2. Parameters $\alpha, \beta, \gamma, \omega, \eta_{no}, \eta_{yes}, \lambda$ were sampled from Gamma distribution, κ was sampled from Normal distribution, and p_{min} and p_{max} were sampled from Beta distribution. The generated intervention decisions of virtual participants were then exported to GLMM1 to obtain the effect size for each variable and their interactions. The power was defined as the percentage that the three-way interaction effect reaches significance over a specific sample size. We tested different sample sizes ranging from 100 to 1500 virtual participants, with increments of 100. Within each sample size, we repeated the synthetic data generation and power calculation procedure 500 times. The power of the three-way interaction effect increased monotonically with sample size and achieved a power of 80% with at least 1200 participants (see Fig. S5). Our final valid sample size was 1258 participants from sixty-six countries (Supplementary Table S2).

Experimental procedure

The procedure of Experiment 2 was the same as that of Experiment 1, except that it was conducted on the Prolific platform. After the task, participants were asked "Did you think the experimenter had deceived you in any way at any point during the experiment?", with a binary choice of "yes" or "no". Seventy-four participants answered "yes", while the remaining 1184 participants answered "no". To investigate whether participants who had doubts (answered "yes") employed different strategies compared to those who did not have doubts (answered "no") during the task, we conducted a generalized linear mixed model (like GLMM2) and included "doubt" as a predictor (categorical variable) in the model. We found that the effect of doubt (b = 0.15, 95% CI [–0.09, 0.41], *p* = 0.221) was not statistically significant to predict participants' choices, suggesting that participants who reported doubts did not employ different strategies in the task. Therefore, all participants were included in the subsequent analysis.

Attention check

We used the same intervene-or-watch task in Experiment 2 and included several attention checks during the task to ensure participants remained constantly attentive to the current task. The attention checks consisted of 12 questions, with two questions interspersed in each block. For each block, the questions appeared randomly without telling the participants, and participants were asked to answer the questions with binary options about

their last decision. Specifically, the questions were either “In the last trial, your decision was: yes/no?” or “The last trial was in the increase/reduce scenario?” in each block. For those (107 participants) who gave less than 75% accuracy in the attention checks (incorrect answers on more than three questions) were excluded from further analyses.

Model-free analysis

All 1258 participants in Experiment 2 were included in the model-free analysis (Table S2). Among them, 492 (39.10%) out of 1258 participants were best described by a heuristic model and were therefore excluded from the analyses in relation to the motive cocktail model. Specifically, only the remaining 60.90% of participants whose intervention patterns could be categorized as justice warriors, pragmatic helpers, and rational moralists were included in the following analyses: data versus model prediction (Fig. 5), Kruskal-Wallis tests on the parameters η_{yes}, κ, η_{no} (Fig. S3), correlations between the parameters estimated from the motive cocktail model and the intervention sensitivities (Fig. S4) as well as the personality measurements (Fig. S10).

Behavioral modeling

Model space. We constructed two additional models (Models 8 and 9) in Experiment 2 to capture the behavioral patterns that online participants would make random choices in a certain amount of trials. Model 8 was constructed based on the motive cocktail model. Model 9 is a heuristic model to capture the behavioral patterns of a proportion of participants in the online Experiment 2 (39.10%) who only responded to part of the manipulated variables and seemed also entirely ignored the others.

Model 8: The motive cocktail model with two lapse rate parameters. The model assumes that participants make an intervention decision by considering both self-interest and all socioeconomic motives assumed in the motive cocktail model. However, participants’ minimal and maximal intervention probability are bounded by two free parameters. Specifically, participants are willing to randomly intervene with a probability of p_{min} ($p_{min} \in [0, 0.5]$). Meanwhile, they constrain their maximum intervention probability below $1 - p_{max}$($p_{max} \in [0, 0.5]$). The utility calculations and choice mapping remain the same as Eqs.14-17 and Eq.1, respectively.

$$p(yes)' = p_{\min} + (1 - p_{min} - p_{max}) \cdot p(yes) \tag{18}$$

where $p(yes)$ represents the choice probability based on the motive cocktail model.

Model 9: Heuristic model. Some of these online participants were sensitive to only a few of the manipulated variables and seemed to use simple heuristic rules for responses. Thus,

we also included a heuristic model that linearly combines different manipulated variables (scenario, inequality, cost, and ratio) to describe participants' behavior:

$$p(yes) = \frac{1}{1 + e^{\gamma(\beta_1 Scenario + \beta_2 Inqueality + \beta_3 Cost + \beta_4 Ratio)}} \tag{19}$$

$$p(yes)' = p_{min} + (1 - p_{min} - p_{max}) \cdot p(yes) \tag{20}$$

References

Balafoutas, L., Nikiforakis, N., & Rockenbach, B. (2014). Direct and indirect punishment among strangers in the field. *Proceedings of the National Academy of Sciences*, *111*(45), 15924–15927. https://doi.org/10.1073/pnas.1413170111

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting Linear Mixed-Effects Models Using **lme4**. *Journal of Statistical Software*, *67*(1). https://doi.org/10.18637/jss.v067.i01

Batistoni, T., Barclay, P., & Raihani, N. J. (2022). Third-party punishers do not compete to be chosen as partners in an experimental game. *Proceedings of the Royal Society B: Biological Sciences*, *289*(1966), 20211773. https://doi.org/10.1098/rspb.2021.1773

Bernhard, R. M., Martin, J. W., & Warneken, F. (2020). Why do children punish? Fair outcomes matter more than intent in children's second- and third-party punishment. *Journal of Experimental Child Psychology*, *200*, 104909. https://doi.org/10.1016/j.jecp.2020.104909

Blain, B., Marks, J., Czech, P., & Sharot, T. (2022). Observing others give & take: A computational account of bystanders' feelings and actions. *PLOS Computational Biology*, *18*(5), e1010010. https://doi.org/10.1371/journal.pcbi.1010010

Bone, J. E., & Raihani, N. J. (2015). Human punishment is motivated by both a desire for revenge and a desire for equality. *Evolution and Human Behavior*, *36*(4), 323–330. https://doi.org/10.1016/j.evolhumbehav.2015.02.002

Ciaramidaro, A., Toppi, J., Casper, C., Freitag, C. M., Siniatchkin, M., & Astolfi, L. (2018). Multiple-Brain Connectivity During Third Party Punishment: An EEG Hyperscanning Study. *Scientific Reports*, *8*(1), 6822. https://doi.org/10.1038/s41598-018-24416-w

Civai, C., Huijsmans, I., & Sanfey, A. G. (2019). Neurocognitive mechanisms of reactions to second- and third-party justice violations. *Scientific Reports*, *9*(1), 9271. https://doi.org/10.1038/s41598-019-45725-8

Cui, F., Wang, C., Cao, Q., & Jiao, C. (2019). Social hierarchies in third-party punishment: A behavioral and ERP study. *Biological Psychology*, *146*, 107722. https://doi.org/10.1016/j.biopsycho.2019.107722

Darley, J. M., & Pittman, T. S. (2003). The Psychology of Compensatory and Retributive Justice. *Personality and Social Psychology Review*, *7*(4), 324–336.

https://doi.org/10.1207/S15327957PSPR0704_05

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113. https://doi.org/10.1037/0022-3514.44.1.113

Dawes, C. T., Fowler, J. H., Johnson, T., McElreath, R., & Smirnov, O. (2007). Egalitarian motives in humans. *Nature*, *446*(7137), 794–796. https://doi.org/10.1038/nature05651

Doñate-Buendía, A., García-Gallego, A., & Petrović, M. (2022). Gender and other moderators of giving in the dictator game: A meta-analysis. *Journal of Economic Behavior & Organization*, *198*, 280–301. https://doi.org/10.1016/j.jebo.2022.03.031

Egas, M., & Riedl, A. (2008). The economics of altruistic punishment and the maintenance of cooperation. *Proceedings of the Royal Society B: Biological Sciences*, *275*(1637), 871–878. https://doi.org/10.1098/rspb.2007.1558

Engel, C. (2011). Dictator games: A meta study. *Experimental Economics*, *14*(4), 583–610. https://doi.org/10.1007/s10683-011-9283-7

Engelmann, D., & Strobel, M. (2004). *Inequality Aversion, Efficiency, and Maximin Preferences in Simple Distribution Experiments*. 37.

Fehr, E., & Fischbacher, U. (2004). Third-party punishment and social norms. *Evolution and Human Behavior*, *25*(2), 63–87. https://doi.org/10.1016/S1090-5138(04)00005-4

Fehr, E., & Gächter, S. (2002). Altruistic punishment in humans. *Nature*, *415*(6868), Article 6868. https://doi.org/10.1038/415137a

Fehr, E., & Schmidt, K. M. (1999). A theory of fairness, competition, and cooperation. *The Quarterly Journal of Economics*, *114*(3), 817–868. https://doi.org/10.1162/003355399556151

FeldmanHall, O., Otto, A. R., & Phelps, E. A. (2018). Learning moral values: Another's desire to punish enhances one's own punitive behavior. *Journal of Experimental Psychology: General*, *147*(8), 1211–1224. https://doi.org/10.1037/xge0000405

FeldmanHall, O., Sokol-Hessner, P., Van Bavel, J. J., & Phelps, E. A. (2014). Fairness violations elicit greater punishment on behalf of another than for oneself. *Nature Communications*, *5*(1), 5306. https://doi.org/10.1038/ncomms6306

Ferguson, E. (2021). Inequality averse and compassionate blood donor: Implication for interventions. *Vox Sanguinis*, *116*(8), 862–871. https://doi.org/10.1111/vox.13088

Gintis, H. (2000). Strong Reciprocity and Human Sociality. *Journal of Theoretical Biology*,

206(2), 169–179. https://doi.org/10.1006/jtbi.2000.2111

Gummerum, M., & Chu, M. T. (2014). Outcomes and intentions in children's, adolescents', and adults' second- and third-party punishment behavior. *Cognition*, *133*(1), 97–103. https://doi.org/10.1016/j.cognition.2014.06.001

Guo, R., Ding, J., & Wu, Z. (2020). How intergroup relation moderates group bias in Third-Party Punishment. *Acta Psychologica*, *205*, 103055. https://doi.org/10.1016/j.actpsy.2020.103055

Hartigan, J. A., & Wong, M. A. (1979). Algorithm AS 136: A k-means clustering algorithm. *Journal of the Royal Statistical Society. Series c (Applied Statistics)*, *28*(1), 100–108.

Henrich, J., McElreath, R., Barr, A., Ensminger, J., Barrett, C., Bolyanatz, A., Cardenas, J. C., Gurven, M., Gwako, E., Henrich, N., Lesorogol, C., Marlowe, F., Tracer, D., & Ziker, J. (2006). Costly Punishment Across Human Societies. *Science*, *312*(5781), 1767–1770. https://doi.org/10.1126/science.1127333

Hsu, M., Anen, C., & Quartz, S. R. (2008). The Right and the Good: Distributive Justice and Neural Encoding of Equity and Efficiency. *Science*, *320*(5879), 1092–1095. https://doi.org/10.1126/science.1153651

Hurvich, C. M., & Tsai, C.-L. (1989). *Regression and time series model selection in small samples*. 11. https://doi.org/10.1093/biomet/76.2.297

Jordan, J. J., Hoffman, M., Bloom, P., & Rand, D. G. (2016). Third-party punishment as a costly signal of trustworthiness. *Nature*, *530*(7591), 473–476. https://doi.org/10.1038/nature16981

Jordan, J. J., McAuliffe, K., & Warneken, F. (2014). Development of in-group favoritism in children's third-party punishment of selfishness. *Proceedings of the National Academy of Sciences*, *111*(35), 12710–12715. https://doi.org/10.1073/pnas.1402280111

Kumle, L., Võ, M. L.-H., & Draschkow, D. (2021). Estimating power in (generalized) linear mixed models: An open introduction and tutorial in R. *Behavior Research Methods*, *53*(6), 2528–2543. https://doi.org/10.3758/s13428-021-01546-0

Lee, M. D., & Dry, M. J. (2006). Decision Making and Confidence Given Uncertain Advice. *Cognitive Science*, *30*(6), 1081–1095. https://doi.org/10.1207/s15516709cog0000_71

Leliveld, M. C., Dijk, E., & Beest, I. (2012). Punishing and compensating others at your own expense: The role of empathic concern on reactions to distributive injustice: Punishing and compensating others at your own expense. *European Journal of*

Social Psychology, *42*(2), 135–140. https://doi.org/10.1002/ejsp.872

Lenth, R., Singmann, H., Love, J., Buerkner, P., & Herve, M. (2018). Emmeans: Estimated marginal means, aka least-squares means. *R Package Version*, *1*(1), 3. https://doi.org/10.1016/B978-0-12-811080-5.00002-5

Li, Y., Hu, J., Ruff, C. C., & Zhou, X. (2022). Neurocomputational evidence that conflicting prosocial motives guide distributive justice. *Proceedings of the National Academy of Sciences*, *119*(49), e2209078119. https://doi.org/10.1073/pnas.2209078119

Lotz, S., Baumert, A., Schlösser, T., Gresser, F., & Fetchenhauer, D. (2011). Individual Differences in Third-Party Interventions: How Justice Sensitivity Shapes Altruistic Punishment: Individual Differences in Third-Party Interventions. *Negotiation and Conflict Management Research*, *4*(4), 297–313. https://doi.org/10.1111/j.1750-4716.2011.00084.x

Luce, R. D. (1959). *Individual Choice Behavior: A theoretical analysis, New York, NY: John Willey and Sons*. Inc.

Marlowe, F. W., Berbesque, J. C., Barr, A., Barrett, C., Bolyanatz, A., Cardenas, J. C., Ensminger, J., Gurven, M., Gwako, E., Henrich, J., Henrich, N., Lesorogol, C., McElreath, R., & Tracer, D. (2008). More ‘altruistic’ punishment in larger societies. *Proceedings of the Royal Society B: Biological Sciences*, *275*(1634), 587–592. https://doi.org/10.1098/rspb.2007.1517

McAuliffe, K., Jordan, J. J., & Warneken, F. (2015). Costly third-party punishment in young children. *Cognition*, *134*, 1–10. https://doi.org/10.1016/j.cognition.2014.08.013

Mothes, H., Enge, S., & Strobel, A. (2016). The interplay between feedback-related negativity and individual differences in altruistic punishment: An EEG study. *Cognitive, Affective, & Behavioral Neuroscience*, *16*(2), 276–288. https://doi.org/10.3758/s13415-015-0388-x

Murphy, R. O., Ackermann, K. A., & Handgraaf, M. (2011). Measuring Social Value Orientation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1804189

Ouyang, H., Yu, J., Duan, J., Zheng, L., Li, L., & Guo, X. (2021). Empathy-based tolerance towards poor norm violators in third-party punishment. *Experimental Brain Research*, *239*(7), 2171–2180. https://doi.org/10.1007/s00221-021-06128-2

Paulus, M., Gillis, S., Li, J., & Moore, C. (2013). Preschool children involve a third party in a dyadic sharing situation based on fairness. *Journal of Experimental Child Psychology*, *116*(1), 78–85. https://doi.org/10.1016/j.jecp.2012.12.014

Qu, C., Tang, Z., Zhang, H., Hu, Y., & Dreher, J. C. (2018). *Neural Modulation of Social*

Distance on Third-Party Punishment [Preprint]. Neuroscience. https://doi.org/10.1101/274720

R Core Team, R. (2013). *R: A language and environment for statistical computing*. https://doi.org/10.1017/CBO9781316584460.003

Ratcliff, R., & Starns, J. J. (2013). Modeling confidence judgments, response times, and multiple choices in decision making: Recognition memory and motion discrimination. *Psychological Review*, *120*(3), 697–719. https://doi.org/10.1037/a0033152

Rauthmann, J. F. (2013). Investigating the MACH–IV With Item Response Theory and Proposing the Trimmed MACH*. *Journal of Personality Assessment*, *95*(4), 388–397. https://doi.org/10.1080/00223891.2012.742905

Rigoux, L., Stephan, K. E., Friston, K. J., & Daunizeau, J. (2014). Bayesian model selection for group studies—Revisited. *Neuroimage*, *84*, 971–985. https://doi.org/10.1016/j.neuroimage.2013.08.065

Rockenbach, B., & Milinski, M. (2006). The efficient interaction of indirect reciprocity and costly punishment. *Nature*, *444*(7120), Article 7120. https://doi.org/10.1038/nature05229

Rousseeuw, P. J. (1987). Silhouettes: A graphical aid to the interpretation and validation of cluster analysis. *Journal of Computational and Applied Mathematics*, *20*, 53–65. https://doi.org/10.1016/0377-0427(87)90125-7

Sanders, S. (2021). 125 questions: Exploration and Discovery. *Science/AAAS Custom Publishing Office: Washington, DC, USA*.

Singh, M., & Garfield, Z. H. (2022). *Evidence for third-party mediation but not punishment in Mentawai justice*. 21.

Stallen, M., Rossi, F., Heijne, A., Smidts, A., De Dreu, C. K. W., & Sanfey, A. G. (2018). Neurobiological Mechanisms of Responding to Injustice. *The Journal of Neuroscience*, *38*(12), 2944–2954. https://doi.org/10.1523/JNEUROSCI.1242-17.2018

Tricomi, E., Rangel, A., Camerer, C. F., & O'Doherty, J. P. (2010). Neural evidence for inequality-averse social preferences. *Nature*, *463*(7284), 1089–1091. https://doi.org/10.1038/nature08785

van Baar, J. M., Chang, L. J., & Sanfey, A. G. (2019). The computational and neural substrates of moral strategies in social decision-making. *Nature Communications*, *10*(1), 1483. https://doi.org/10.1038/s41467-019-09161-6

van Doorn, J., Zeelenberg, M., & Breugelmans, S. M. (2018). An exploration of third

parties' preference for compensation over punishment: Six experimental demonstrations. *Theory and Decision*, *85*(3–4), 333–351. https://doi.org/10.1007/s11238-018-9665-9

van Prooijen, J.-W. (2009). Retributive versus compensatory justice: Observers' preference for punishing in response to criminal offenses. *European Journal of Social Psychology*, n/a-n/a. https://doi.org/10.1002/ejsp.611

Wiessner, P. (2020). The role of third parties in norm enforcement in customary courts among the Enga of Papua New Guinea. *Proceedings of the National Academy of Sciences*, *117*(51), 32320–32328. https://doi.org/10.1073/pnas.2014759117

Xie, W., Ho, B., Meier, S., & Zhou, X. (2017). Rank reversal aversion inhibits redistribution across societies. *Nature Human Behaviour*, *1*(8), 0142. https://doi.org/10.1038/s41562-017-0142

Yang, J., Gu, R., Liu, J., Deng, K., Huang, X., Luo, Y.-J., & Cui, F. (2022). To Blame or Not? Modulating Third-Party Punishment with the Framing Effect. *Neuroscience Bulletin*, *38*(5), 533–547. https://doi.org/10.1007/s12264-021-00808-3

Yang, Q., Bellucci, G., Hoffman, M., Hsu, K.-T., Lu, B., Deshpande, G., & Krueger, F. (2021). Intrinsic functional connectivity of the frontoparietal network predicts inter-individual differences in the propensity for costly third-party punishment. *Cognitive, Affective, & Behavioral Neuroscience*, *21*(6), 1222–1232. https://doi.org/10.3758/s13415-021-00927-4

Ying, L., Yan, Q., Shen, X., & Zhang, C. (2022). Social Value Orientation Moderated the Effect of Acute Stress on Individuals' Prosocial Behaviors. *Frontiers in Psychology*, *13*, 803184. https://doi.org/10.3389/fpsyg.2022.803184

Zhong, S., Chark, R., Hsu, M., & Chew, S. H. (2016). Computational substrates of social norm enforcement by unaffected third parties. *NeuroImage*, *129*, 95–104. https://doi.org/10.1016/j.neuroimage.2016.01.040

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Formal analysis: XW.

Funding acquisition: CL, HZ.

Investigation: XW, XR.

Methodology-development and design of methodology: XW, XR, CL, HZ.

Methodology-creation of models: XW, XR, HZ.

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Competing interests

The authors declare no competing interests.

Data availability

All data and study materials will be made publicly available upon acceptance of the paper.

Code availability

All codes will be made publicly available upon acceptance of the paper.

Supplementary Materials for

The “motive cocktail” in altruistic behaviors

Supplementary Methods

We introduced the concept of “inequality inattention” (II) to explain the observation that participants were still willing to intervene when they could only achieve a small intervention effect (cost × ratio) but were confronted with a large inequality between the transgressor and the victim. In a supplementary analysis, we tested four more variants of the full motive cocktail model (Model 7 in the main text) to demonstrate the necessity of the inequality inattention assumption (the interaction items) in the full model as well as the nonlinear modulation of self-interest on the victim-centered inequality term in fitting the behavioral data. Its results are presented in Figure S2.

The further comparison between different modulation forms of II demonstrated that the nonlinear assumption better captures the intervention patterns. Note that the II exerted its effects in the form of an interaction with inequality and only affected the utility calculation, whereas the response mapping remained the same in all models. This bifurcated analysis below, beyond the alternative models in the main texts, was designed to confirm the necessity of inequality inattention as well as its modulation form.

In the first line of analysis, the self-centered and victim-centered inequality were modulated by additional parameters respectively, which allowed us to test whether the assumption of interaction on inequality would improve the performance of the model.

Variant model 1 (VM1). Based on model 6 (SI+SCI+VCI+EC+RP), the model assumes that the self-centered inequalities (SCI) are jointly modulated by two additional free parameters (η_{no} and η_{yes}), resulting in unequal contributions (or weights) of disadvantageous and advantageous SCI in the context of the intervention and not.

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0) - [\alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) + \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0)]\eta_{no} + \omega(x_1 + x_2) + \kappa \max(x_2 - x_{1,}0) \quad \text{(S1)}$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0) - [\alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) + \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0)]\eta_{yes} + \omega(x_1' + x_2') + \kappa \max(x_2' - x_1', 0) \quad \text{(S2)}$$

Variant model 2 (VM2). Similar to VM1, VM2 assumes an invariant modulation

to the victim-centered inequality (VCI) component by introducing another free parameter, η.

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0) - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0) + \omega(x_1 + x_2) + \kappa \max(x_2 - x_{1,}0) \quad \text{(S3)}$$

$$U_{yes} = x_3' - \eta \max(x_1' - x_2', 0) - \alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) - \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0) + \omega(x_1' + x_2') + \kappa \max(x_2' - x_1', 0) \quad \text{(S4)}$$

Model comparison between VM1, VM2 and the first six models in the main texts showed that the model incorporating interaction items excelled the others (see Fig.S2a and Fig.S2e), with VM2 performing the best. The analysis provided direct evidence that the inclusion of the interaction assumption (i.e., inequality inattention) is necessary and that the modulation is sensitive to victim-centered inequality aversion.

Following the conclusion of the modulation assumption, the next line of analysis focused on the modulation form of inequality inattention. Instead of an invariant effect, a variant modulation of victim-centered inequality was assumed. This assumption was derived from the rational framework of economic decision (Scott, 2000), where people systematically disregard victim-centered advantageous inequality as the intervention cost increase. Two forms of modulation were tested: diminishing linear and nonlinear.

Variant model 3 (VM3). The model assumes that the modulation of self-interest to victim-centered inequality decreases linearly with increasing intervention cost, with the parameters η_{no} and η_{yes} controlling the modulatory magnitudes at different costs.

$$U_{no} = x_3 - \gamma \max(x_1 - x_{2,}0)\, \delta_{III} - \alpha \sum_{j=1}^{2} \max(x_j - x_{3,}0) - \beta \sum_{j=1}^{2} \max(x_3 - x_j, 0)\, \delta_{II} + \omega(x_1 + x_2) + \kappa \max(x_2 - x_{1,}0) \quad \text{(S5)}$$

$$U_{yes} = x_3' - \gamma \max(x_1' - x_2', 0)\delta_{IIA} - \alpha \sum_{j=1}^{2} \max(x_j' - x_3', 0) - \beta \sum_{j=1}^{2} \max(x_3' - x_j', 0) + \omega(x_1' + x_2') + \kappa \max(x_2' - x_1', 0) \quad \text{(S6)}$$

$$\delta_{III} = -\eta_{no}(cost/50) + 1 \quad \text{(S7)}$$

$$\delta_{IIA} = -\eta_{yes}(cost/50) + 1 \quad \text{(S8)}$$

Variant model 4 (VM4). The model assumes a nonlinear modulation of self-interest to victim-centered inequality.

$$\delta_{III} = \frac{2}{1 + e^{\eta_{no}(cost/50)}} \tag{S9}$$

$$\delta_{IIA} = \frac{2}{1 + e^{\eta_{yes}(cost/50)}} \tag{S10}$$

Both model comparison and model predictions indicated that the nonlinear assumption outperformed its alternatives in fitting behavioral data (Fig.S2). Therefore, the modulation form assumed in VM4 (i.e., the full model) was reported in the main texts.

Supplementary Tables

Table S1. Statistical results of GLMM1

Fixed effects	Estimated beta value	SE	Z value	P value
(Intercept)	-3.61	0.28	-12.81	$p < 0.001$
Trial number	-0.20	0.05	-3.79	$p < 0.001$
Scenario	-1.22	0.21	-5.71	$p < 0.001$
Inequality	1.61	0.11	15.08	$p < 0.001$
Cost	-2.12	0.13	-16.43	$p < 0.001$
Ratio	0.82	0.10	8.21	$p < 0.001$
Trial number×Scenario	0.07	0.05	1.36	$p = 0.174$
Trial number×inequality	0.02	0.03	0.60	$p = 0.548$
Scenario×inequality	-0.03	0.05	-0.67	$p = 0.499$
Trial number×Cost	-0.04	0.03	-1.26	$p = 0.209$

Scenario×Cost	0.00	0.05	-1.33	$p = 0.894$
Inequality×Cost	-0.09	0.03	-2.92	$p = 0.003$
Trial number×Ratio	-0.07	0.03	-2.24	$p = 0.003$
Scenario×Ratio	-0.39	0.05	-8.65	$p < 0.001$
Inequality×Ratio	-0.08	0.03	-2.50	$p = 0.012$
Cost×Ratio	-0.08	0.03	-2.44	$p = 0.015$
Trial number×Scenario×Inequality	-0.08	-0.05	-1.17	$p = 0.087$
Trail number×Scenario×Cost	-0.01	0.05	-0.21	$p = 0.831$
Trial number×Inequality×Cost	-0.01	0.05	-0.23	$p = 0.814$
Scenario×Inequality×Cost	-0.01	0.03	0.18	$p = 0.861$
Trial number×Scenario×Ratio	-0.23	0.05	5.19	$p < 0.001$
Trial number×Inequality×Ratio	0.01	0.03	0.22	$p = 0.823$
Scenario×Inequality×Ratio	0.04	0.04	0.99	$p = 0.322$
Trial number×Cost×Ratio	-0.05	0.03	-1.62	$p = 0.106$
Scenario×Cost×Ratio	-0.03	0.04	-0.77	$p = 0.441$
Inequality×Cost×Ratio	-0.21	0.03	-6.97	$p < 0.001$
Trial number×Scenario×Inequality×Cost	-0.04	0.04	-0.88	$p = 0.380$
Trial number×Scenario×Inequality×Ratio	-0.05	0.04	-1.25	$p = 0.210$
Trial number×Scenario×Cost×Ratio	0.02	0.04	0.42	$p = 0.673$
Trial number×Inequality×Cost×Ratio	0.06	0.03	-1.90	$p = 0.057$

Scenario×Inequality×Cost×Ratio	0.05	0.04	1.21	$p = 0.226$
Trial number×Scenario×Inequality×Cost×Ratio	0.04	0.04	0.93	$p = 0.352$

Table S2. The nationality of participants in experiment 2.

Nationality	N	Percentage	Nationality	N	Percentage
South Africa	193	15.34%	Australia	3	0.24%
Italy	164	13.04%	Pakistan	2	0.16%
Mexico	141	11.21%	Moldova	2	0.16%
Poland	132	10.49%	Egypt	2	0.16%
Portugal	118	9.38%	Norway	2	0.16%
Greece	72	5.72%	Vietnam	2	0.16%
Spain	69	5.48%	Venezuela, Bolivarian Republic of	2	0.16%
Chile	40	3.18%	New Zealand	2	0.16%
Hungary	30	2.38%	Indonesia	2	0.16%
Germany	28	2.23%	Uganda	2	0.16%
United Kingdom	26	2.07%	Sri Lanka	1	0.08%
Canada	26	2.07%	Namibia	1	0.08%
France	17	1.35%	Lebanon	1	0.08%

Netherlands	16	1.27%	Cameroon	1	0.08%
Czech Republic	15	1.19%	Nepal	1	0.08%
United States	14	1.11%	India	1	0.08%
Slovenia	13	1.03%	Bosnia and Herzegovina	1	0.08%
Latvia	10	0.79%	Croatia	1	0.08%
Estonia	10	0.79%	Switzerland	1	0.08%
Belgium	9	0.72%	Peru	1	0.08%
Ireland	8	0.64%	Bulgaria	1	0.08%
Austria	7	0.56%	Singapore	1	0.08%
Brazil	6	0.48%	Ghana	1	0.08%
Zimbabwe	6	0.48%	Argentina	1	0.08%
Turkey	6	0.48%	Algeria	1	0.08%
Finland	6	0.48%	Lesotho	1	0.08%
Sweden	5	0.40%	Bangladesh	1	0.08%
Iran	5	0.40%	Morocco	1	0.08%
Philippines	5	0.40%	Suriname	1	0.08%
Nigeria	4	0.32%	Zambia	1	0.08%
Israel	4	0.32%	Colombia	1	0.08%
China	4	0.32%	Saudi Arabia	1	0.08%

Romania	3	0.24%
Ukraine	3	0.24%

Table S3. Statistical results of GLMM2.

Fixed effects	Estimated beta value	SE	Z value	P value
(Intercept)	-1.04	0.07	-15.13	$p < 0.001$
Trial number	-0.13	0.01	-8.93	$p < 0.001$
Scenario	-1.19	0.06	-18.37	$p < 0.001$
Inequality	0.59	0.03	20.16	$p < 0.001$
Cost	-0.78	0.03	-25.47	$p < 0.001$
Ratio	0.71	0.03	25.19	$p < 0.001$
Trial number×Scenario	-0.03	0.01	-2.43	$p = 0.015$
Trial number×inequality	0.03	0.00	4.70	$p < 0.001$
Scenario×inequality	0.16	0.01	15.50	$p < 0.001$
Trial number×Cost	-0.02	0.00	-2.89	$p < 0.004$
Scenario×Cost	-0.09	0.01	-8.64	$p < 0.001$
Inequality×Cost	-0.00	0.01	-0.36	$p = 0.716$
Trial number×Ratio	-0.04	0.01	-5.63	$p < 0.001$
Scenario×Ratio	-0.31	0.01	-30.67	$p < 0.001$
Inequality×Ratio	-0.01	0.01	-1.85	$p = 0.064$
Cost×Ratio	0.04	0.01	5.46	$p < 0.001$
Trial number×Scenario×Inequality	-0.03	0.01	-2.87	$p = 0.004$

Trail number×Scenario×Cost	0.03	0.01	2.63	$p = 0.008$
Trial number×Inequality×Cost	-0.02	0.01	-2.71	$p = 0.007$
Scenario×Inequality×Cost	0.02	0.01	2.12	$p = 0.034$
Trial number×Scenario×Ratio	0.05	0.01	4.87	$p < 0.001$
Trial number×Inequality×Ratio	0.01	0.01	1.55	$p = 0.119$
Scenario×Inequality×Ratio	0.03	0.01	2.66	$p = 0.008$
Trial number×Cost×Ratio	-0.03	0.01	-4.58	$p < 0.001$
Scenario×Cost×Ratio	-0.04	0.01	-4.33	$p < 0.001$
Inequality×Cost×Ratio	-0.02	0.00	-2.30	$p = 0.021$
Trial number×Scenario×Inequality×Cost	0.02	0.01	2.07	$p = 0.038$
Trial number×Scenario×Inequality×Ratio	-0.02	0.01	-2.09	$p = 0.036$
Trial number×Scenario×Cost×Ratio	0.02	0.01	2.24	$p = 0.025$
Trial number×Inequality×Cost×Ratio	0.02	0.01	1.80	$p = 0.070$
Scenario×Inequality×Cost×Ratio	-0.01	0.01	-3.14	$p = 0.002$
Trial number×Scenario×Inequality×Cost×Ratio	0.00	0.01	-0.70	$p = 0.485$

Table S4. Statistical results of LMM1.

Fixed effects	Estimate	SE	df	t value	P value
(Intercept)	896.94	45.75	163.00	19.61	$p < 0.001$

Trial number	-74.12	43.10	197.25	-1.72	$p = 0.087$
Choice	467.24	83.68	126.07	5.58	$p < 0.001$
Scenario	4.76	35.25	166.78	0.14	$p = 0.893$
Inequality	112.89	21.65	363.48	5.21	$p < 0.001$
Cost	-124.28	23.17	322.57	-5.37	$p < 0.001$
Ratio	35.26	16.49	2222.65	2.14	$p = 0.032$
Trial number×Choice	-214.71	45.39	36910.76	-4.73	$p < 0.001$
Trial number×Scenario	-31.55	26.16	36066.02	-1.21	$p = 0.227$
Choice×Scenario	75.77	68.07	11285.37	1.11	$p = 0.266$
Trial number×Inequality	-3.76	16.72	35212.74	-0.23	$p = 0.822$
Choice×Inequality	-223.81	41.93	18985.66	-5.34	$p < 0.001$
Scenario×Inequality	6.71	22.09	44119.63	0.30	$p = 0.761$
Trial number×Cost	-24.60	17.13	32627.23	-1.44	$p = 0.151$
Choice×Cost	382.64	41.56	16281.44	9.21	$p < 0.001$
Scenario×Cost	17.15	22.40	44094.58	0.77	$p = 0.444$
Inequality×Cost	-39.82	16.43	41892.31	-2.42	$p = 0.015$
Trial number×Ratio	-5.07	16.44	35165.99	-0.31	$p = 0.758$
Choice×Ratio	-71.55	41.49	20079.08	-1.72	$p = 0.085$
Scenario×Ratio	-19.96	21.84	46036.13	-0.91	$p = 0.361$
Inequality×Ratio	16.24	16.03	46063.51	1.01	$p = 0.311$

Cost×Ratio	-33.50	16.28	46051.56	-2.06	p = 0.039
Trial number×Choice×Scenario	129.11	68.37	32043.70	1.89	p = 0.058
Trial number×Choice×Inequality	29.44	41.25	40221.26	0.71	p = 0.475
Trial number×Scenario×Inequality	-52.37	22.64	21527.93	-2.31	p = 0.021
Choice×Scenario×Inequality	-7.91	62.35	33869.84	-0.13	p = 0.899
Trial number×Choice×Cost	-18.81	39.38	40746.60	-0.48	p = 0.632
Trial number×Scenario×Cost	58.78	23.38	18127.98	2.51	p = 0.012
Choice×Scenario×Cost	-81.51	60.42	29263.29	-1.35	p = 0.187
Trial number×Inequality×Cost	-28.20	16.74	46405.25	-1.69	p = 0.092
Choice×Inequality×Cost	106.58	38.56	34442.40	2.76	p = 0.005
Scenario×Inequality×Cost	-1.21	22.34	46218.66	-0.05	p = 0.957
Trial number×Choice×Ratio	-62.39	41.01	41046.91	-1.52	p = 0.128
Trial number×Scenario×Ratio	3.81	22.14	20674.98	0.17	p = 0.863
Choice×Scenario×Ratio	-20.11	64.08	33313.35	-0.31	p = 0.754
Trial number×Inequality×Ratio	12.00	16.41	46357.25	0.73	p = 0.464
Choice×Inequality×Ratio	3.03	39.81	41309.84	0.08	p = 0.939
Scenario×Inequality×Ratio	5.82	21.94	46387.69	0.27	p = 0.791
Trial number×Cost×Ratio	-8.31	16.69	46380.40	-0.50	p = 0.618
Choice×Cost×Ratio	-33.88	38.22	40072.88	-0.89	p = 0.375
Scenario×Cost×Ratio	15.63	22.23	46404.12	0.70	p = 0.482

Inequality×Cost×Ratio	-28.87	16.27	46329.75	-1.78	*p* = 0.076
Trial number×Choice×Scenario×Inequality	26.38	61.42	41519.65	0.43	*p* = 0.668
Trial number×Choice×Scenario×Cost	43.79	58.89	41220.79	0.74	*p* = 0.457
Trial number×Choice×Inequality×Cost	19.28	38.16	44991.68	0.51	*p* = 0.613
Trial number×Scenario×Inequality×Cost	39.06	22.54	46346.32	1.73	*p* =0.083
Choice×Scenario×Inequality×Cost	5.44	57.14	44983.34	0.10	*p* = 0.924
Trial number×Choice×Scenario×Ratio	66.46	62.57	43477.95	1.06	*p* = 0.288
Trial number×Choice×Inequality×Ratio	9.96	40.32	45794.41	0.25	*p* = 0.805
Trial number×Scenario×Inequality×Ratio	-8.41	22.08	46340.55	-0.38	*p* = 0.703
Choice×Scenario×Inequality×Ratio	40.75	61.14	45385.80	0.67	*p* = 0.505
Trial number×Choice×Cost×Ratio	-59.07	38.08	45977.19	-1.55	*p* = 0.121
Trial number×Scenario×Cost×Ratio	2.83	22.43	46364.57	0.13	*p* = 0.899
Choice×Scenario×Cost×Ratio	27.30	58.65	44765.80	0.47	*p* = 0.642
Trial number×Inequality×Cost×Ratio	-23.03	16.67	46330.29	-1.38	*p* = 0.167
Choice×Inequality×Cost×Ratio	65.75	37.47	45747.95	1.76	*p* = 0.079
Scenario×Inequality×Cost×Ratio	34.56	22.27	46351.37	1.55	*p* = 0.121
Trial number×Choice×Scenario×Inequality×Cost	-82.37	56.43	44287.02	-1.46	*p* = 0.144
Trial number×Choice×Scenario×Inequality×Ratio	27.35	60.35	45726.27	0.45	*p* = 0.650
Trial number×Choice×Scenario×Cost×Ratio	-28.45	57.30	45945.02	-0.50	*p* = 0.619
Trial number×Choice×Inequality×Cost×Ratio	70.88	37.86	46371.83	1.87	*p* = 0.061

Trial number×Scenario×Inequality×Cost×Ratio	8.77	22.44	46326.13	0.39	p = 0.696
Choice×Scenario×Inequality×Cost×Ratio	-45.65	56.79	46362.43	-0.80	p = 0.421
Trial number×Choice×Scenario×Inequality×Cost×Ratio	2.87	55.99	46361.06	0.05	p = 0.959

Table S5. Statistical results of LMM2.

Fixed effects	Estimate	SE	df	t value	P value
(Intercept)	1.61	0.09	1511	18.03	$p < 0.001$
Trial number	0.15	0.06	13730	2.43	$p = 0.015$
Choice	-0.15	0.11	4271	-1.32	$p = 0.188$
Scenario	-0.13	0.09	3146	-1.44	$p = 0.150$
Inequality	-0.08	0.07	6831	-1.14	$p = 0.253$
Cost	-0.14	0.06	21800	-2.24	$p = 0.025$
Ratio	-0.03	0.06	13370	-0.54	$p = 0.593$
Trial number×Choice	-0.06	0.09	212100	-0.65	$p = 0.519$
Trial number×Scenario	-0.06	0.08	299900	-0.71	$p = 0.475$
Choice×Scenario	0.43	0.14	76670	3.03	$p = 0.002$
Trial number×Inequality	-0.11	0.06	373600	-1.84	$p = 0.066$
Choice×Inequality	0.12	0.09	232100	1.31	$p = 0.191$
Scenario×Inequality	0.10	0.08	366100	1.24	$p = 0.216$
Trial number×Cost	-0.05	0.06	371400	-0.93	$p = 0.352$
Choice×Cost	0.20	0.09	203200	2.14	$p = 0.032$
Scenario×Cost	0.08	0.08	357100	0.98	$p = 0.325$
Inequality×Cost	0.03	0.06	366200	0.47	$p = 0.636$

Trial number×Ratio	-0.01	0.06	369100	-0.24	*p* = 0.809
Choice×Ratio	0.01	0.09	207500	0.11	*p* = 0.916
Scenario×Ratio	0.03	0.08	353300	0.38	*p* = 0.704
Inequality×Ratio	0.17	0.06	369700	2.97	*p* = 0.003
Cost×Ratio	0.02	0.06	368700	0.35	*p* = 0.729
Trial number×Choice×Scenario	0.17	0.14	313600	1.27	*p* = 0.205
Trial number×Choice×Inequality	0.08	0.09	368900	0.87	*p* = 0.382
Trial number×Scenario×Inequality	0.03	0.08	372200	0.42	*p* = 0.673
Choice×Scenario×Inequality	-0.29	0.14	296700	-2.08	*p* = 0.037
Trial number×Choice×Cost	0.01	0.09	361400	0.16	*p* = 0.877
Trial number×Scenario×Cost	0.05	0.08	372500	0.66	*p* = 0.511
Choice×Scenario×Cost	0.09	0.14	276200	0.68	*p* = 0.499
Trial number×Inequality×Cost	0.02	0.06	375300	0.31	*p* = 0.753
Choice×Inequality×Cost	0.08	0.09	358700	0.83	*p* = 0.405
Scenario×Inequality×Cost	-0.07	0.08	374900	-0.91	*p* = 0.366
Trial number×Choice×Ratio	0.01	0.09	353400	0.16	*p* = 0.874
Trial number×Scenario×Ratio	0.01	0.08	372700	0.07	*p* = 0.942
Choice×Scenario×Ratio	-0.15	0.14	318000	-1.09	*p* = 0.275
Trial number×Inequality×Ratio	0.06	0.06	375300	1.04	*p* = 0.300
Choice×Inequality×Ratio	-0.17	0.09	355600	-1.82	*p* = 0.068

Scenario×Inequality×Ratio	-0.15	0.08	374900	-1.87	*p* = 0.062
Trial number×Cost×Ratio	0.04	0.06	375300	0.73	*p* = 0.467
Choice×Cost×Ratio	-0.03	0.09	353300	-0.30	*p* = 0.762
Scenario×Cost×Ratio	-0.03	0.08	374900	-0.39	*p* = 0.694
Inequality×Cost×Ratio	-0.11	0.06	374900	-1.87	*p* = 0.061
Trial number×Choice×Scenario×Inequality	-0.15	0.14	375100	-1.12	*p* = 0.263
Trial number×Choice×Scenario×Cost	0.08	0.13	371800	0.61	*p* = 0.539
Trial number×Choice×Inequality×Cost	0.05	0.09	375400	0.57	*p* = 0.571
Trial number×Scenario×Inequality×Cost	-0.02	0.08	375400	-0.20	*p* = 0.844
Choice×Scenario×Inequality×Cost	-0.05	0.13	372800	-0.38	*p* = 0.704
Trial number×Choice×Scenario×Ratio	-0.10	0.14	372300	-0.74	*p* = 0.460
Trial number×Choice×Inequality×Ratio	0.01	0.09	375400	0.12	*p* = 0.908
Trial number×Scenario×Inequality×Ratio	-0.03	0.08	375300	-0.33	*p* = 0.744
Choice×Scenario×Inequality×Ratio	0.33	0.14	374300	2.45	*p* = 0.014
Trial number×Choice×Cost×Ratio	-0.02	0.09	375200	-0.19	*p* = 0.847
Trial number×Scenario×Cost×Ratio	-0.09	0.08	375400	-1.17	*p* = 0.243
Choice×Scenario×Cost×Ratio	-0.03	0.13	372900	-0.24	*p* = 0.810
Trial number×Inequality×Cost×Ratio	-0.05	0.06	375300	-0.88	*p* = 0.377
Choice×Inequality×Cost×Ratio	0.07	0.09	375200	0.74	*p* = 0.458
Scenario×Inequality×Cost×Ratio	0.10	0.08	375300	1.30	*p* = 0.193

Trial number×Choice×Scenario×Inequality×Cost	-0.11	0.13	375700	-0.80	*p* = 0.426
Trial number×Choice×Scenario×Inequality×Ratio	0.25	0.13	375900	1.82	*p* = 0.068
Trial number×Choice×Scenario×Cost×Ratio	0.06	0.13	375900	0.45	*p* = 0.652
Trial number×Choice×Inequality×Cost×Ratio	0.02	0.09	375400	0.26	*p* = 0.797
Trial number×Scenario×Inequality×Cost×Ratio	-0.01	0.08	375300	-0.08	*p* = 0.935
Choice×Scenario×Inequality×Cost×Ratio	-0.01	0.13	375900	-0.08	*p* = 0.937
Trial number×Choice×Scenario×Inequality×Cost×Ratio	0.10	0.13	375900	0.73	*p* = 0.466

Supplementary Figures

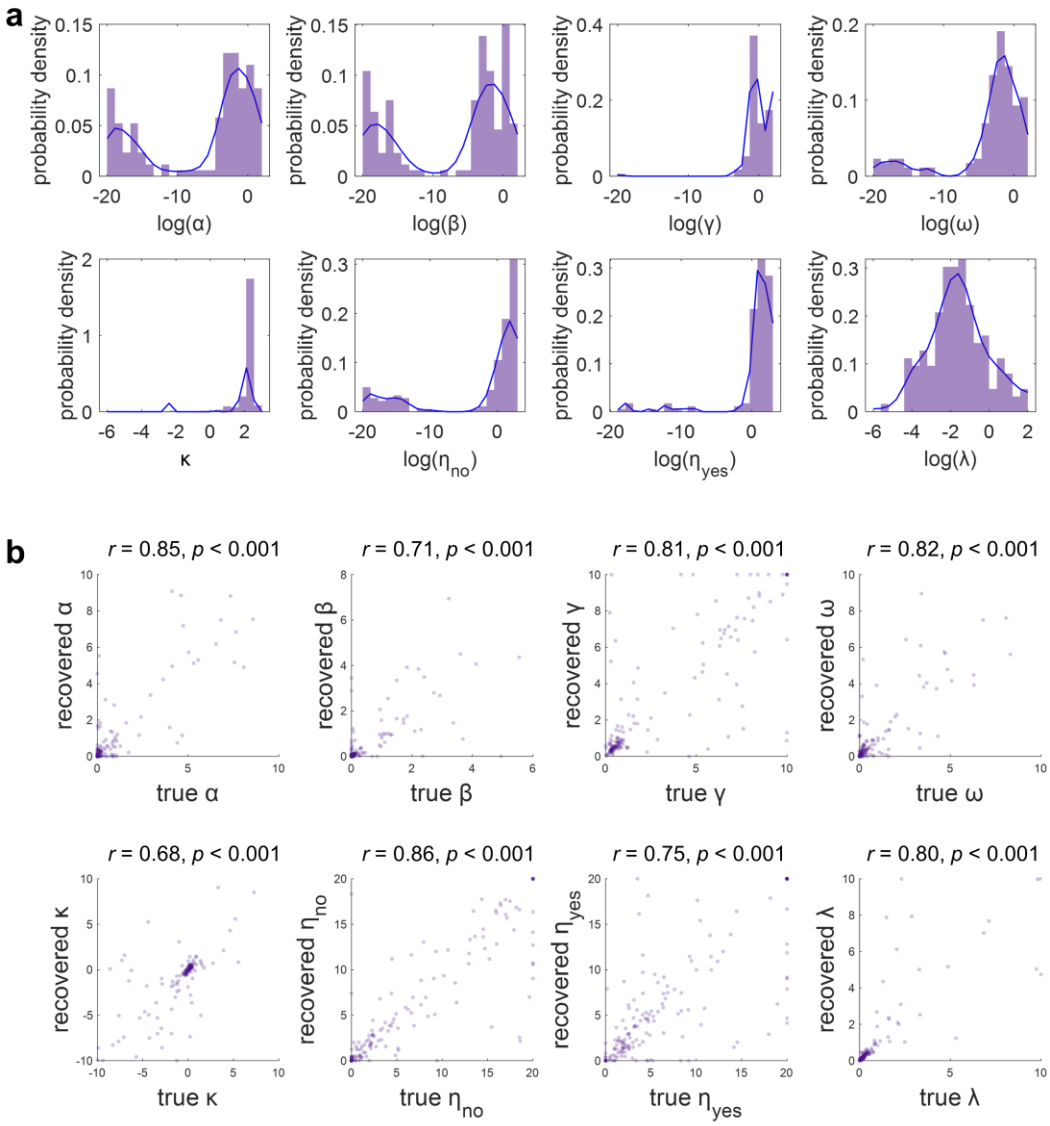

Fig. S1 | The estimated parameters and parameter identifiability analysis for Experiment 1. a, The distributions of the estimated parameters of the 157 participants for the motive cocktail model (model 7: SI+SCI+VCI+EC+RP+II). Each panel is for one parameter. The purple bars and blue curve respectively denote the histogram and its kernel fit. Except for κ, all parameters were transformed into log scale for better visualization. **b**, Results of parameter recovery for the motive cocktail model. The recovered parameters from 157 synthetic datasets are plotted against the generative parameters. Each panel is for one parameter. Each dot is for one virtual participant. The value of *r* indicates Pearson's correlation coefficient between the estimated and recovered parameters.

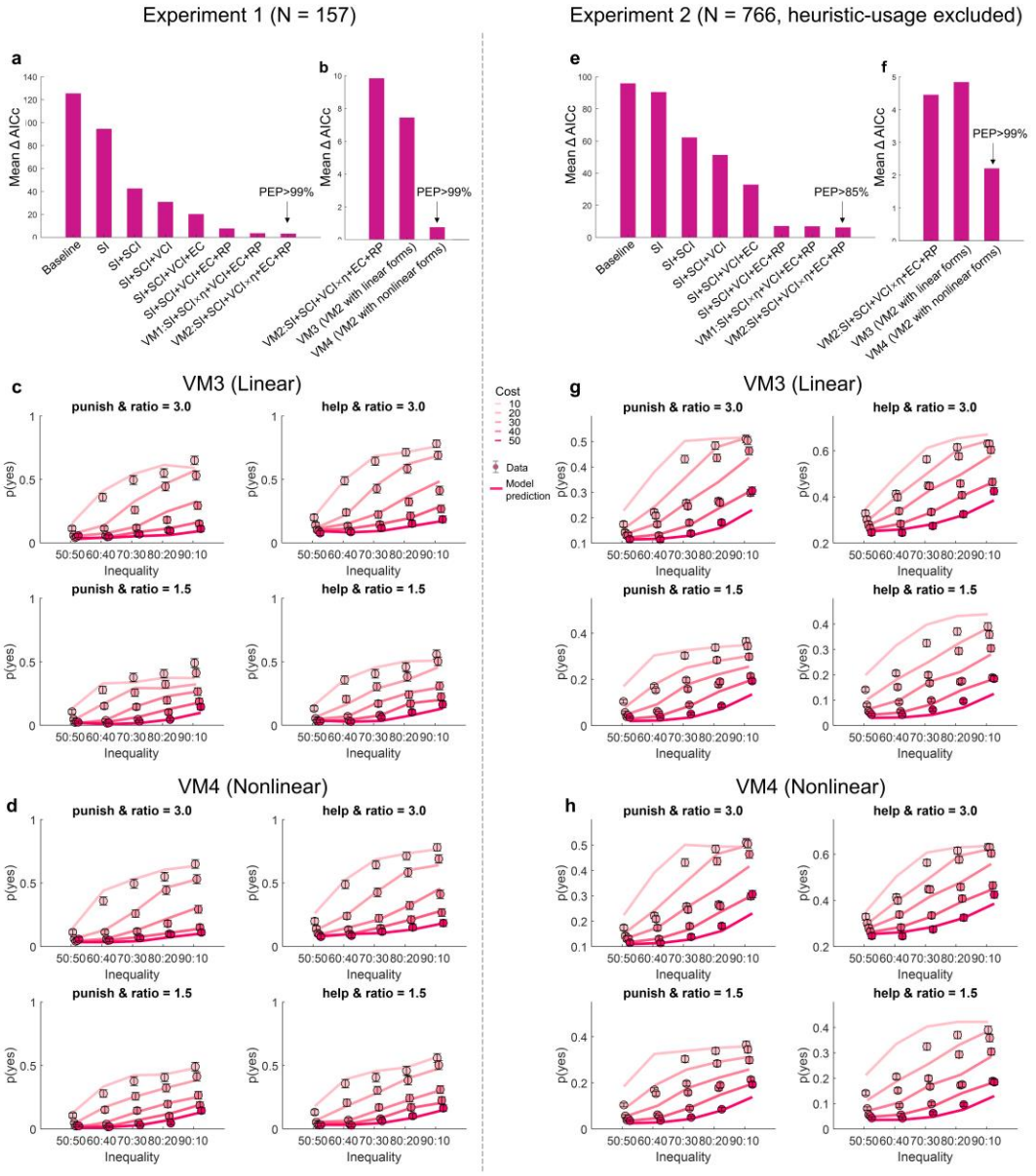

Fig. S2 | Comparisons between models without and with inequality inattention assumption for Experiment 1 (left panel) and Experiment 2 (right panel). (a&e) Model comparisons of models 1 to 6, along with VM1 and VM2. (b&f) Model comparisons of VM2, VM3 and VM4. Model predictions of VM3 (c&g) and VM4 (d&h). For figures c&d&g&h, the probability of intervention, *p*(yes), is plotted against the inequality (from 50:50 to 90:10). Different colors code different levels of intervention cost (from 10 to 50, darker color for higher cost). Each sub-panel corresponds to one scenario and impact ratio condition. The dots and error bars respectively denote the mean and SEM across participants. The solid lines denote the predictions of the models.

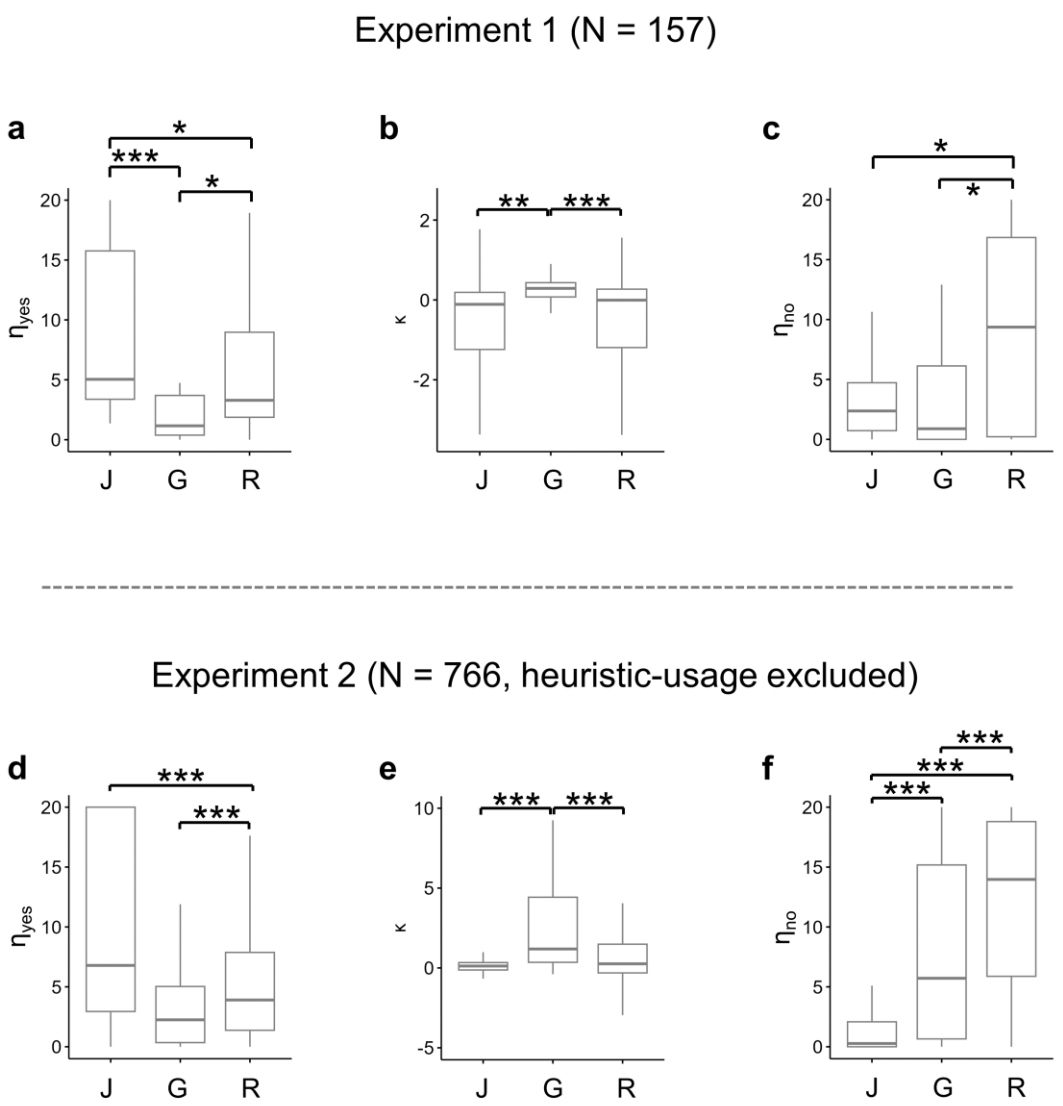

Fig. S3 | Kruskal-Wallis test on parameter η_{yes}, κ and η_{no} across three clusters of participants. For Experiment 2, participants who used simple heuristics (i.e., best fit by Model 9) were excluded from analysis. The bottom/top and middle lines of the box plot represent the first/third quartiles and the median of the data. The lines extending beyond the box refer to 1.5 times the interquartile range (IQR), which is the distance between the third quartile (Q3) and the first quartile (Q1). ***, and *: $p < 0.001$ and $p < 0.05$ after multi-comparison corrections.

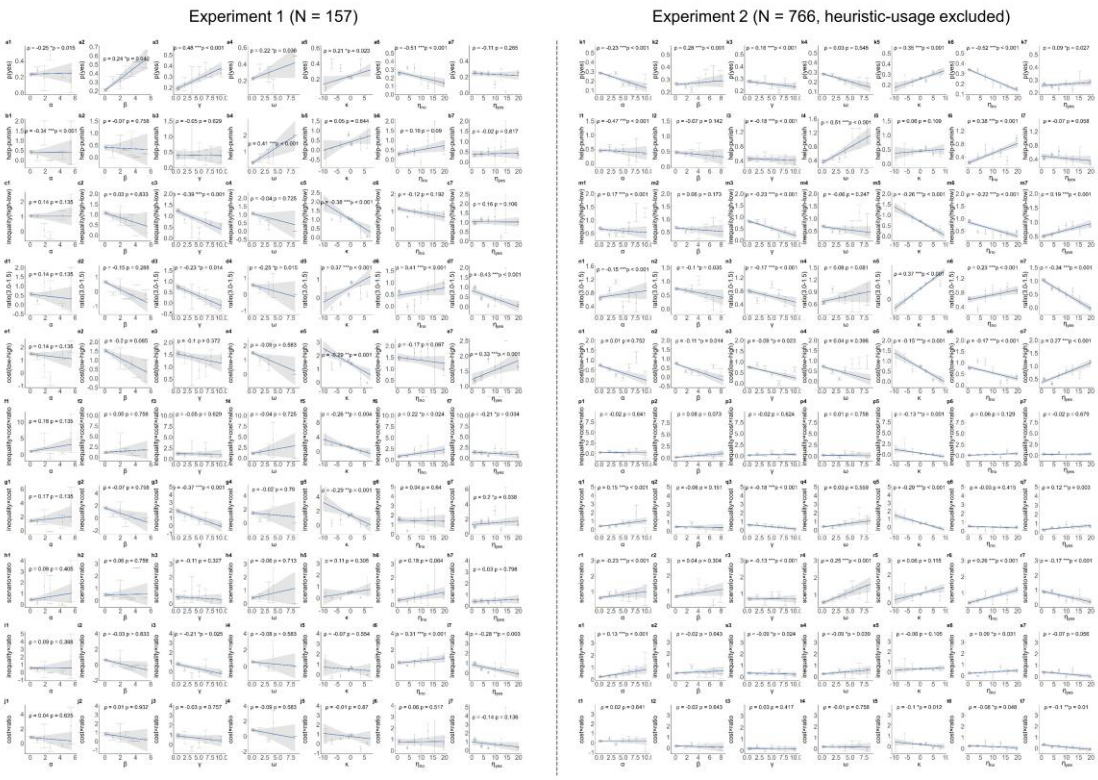

Fig. S4 | The correlations between parameters estimated from the motive cocktail model and the model-free measurements for Experiment 1 (a–j) and Experiment 2 (heuristic-usage excluded, k-t). **a & k**, The y-axis *p*(yes) represents the probability of intervention across all conditions for each participant. **b & l**, The y-axis represents relative preference to help over punish, calculated as the probability of intervention in the helping scenario relative to that in the punishment scenario, normalized by the overall *p*(yes). **c & m**, The y-axis represents the sensitivity to inequality, calculated as the probability of intervention in the high inequality trials (i.e., 70:30, 80:20, 90:10) relative to that in the low inequality trials (i.e., 50:50, 60:40), normalized by the overall *p*(yes). **d & n**, The y-axis represents the sensitivity to ratio, calculated as the intervention probability difference between high impact ratio trials (ratio = 3.0) and low impact ratio trials (ratio = 1.5), normalized by the overall *p*(yes). **e & o**, The y-axis represents the sensitivity to cost, calculated as the probability of intervention in low intervention cost trials (i.e., cost = 10, 20) minus that in high intervention cost trials (i.e., cost = 30, 40 and 50), normalized by the overall *p*(yes). **f & p**, The y-axis represents the sensitivity to inequality under different levels of cost and ratio conditions, calculated as the normalized intervention probability difference in trials with different combinations of inequality, cost, and ratio: [(high ratio & high inequality & low cost - high ratio & high inequality & high cost)- (high ratio & low inequality & low cost - high ratio & low inequality & high cost)] minus [(low ratio & high inequality & low cost - low ratio & high inequality & high cost) - (low ratio & low inequality & low cost - low ratio & low inequality & high cost)]. **g & q**, The y-axis represents the sensitivity to inequality under high-cost versus low-cost condition, calculated as the normalized intervention probability difference in trials with different combinations of inequality and cost: (high inequality & low cost – high inequality & high cost) - (low inequality & low cost – low inequality & high cost). **h & r**, The y-axis represents the relative preference to help over punish under high versus low ratio conditions, calculated as the normalized

intervention probability difference in trials with different combinations of scenario and ratio: (help & high ratio – help & low ratio) minus (punish & high ratio – punish & low ratio). **i & s**, The y-axis represents the sensitivity to inequality under high versus low ratio conditions, calculated as the normalized intervention probability difference in trials with different combinations of inequality and ratio: (high inequality & high ratio – high inequality & low ratio) minus (low inequality & high ratio – low inequality & low ratio). **j & t**, The y-axis represent the sensitivity to cost in high versus low ratio conditions, calculated as the normalized intervention probability difference in trials with different combination of cost and ratio: (low cost & high ratio – low cost & low ratio) minus (high cost & high ratio – high cost & low ratio). The x-axis for each column corresponds to one motive parameter of the motive cocktail model. Each panel illustrates the relationship between a motive parameter and a behavioral measure, with the x-axis divided into 8 bins across participants, and the y-axis displaying the mean (points) and standard deviation (error bars) within the corresponding bin. The blue line in each plot represents a linear regression between the original x and y coordinates (i.e., no bins), while the shaded area indicates the 95% confidence interval. The ρ denotes partial correlation coefficient after controlling all other parameters. The p value was corrected for multiple comparisons using FDR.

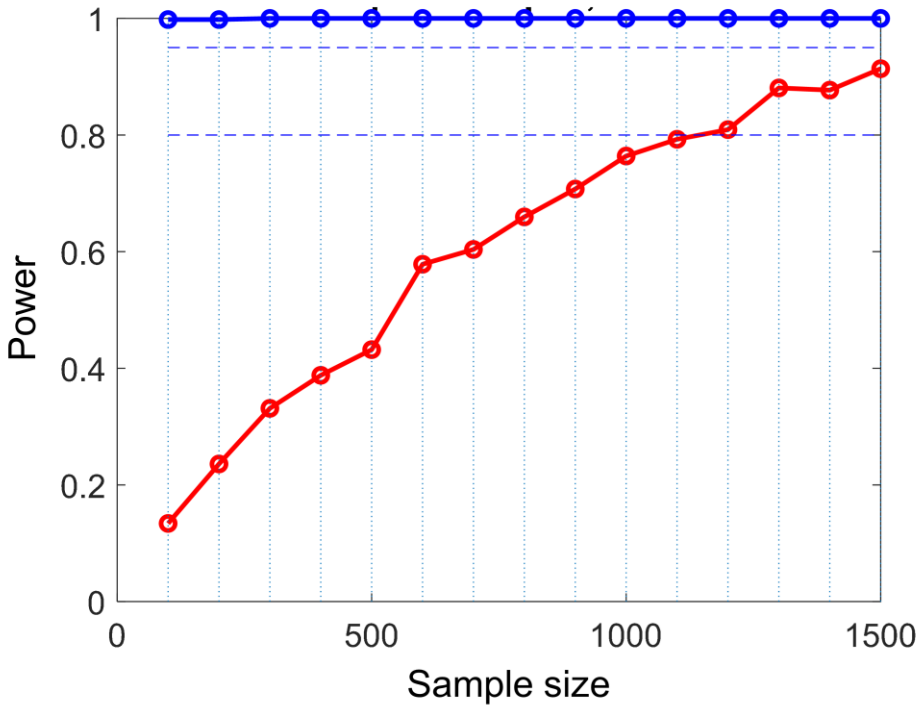

Fig. S5 | Power analysis to determine the sample size in Experiment 2. We used a parametric simulation method derived from our best fitting model (model 8: motive cocktail model + lapse rate) to pre-determine the sample size in Experiment 2. The x-axis is the sample size. The y-axis denotes the power, which is defined as the percentage of significance for an effect across all synthetic datasets within a specific sample size. The red line denotes the power curve obtained from the three-way interaction of inequality × cost × ratio. The blue line is obtained from the two-way interaction of inequality × cost and acted as a sanity check to the red line. The simulation result indicates the 80% power criterion can be achieved with at least 1200 participants.

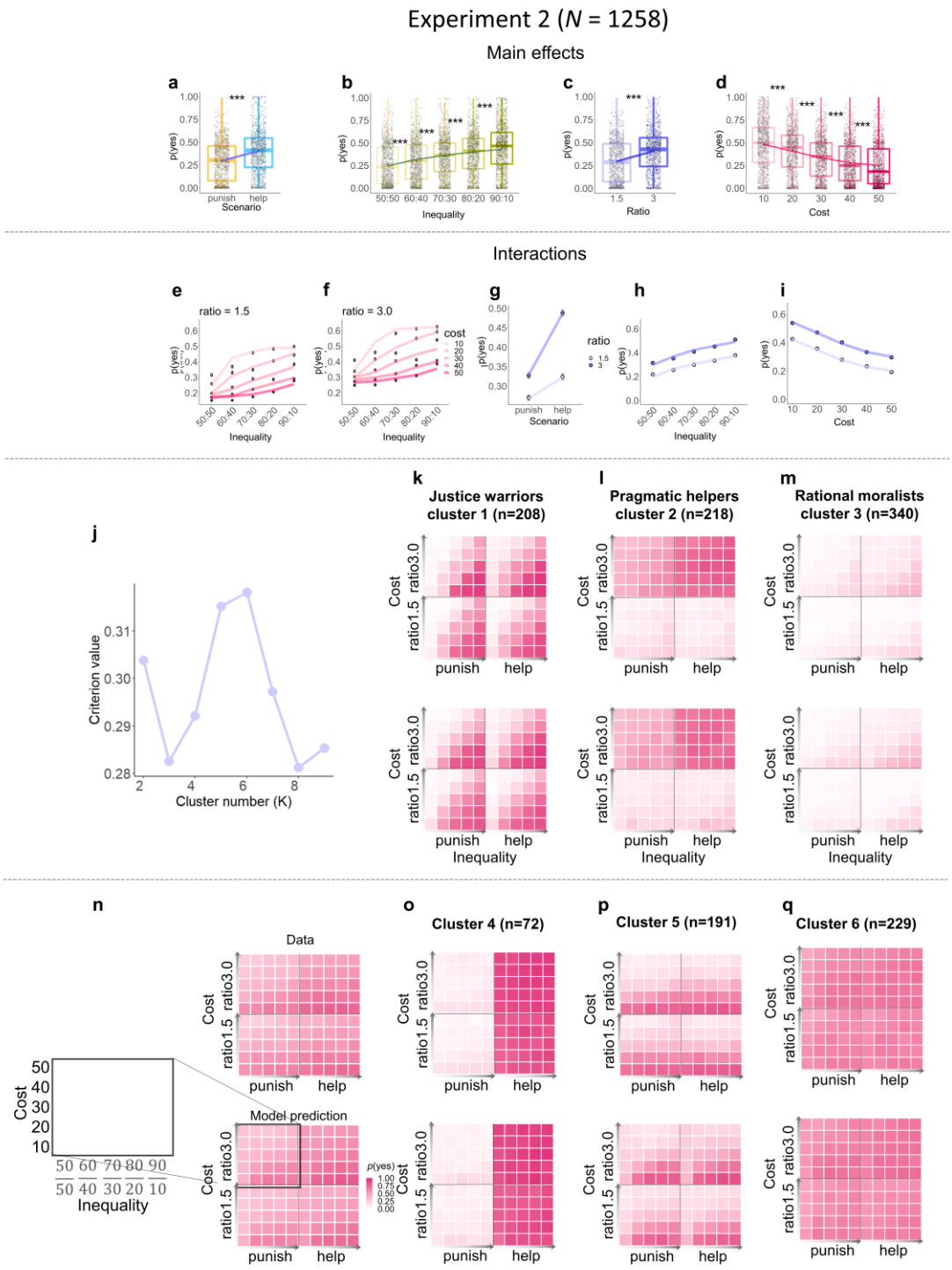

Fig. S6 | All major findings of Experiment 1 were replicated in Experiment 2. **a–d**, The main effects of scenario (a), inequality (b), ratio (c) and cost (d) on choice. **e–f**, The interaction of inequality × cost × ratio. **g**, The interaction of scenario × ratio. **h**, The interaction of inequality × ratio. **i**, The interaction of cost × ratio. **j**, Participants in Experiment 2 can be best classified as 6 clusters. **k–m**, The intervention patterns of the first three clusters of participants in Experiment 2: justice warriors, pragmatic helpers and rational moralists. **n–q**, Intervention probability of participants in the remaining 3 clusters. The participants'

intervention patterns of the newly observed three clusters in Experiment 2 were best fit by a heuristic model (model 9). The x-axis of the heatmap is the severity of inequality from near equality (left, 50:50) to extreme inequality (right, 90:10). The y-axis of the heatmap is the cost of intervention from low cost (bottom, 10) to high cost (up, 50). The darker color on the heatmap represents a higher probability of intervention. The sub-maps on the upper left, upper right, bottom left and bottom right corners represent 4 sub-conditions.

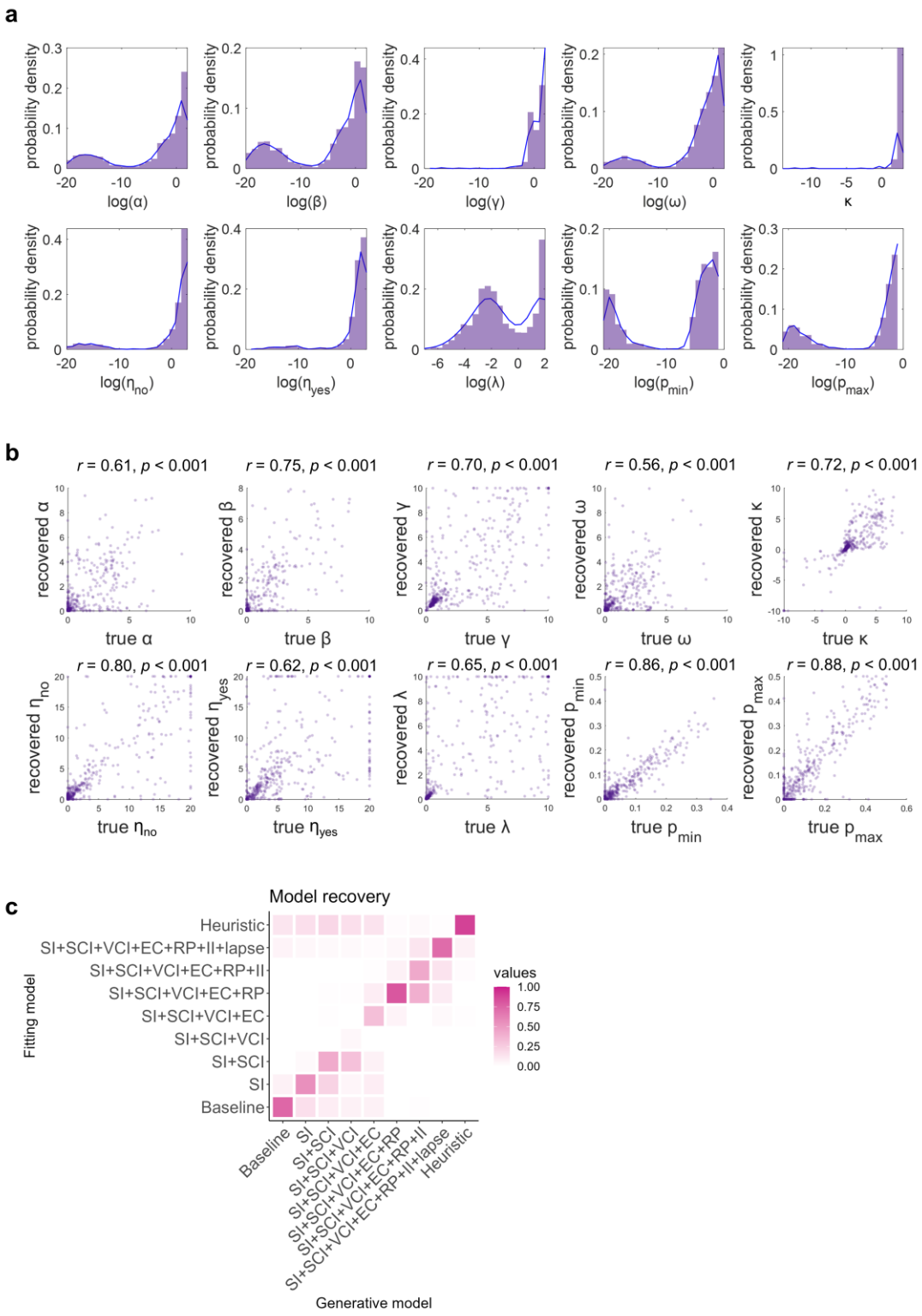

Fig. S7. **Parameter identifiability and model recovery analyses for Experiment 2. a**, The true parameter distributions for the winning model (model 8: motive cocktail model + lapse). The histogram on each panel is plotted based on a specific parameter of 1258 participants. The blue line is an approximation for the parameter distribution across all participants fitted by a kernel-smoothing function. **b**, Parameter recovery for the full model (model 8). The recovered parameters from the synthetic datasets are plotted

against the estimated parameters from the real data. Each panel is for one parameter. Each dot is for one virtual subject. The value of *r* indicates Pearson's correlation coefficient between the estimated and recovered parameters. **c**, Model recovery analysis. Each column and row are for one specific model that was used to generate synthetic datasets and fitted to the synthetic datasets respectively. The darker color in each cell represents a higher probability that the generative model can be best explained by a specific model.

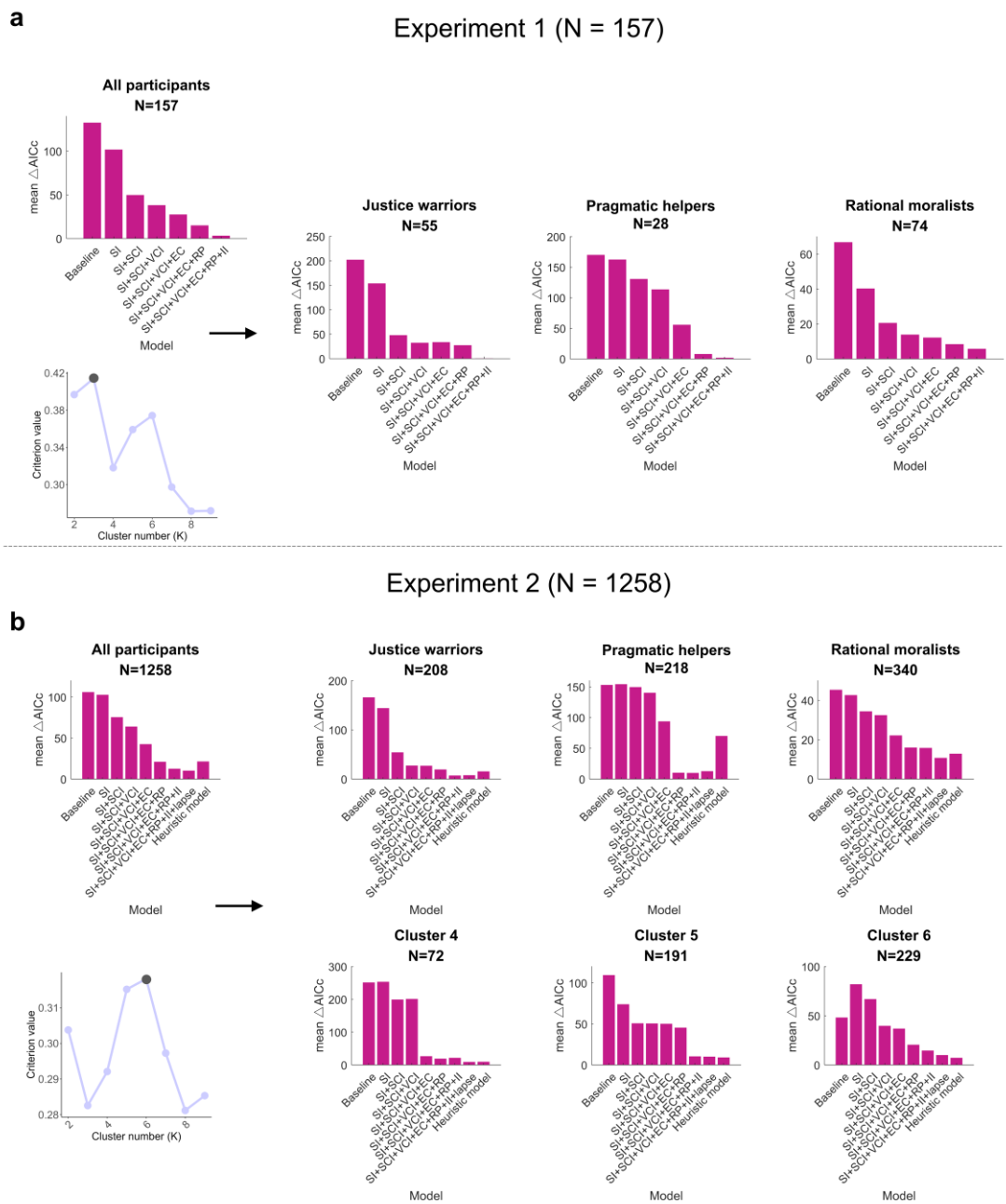

Fig. S8 | Model comparisons for participants in each cluster. **a**, Participants in Experiment 1 are best classified into 3 clusters, with all of them best accounted by the motive cocktail model. **b**, Participants in Experiment 2 are best classified into 6 clusters, with the first 3 clusters best accounted for by the motive cocktail model (model 7 or its derivative model 8: motive cocktail model + lapse rates) and the remaining 3 clusters best by model 9 (heuristic model).

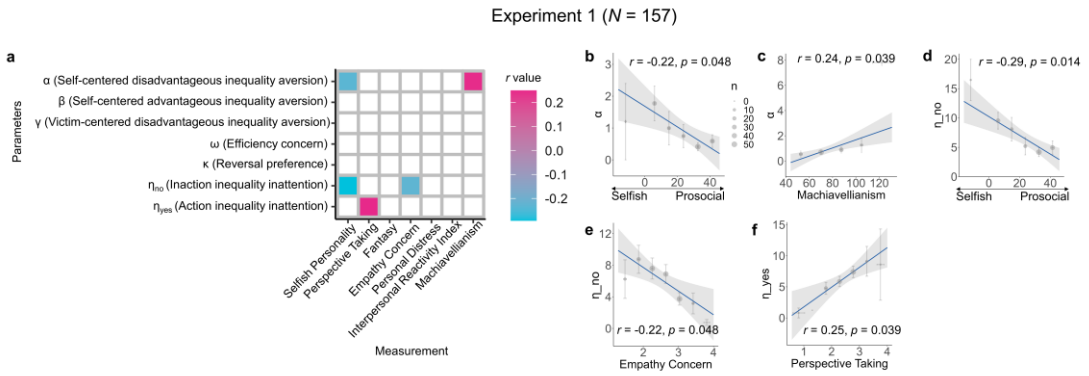

Fig. S9 | The correlation between free parameters in the motive cocktail model and personality measurements in Experiment 1. a, The correlation confusion matrix. For the personality measurement, the Selfish Personality was assessed by SVO (Murphy et al., 2011); Perspective Taking, Fantasy, Empathy Concern, Personal Distress and Interpersonal Reactivity Index were assessed by IRI (Davis, 1983); and Machiavellianism was assessed by MACH–IV (Rauthmann, 2013). Colored cells denote significant correlations, with warm and cool color representing the positive and negative correlation values. **b - f**, Regression plot for the six significant correlations. The *r* denotes Pearson's correlation coefficient. The *p* value was corrected for multiple comparisons using FDR.

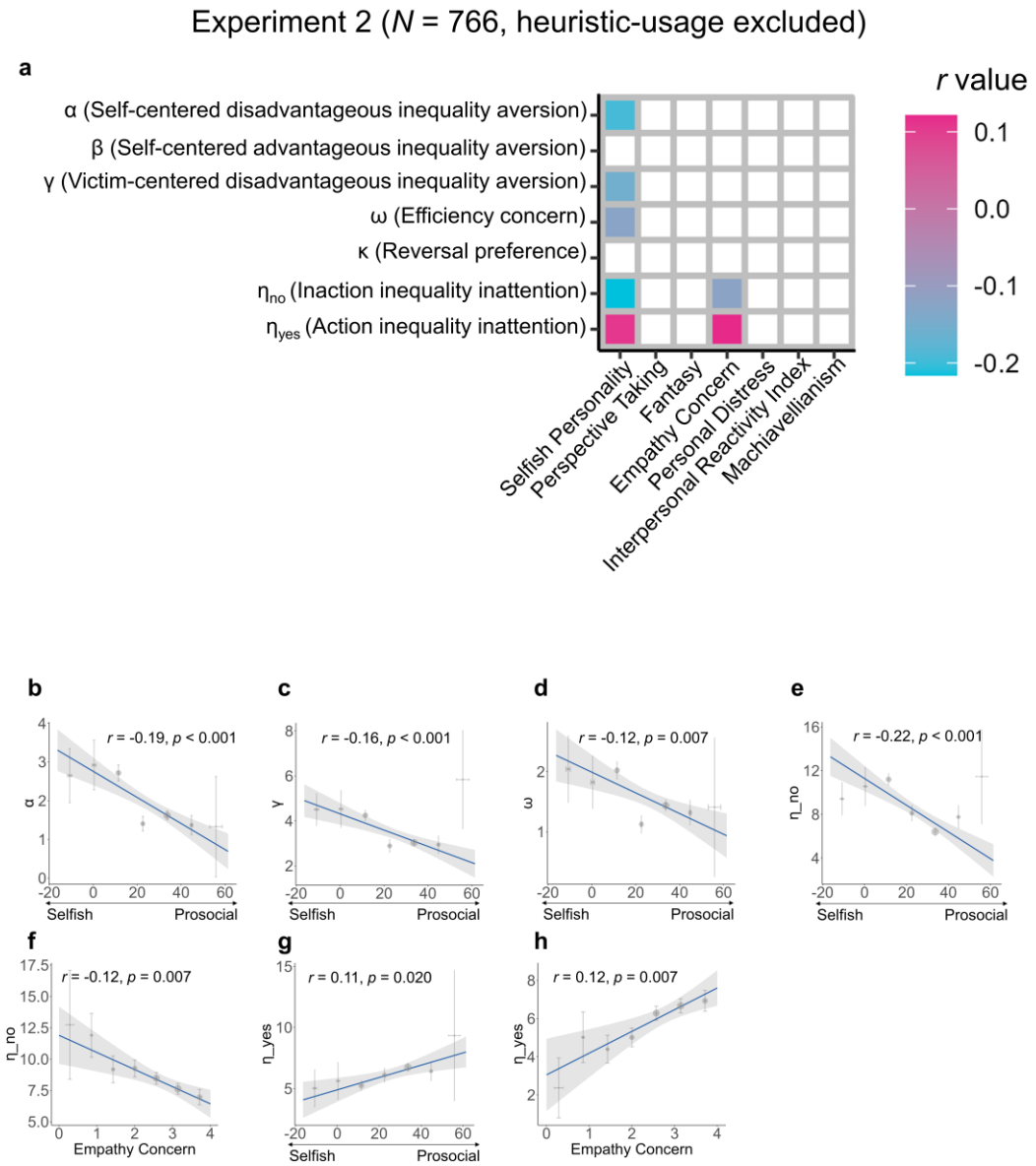

Fig. S10 | The correlation between the estimated parameters from the motive cocktail model (with lapse rate; model 8) and personality measurements for justice warriors, pragmatic helpers and rational moralists in Experiment 2. Participants who used simple heuristics (i.e., best fit by Model 9) were excluded from analysis. **a**, The correlation confusion matrix. For the measurement, the Selfish Personality was assessed by SVO (Murphy et al., 2011); Perspective Taking, Fantasy, Empathy Concern, Personal Distress and Interpersonal Reactivity Index were assessed by IRI (Davis, 1983); and Machiavellianism was assessed by MACH–IV (Rauthmann, 2013). Colored cells denote significant correlations, with warm and cool color representing the positive and negative correlation values. **b**–**h**, Regression plot for the seven significant correlations. All results reported here are corrected by FDR.

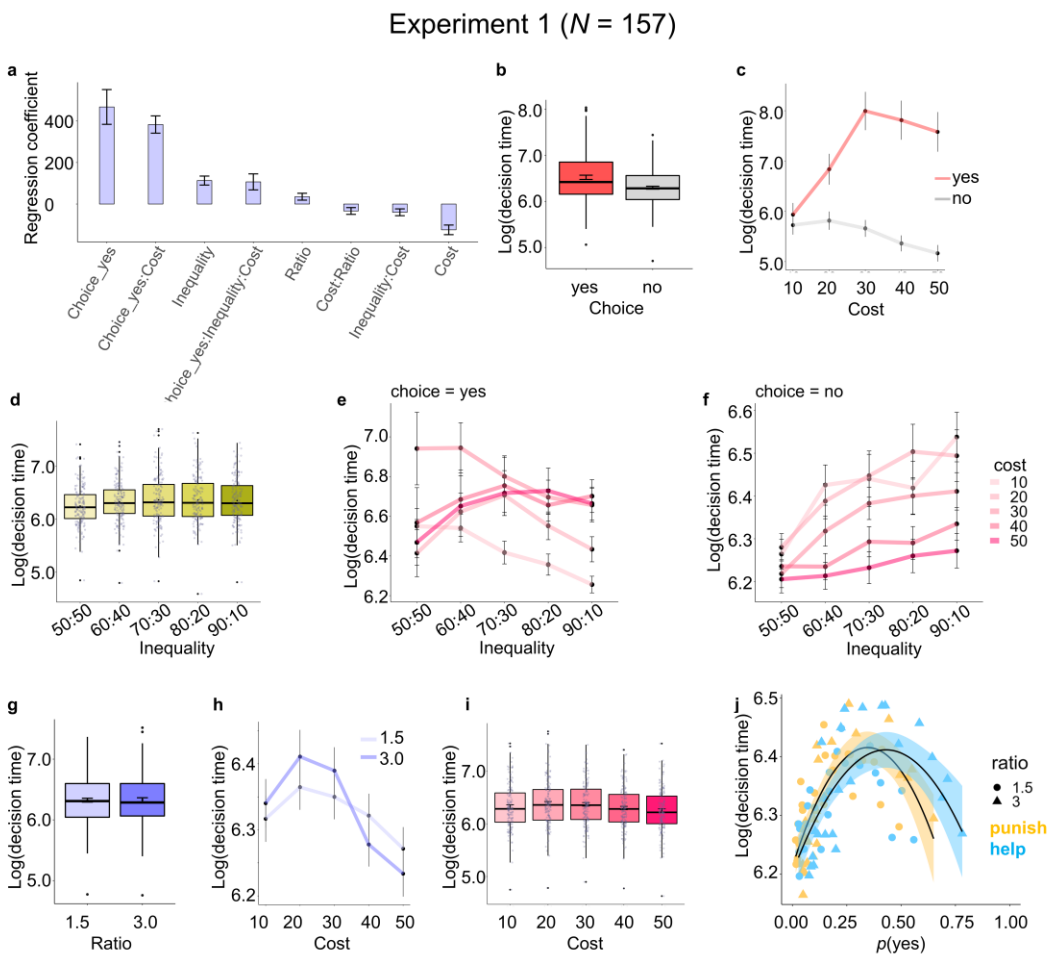

Fig. S11 | Results of decision times in Experiment 1. a, The variables that can significantly predict intervention decision time. A linear mixed-effect model was developed to assess the influence of all manipulated variables, participants' choice and their interactions on participants' decision time (see LMM1 and Table S4 for more details). Only the regression coefficients that were statistically significant are plotted. Figures **b - i** are further exhibitions of the effects shown in **a**. Decision time in y-axis (unit: milliseconds) was transformed into log-scale for readability. **b**, The main effect of choice on decision time. The average decision time when participants chose "yes" is longer than they chose "no". **c**, The interaction effect of cost × choice on decision time. In "yes" trials where participants decided to intervene, their decision time increases non-monotonically as intervention cost rises. While in "no" trials, participants' decision time monotonically decreases with rising cost. **d**, The main effect of inequality on decision time. Participants' decision time increases with the increasing inequality severity. **e - f**, The interaction effect of inequality × cost × choice on decision time. The interaction effect of inequality × cost is modulated by participants' choice. In "yes" trials, participants' decision time increases with inequality severity when the intervention cost is high, but decreases with inequality severity when the cost is low and moderately high. In "no" trials, participants' decision time consistently increases with the increasing inequality severity within each intervention cost condition and decreases overall as intervention cost rises. **g**, The main effect of ratio on decision time. Participants' overall decision time is longer in the high-impact ratio condition than in the

low-impact ratio condition. **h**, The interaction effect of cost × ratio on decision time. Participants' decision time changes as an inverse-U shape as intervention cost rises. The high-impact ratio triggers a larger extent of amplitude change in the decision time. **i**, The main effect of cost on decision time. Participants' decision time decreases overall as intervention cost increases. **j**, The bell-shape relationship between participants' decision time (y-axis) and their intervention probability (x-axis) either in punishment (orange) or helping (cyan) scenario. Black curves denote the prediction of the multivariable nonlinear function. Shadings denote the SEM. For figures **a**, **c**, **e**, **f**, **h**, the bars or the dots represent mean value of measured variables across all participants, and the error bars denote SEM. For figures **b**, **d**, **g** and **i**, the bottom/top and middle lines of the box respectively indicate the first/third quartiles (Q1/Q3) and the median; the whiskers represent 1.5 times the IQR, which is the distance between the Q3 and the Q1. Data points beyond 1.5 times the IQR from the upper and lower quartiles are considered outliers and are represented by the filled points.

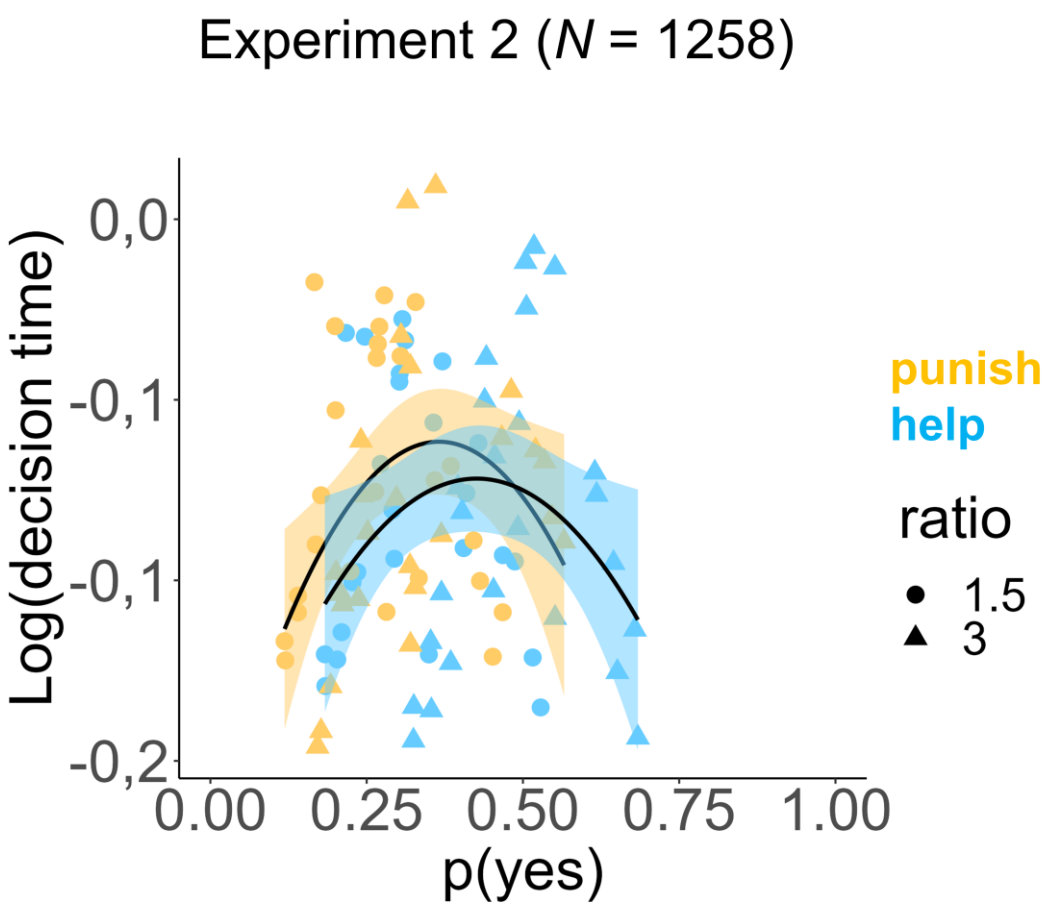

Fig. S12 | The inverted-U shape between decision times and intervention probability in Experiment 2. The bell-shape relationship between participants' decision time (y-axis) and their intervention probability (x-axis) either in punishment (orange) or helping (cyan) scenario. Black curves denote the prediction of the multivariable nonlinear function. Shadings denote the SEM.

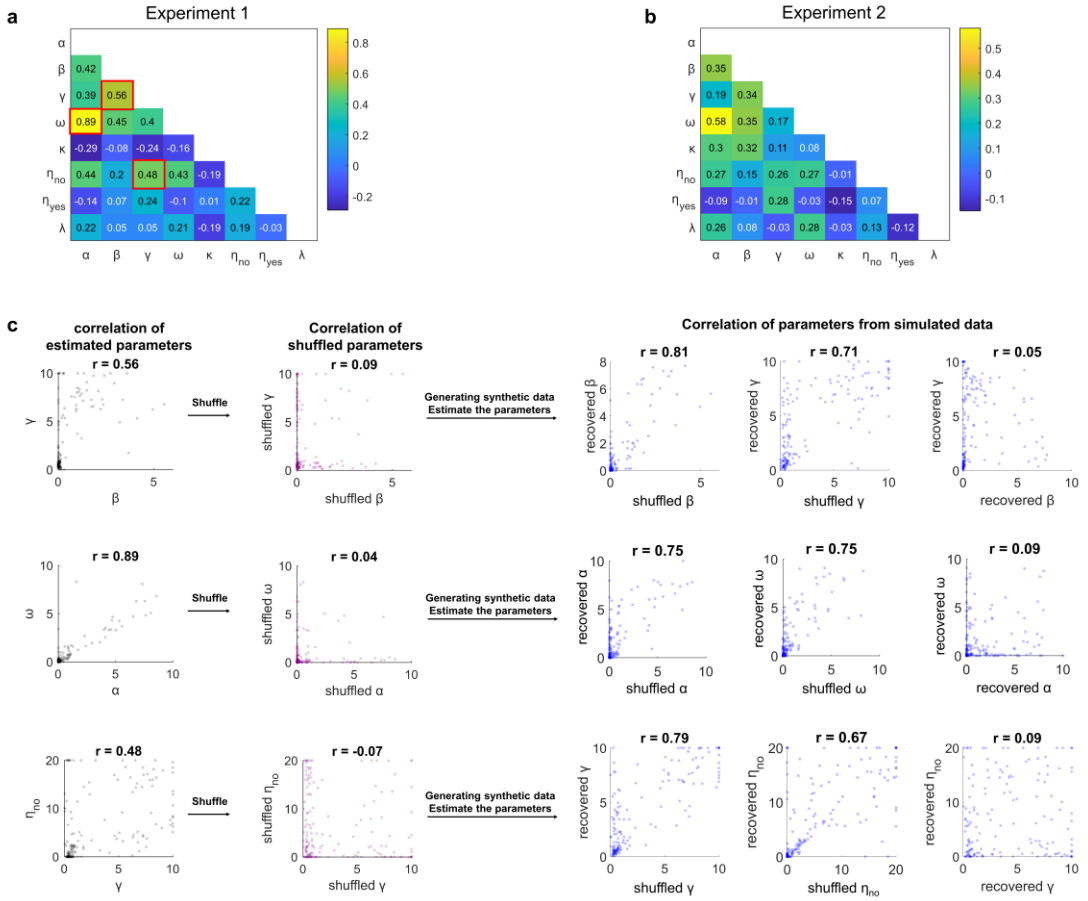

Fig. S13 | Redundancy checks on the parameter space in the motive cocktail model. **a–b**, Correlation matrix of parameters for Experiment 1 and Experiment 2. Colors code Pearson's *r*, where more yellow (blue) corresponds to a more positive (negative) correlation. Three high correlations (framed in red) between parameters β and γ, α and ω, γ and η_{no} across all participants were examined. **c**, No evidence supports parameter redundancy. We used the following method to reject the possibility of parameter redundancy: we first shuffled the relationship between parameters across participants to decrease their correlation coefficient (Pearson's *r*, see column1 and column 2). The shuffled parameters were assigned to each participant randomly and used to generate synthetic intervention decisions, which were then used to fit the full motive cocktail model. If the high correlation pairs we observed in the real data were due to parameter redundancy, we would expect high correlations between the recovered parameters, although their correlations had been eliminated. In contrast, we observed the shuffled parameters are recoverable (columns 3 and 4) and more importantly, there is no correlation between the recovered parameters, in line with the shuffled pattern. These results suggest that the high correlations observed between β and γ, between α and ω, and between γ and η_{no} reflected human participants' behavioral characteristics instead of redundancy in the model itself.

Supplemental References

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113. https://doi.org/10.1037/0022-3514.44.1.113

Murphy, R. O., Ackermann, K. A., & Handgraaf, M. (2011). Measuring Social Value Orientation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1804189

Rauthmann, J. F. (2013). Investigating the MACH–IV With Item Response Theory and Proposing the Trimmed MACH*. *Journal of Personality Assessment*, *95*(4), 388–397. https://doi.org/10.1080/00223891.2012.742905

Scott, J. (2000). Rational choice theory. *Understanding Contemporary Society: Theories of the Present*, *129. Jg.*, 126–138. https://doi.org/10.4135/9781446218310.n9