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Effort-based decision making in joint action: Evidence of a sense of fairness☆

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ABSTRACT

As humans, we are unique with respect to the flexibility and scope of our cooperative behavior. In recent years, considerable research has been devoted to investigating the psychological mechanisms which support this. One key finding is that people frequently calibrate their effort level to match a cooperation partner's effort costs - although little is known about exactly why they do so. We hypothesized that people calibrate with the ultimate goal of attracting and keeping good collaboration partners, with the proximal psychological motive being a preference for fairness. Across four lab-based, pre-registered experiments ($N = 142$), we found support for these hypotheses, and distinguished them from plausible alternative explanations, such as the conjecture that people may use their partner's effort costs as information to infer the value of opportunities afforded by their environment, and the conjecture that people may calibrate their effort investment in order to appear competent.

Statement of relevance: As humans, we have unique skills and motivations for acting together. Crucially, acting together requires effort and a growing body of empirical work on cooperation and joint action suggests that people calibrate their effort level to match that of a partner's effort costs - although little is known about the mechanisms leading them to do so. Our findings show that people calibrate their effort investment in joint action with the ultimate goal of attracting and keeping good collaboration partners and that the psychological mechanism that drives them to do so is a preference for fairness. These findings provide a valuable addition to existing research on the sense of fairness, providing evidence that the sense of fairness leads people not only to distribute resources according to individual effort costs but to distribute effort costs according to the expected reward distribution as well.

As humans, we have unique skills and motivations for acting together (Nowak, 2006; Sebanz et al., 2006; Tomasello et al., 2012). Crucially, acting together requires effort - and recent empirical research on joint action has begun focusing on how people negotiate economies of effort. In one line of research (Chennells & Michael, 2018; Székely & Michael, 2018), it has been found that people make use of perceptual cues to infer a partner's investment of effort and aim to calibrate their effort level to match that of their partner's effort costs - however, these studies do not resolve the question as to why, or under what circumstances, people do so.

Research on the evolution of cooperation provides a tentative explanation. In particular, recent research on strategies for cooperation in biological markets suggests that when individuals can choose partners, this can lead to selection pressure favoring psychological adaptations for choosing, attracting and maintaining good collaboration partners (Barclay, 2013; Barclay & Willer, 2007). Building on this, one may speculate that people calibrate their effort investment in joint action with the ultimate goal of attracting and retaining good collaboration partners (*The relationship-directed effort calibration hypothesis*).

If it is true that people tend to calibrate their effort investment in joint action with this ultimate goal, what proximal psychological motives drive them to do so? One possibility is linked to fairness. A growing body of theoretical and empirical work suggests that our sense of fairness evolved over the course of human evolution through bargaining over opportunity costs in the context of partner selection, and that our sense of fairness involves a preference for divisions of rewards that are

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proportional to contributions (André & Baumard, 2011; Baumard et al., 2013; Debove et al., 2017; Frohlich, Oppenheimer, & Kurki, 2004; Hamann et al., 2014; Kanngiesser & Warneken, 2012). This research has established that people are highly sensitive to the distribution of effort costs, and that reward distribution is governed by a sense of fairness which takes effort investments into account. Extending these results, Székely & Michael (2023) recently provided evidence that the sense of fairness leads people to distribute effort costs according to the expected reward distribution. This ability is important because in many contexts the success of joint action is uncertain and/or the reward is indivisible. For example, hunting and foraging in ancestral environments were uncertain endeavors, and sometimes did not yield any reward to distribute. In such instances, it would have been important to exhibit a sense of fairness by investing effort equally. This line of reasoning leads us to the following hypothesis: when people expect to share the reward of the joint task equally, we should expect them to ensure fairness by calibrating their effort investment such as to reduce inequity with respect to joint action partners' effort investment (*The equity through effort calibration hypothesis*).

The current study was designed to test the hypothesis that people calibrate their effort investment in joint action with the ultimate goal of attracting and retaining good collaboration partners, and that the proximal psychological motive that drives them to do so is a preference for fairness. In doing so, it is crucially important to distinguish an alternative explanation arising from the fact that sometimes the value of opportunities afforded by the environment is uncertain. In such circumstances, one may use others' investment of effort to infer the reward value they anticipate from an action. For example, if the partner is pursuing a high-cost plan of action, one can infer that the partner expects a high reward. Accordingly, people may use their partner's effort costs as information to infer the value of opportunities afforded by their environment, which may lead them to adjust their effort investment as a function of the inferred value (The *environment-directed effort calibration hypothesis*).

While we believe that there are compelling theoretical reasons to expect that both types of effort calibration (environment-directed and relationship-directed effort calibration) are present in most participants and mutually compatible in most situations, we aimed to create scenarios in which the two motives (and thus the two hypotheses) would not be confounded, but would instead be pitted against each other. Theoretically, we remain neutral as to whether one of the two motives for effort calibration may dominate over the other, whether they cancel each other out, or even whether different participants may be more strongly motivated by one or the other.

In the experiments, we implemented a social effort lottery task with an unknown reward (1 or 5 points). In Experiment 1, the rewards were sometimes the same (Congruent) and sometimes the opposite (Incongruent) for the participant and the partner, and we also manipulated the partner's effort level (High and Low). We reasoned that if participants use the perception of their partner's effort investment as an input to infer the reward value of a trial, then in the Congruent condition (same reward value) we should expect participants to invest more effort in the High Partner Effort condition than in the Low Partner Effort condition, while in the Incongruent condition (opposite reward value), they should invest more effort in the Low Partner Effort condition than in the High Partner Effort condition. In contrast, if participants use the perception of their partner's effort investment to ensure fairness by calibrating their effort investment such as to reduce inequity with respect to joint action partners' effort investment, then we should expect participants to invest more effort in the High Partner Effort condition than in the Low Partner Effort condition regardless of Congruence. It is important to emphasize a crucial aspect of the experimental design: in the Incongruent condition, the optimal strategy to maximize subjective utility in the context of the task is to engage in inverse effort matching ("when my partner invests low effort, I invest high effort, and vice-versa"). Consequently, if participants match their partner's effort in the Incongruent condition, they would incur a cost not just to themselves but also to their partner.

The second and third experiments were designed to rule out an alternative explanation which may equally explain effort calibration in joint action with the ultimate goal of attracting and retaining good collaboration partners. People may be motivated to appear competent and efficient as a means of increasing their value as collaborative partners. Therefore, people may calibrate their effort investment to their partner's belief about the potential reward value of their action (*The appearance of being competent hypothesis*).

In Experiment 2, we again manipulated 1) participants' beliefs about the reward structure of the task (Congruent and Incongruent), and 2) partner's effort (High and Low). But in Experiment 2, unlike Experiment 1, participants were informed that their partner always believed that they were in the Congruent reward structure. This made it possible to control for an alternative explanation for Experiment 1, namely that different subsets of participants may have drawn different inferences about whether their partner was aware that the reward structures were opposite in the Incongruent condition, and accordingly have felt the need either to match their partner's effort level or to do the opposite in order to appear as competent collaboration partners (The appearance of being competent hypothesis).

In Experiment 3, we again manipulated 1) partner's effort (High and Low). Moreover, instead of manipulating the Congruence of reward structure, participants were tested in an uncertain reward structure – that is, participants did not know whether they were in a Congruent or Incongruent condition. In addition, in Experiment 3 participants were informed that their partner always believed that they were in an incongruent reward structure. This design enabled us to distinguish the equity through effort calibration hypothesis from the appearance of being competent hypothesis while ensuring that environment-directed calibration would not play a role in their decision-making. While the equity through effort calibration hypothesis predicts that participants should match their partner's effort more in the High Partner Effort condition than in the Low Partner Effort condition in order to appear as fair collaboration partners, the appearance of being competent hypothesis generates the opposite prediction.

The fourth experiment was designed to test to what extent people's tendency to achieve equity through effort calibration depends on their belief that their reputation is exposed in the cooperation partner market. To this end, we manipulated 1) partner's effort (High and Low) and 2) participants' belief about the identity of their partner (Human partner and Computer partner). Our rationale for this was that, insofar as participants were motivated to appear fair and thus to retain a good reputation as a cooperation partner, their tendency to match their a partner's effort investment should decrease when they are informed that the partner is a computer. Moreover, instead of manipulating the Congruence of reward structure, participants were tested in an incongruent reward structure – that is, participants were led to correctly believe that when their partner could earn a high reward for a trial, then they could earn a low reward, and when their partner could earn a low reward for a trial, then they could earn a high reward. Participants were informed that their partner always believed that they were in a congruent reward structure. We predicted that those participants who matched their partner's effort, that is, who invested more effort in the High Partner Effort condition than in the Low Partner Effort condition within the context of a human partner (RDC group), would not do so within the context of a computer partner. Moreover, we predicted that those participants who invested effort efficiently, that is, who invested more effort in the Low Partner Effort condition than in the High Partner Effort condition within the context of a human partner (EDC group), would behave similarly within the context of a computer partner.

In addition, in Experiment 4, we also measured participants' explicit judgments about fairness using two hypothetical scenarios, in which we manipulated whether a joint action partner prefers equity in terms of effort and gains over utility maximization for the team, or vice-versa. This enabled us to investigate to what extent people's tendency to match their partner's effort or to invest effort efficiently is reflected in people's explicit beliefs about fairness. We predicted that those participants who matched their partner's effort on the primary behavioral task would judge a course of action that involves equity as more fair than a course of action that involves utility maximization for the team. In contrast, we predicted that those participants who engaged in environment-directed effort calibration on the primary behavioral task would judge a course of action that involves utility maximization for the team as more fair than a course of action that involves equity. Furthermore, we also measured participants on Singelis' Self-Construal Scale. This enabled us to investigate to what extent people's tendency to match their partner's effort or to invest effort efficiently is also reflected in their self-construal (independent/interdependent). Here, we did not have clear predictions. On the one hand, one may reasont that those who invest effort efficiently place less value on the joint outcome than on their own outcome, and that those who match effort care more about equity than about the sheer quantity of rewards or efficiency. On this interpretation, one should expect that the effort matchers would be more interdependent than those who invested effort efficiently. On a second interpretation, however, one may speculate that those who match their partner's effort are willing to incur costs to the dyad for their own reputational gain. On this interpretation, one should expect the effort matchers to be more independent than those who invest effort efficiently and increase their partner's payoff the most.

1. Experiment 1

1.1. Method

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

1.1.1. Participants

Using G*power (Faul et al., 2009), we determined that a sample size of 40 participants provides 80% power to detect an effect size of f = 0.1876 or greater in a repeated measures ANOVA with a 5% false-positive rate. During the data collection process, we excluded one pair whose members knew each other prior to participation. The sample includes twenty pairs of individuals (29 female, M_{age} = 24.37 years, SD_{age} = 3.32 years). We did not exclude any data point from the analysis. Participants carried out the experiment in pairs; members in each pair did not know each other prior to participation. Participants were recruited through (removed for double-blind review), were naïve to the purpose of the study, and reported normal or corrected to normal vision. All participants gave their informed written consent prior to the experiment and received gift vouchers for their participation. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by (removed for double-blind review).

1.1.2. Apparatus and stimuli

The experiment was displayed on a 13-in. computer screen (resolution: 2560 × 1600 pixels, refresh rate: 60 Hz). The program for the experiment was written in Python (Peirce, 2007).

1.1.3. Procedure

Participants were first introduced to another participant in the waiting area, whom they were told would be their partner for the experiment, and who would be playing in the adjacent room (in fact, both of them were playing with a virtual partner controlled by the computer, so that maximum experimental control could be maintained). They were informed that their task was to collect points together with their partner and each point increased the probability of getting a bonus at the end of the experiment. Crucially, they were informed that the bonus would be evenly divided between them.

On the effort lottery task, participants had to repeatedly press a button to reach a target in order to obtain an unknown reward (1 or 5 points). When they reached or surpassed the target, they received points. Critically, the target was invisible, so participants could not know whether or not they had reached it when deciding how long to persist before quitting. On quitting, participants received feedback about how many points they earned, but they never learned about the location of the invisible target. Before their turn, they observed as their partner performed the same task in order to obtain some reward (1 or 5 points). Importantly, at the beginning of each trial, the reward value of the trial was only revealed to their partners and their partners invested effort rationally: when they (i.e., partners) had high reward (5 points), they invested a high level of effort (High Partner Effort condition); when they had low reward (1 point), then they invested a low level of effort (Low Partner Effort condition) (see Fig. 1).

The experiment was preceded by four tutorials. The first tutorial introduced participants to the effort lottery task with visible targets; they learned that they had to repeatedly press a button to reach the target and then they had to quit the effort lottery task by pressing another button. The second tutorial introduced participants to the effort lottery task with invisible targets: they had to decide when to quit without knowing whether they had reached the target. The partner's component was introduced in the third tutorial; in four trials, the partner invested 60, 25, 30 and 85 keypresses before quitting.

1.1.4. Design

In a within-subject design experiment, we manipulated participants' beliefs about the reward structure of the task: in one block, they were led to correctly believe that when their partner had high reward for a trial, then they had high reward too, and when their partner had low reward for a trial, then they had low reward as well (Congruent condition); while in another block, they were led to correctly believe that when their partner had high reward for a trial, then they had low reward, and when their partner had low reward for a trial, then they had high reward (Incongruent condition). Furthermore, sometimes their partners invested a high level of effort (High Partner Effort condition), and sometimes they invested a low level of effort (Low Partner Effort condition). In each condition, there were 5 trials and we measured participants' number of keypresses before quitting.

1.1.5. Data preparation and analysis

See the reproducible scientific report and SOM for details.

1.2. Results

To examine the effect of Partner's Effort and Congruence on participants' effort investment in the form of keypresses, we planned to perform a repeated measures ANOVA and a Bayesian analysis, and pre-registered them as the planned analyses. Prior to conducting this analysis, we performed a Shapiro-Wilk test on all four conditions and three of them showed evidence of non-normality (High Congruent (M = 280, Mdn = 272, SD = 99.8), W = 0.908, p = 0.00323; Low Congruent (M = 159, Mdn = 150, SD = 85.9), W = 0.896, p = 0.00147; High Incongruent (M = 232, Mdn = 234, SD = 108), W = 0.952, p = 0.0886); Low Incongruent (M = 229, Mdn = 223, SD = 116), W = 0.931, p = 0.0170) (see Fig. 2). Because the assumption of normality was not met, we could not perform a repeated measures ANOVA as we had pre-registered. We analyzed the data with Bayesian methods with the pre-registered model. We used a generalized linear mixed model, in which the predicted value is described as negative binomial distributed around a linear combination of categorical predictors (Partner's Effort, Congruence, random effect of participant and random slopes of condition nested within participant) mapped to the central tendency of the predicted value via the exponential function. The results revealed a main effect of Partner Effort, no main effect of Congruence, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Congruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and no simple

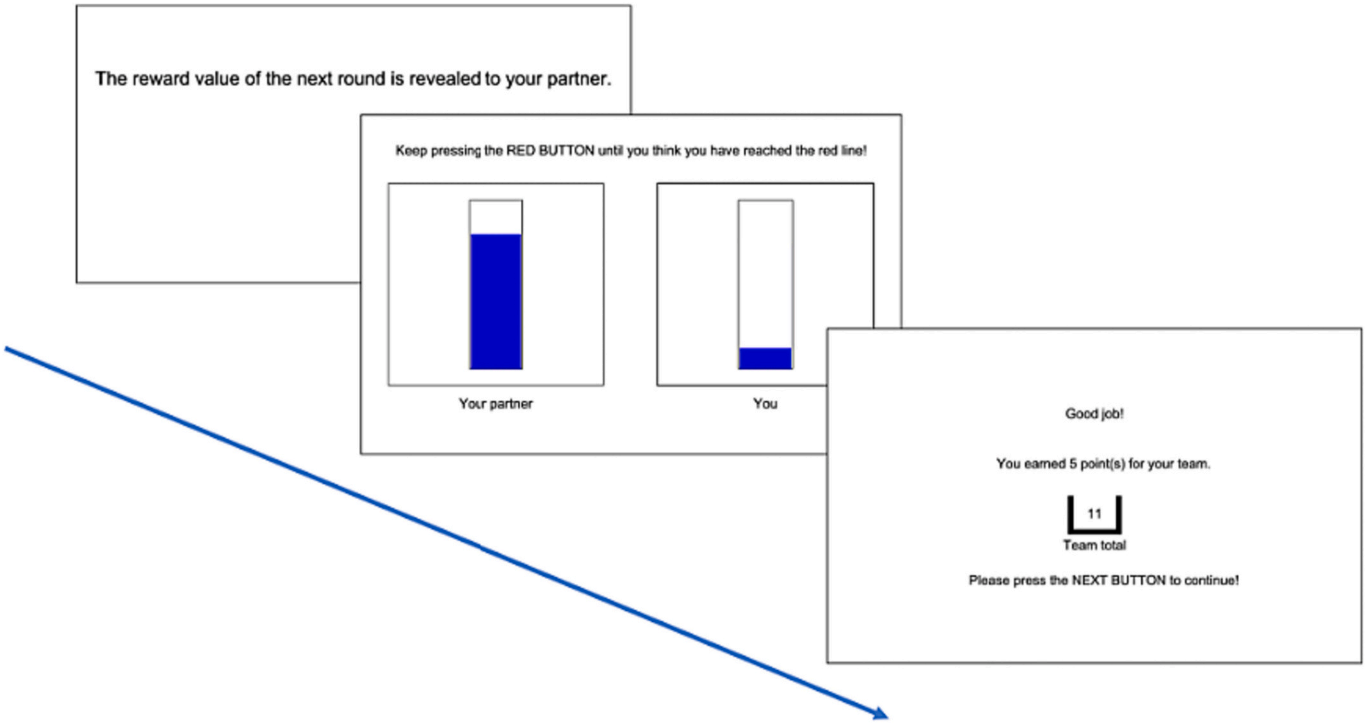

Fig. 1. Trial structure. On each trial, participants observed their (virtual) partner performing the effort lottery task before their own turn on the same task for some reward value.

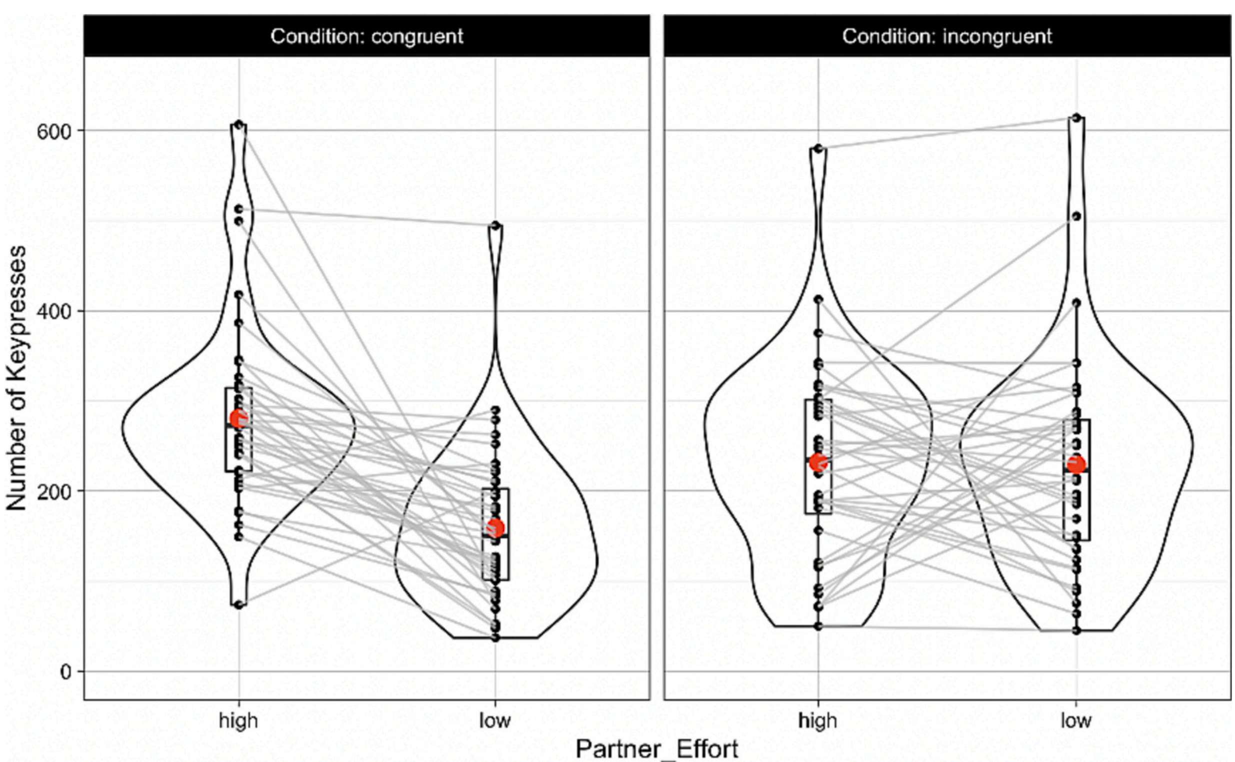

Fig. 2. Participants' effort investment in the form of keypresses across conditions. Each black dot represents one participant's effort investment in the respective condition and the gray line connects one's effort investment in the High and Low Partner's Effort conditions within the respective Congruence condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

effect of Partner Effort in the Incongruent condition. The results also revealed a simple effect of Congruence in the High Partner Effort condition, that is, participants invested more effort in the Congruent condition than in the Incongruent condition, and a simple effect of Congruence in the Low Partner Effort condition, that is, participants invested more effort in the Incongruent condition than in the Congruent condition.

Although in the Incongruent condition we did not find any difference between the High and Low Partner's Effort conditions at the group level, participants' effort investments in the Incongruent condition suggested that there is a difference at the individual level. Specifically, there appears to be a subset of participants who invested more effort in the Low Partner Effort condition than in the High Partner Effort condition (Environment-directed effort calibration group) - that is, there appears to be a subset of participants who pursued rewards in the current task optimally, while there appears to be a distinct subset of participants who invested more effort in the High Partner Effort condition than in the Low Partner Effort condition (Relationship-directed effort calibration group) - that is, there appears to be a subset of participants who incurred costs to match their partner's effort (see Fig. 3).

To probe this, as an exploratory analysis, we analyzed the data of both subsets of participants separately by applying the same pre-registered Bayesian model. The results of the Environment-directed effort calibration group revealed a main effect of Partner Effort, a main effect of Congruence, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Congruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and a simple effect of Partner Effort in the Incongruent condition, that is, participants invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The results also revealed a simple effect of Congruence in the High Partner Effort condition, that is, participants invested more effort in the Congruent condition than in the Incongruent condition, and a simple effect of Congruence in the Low Partner Effort condition, that is, participants invested more effort in the Incongruent condition than in the Congruent condition. The results of the Relationship-directed effort calibration group revealed a main effect of Partner Effort, no main effect of Congruence, and no interaction.

To further probe the conjecture that the behavior of the two groups was produced by different processes, as an exploratory analysis, we examined whether the distribution of the difference of participants' effort investment between the High and Low Partner effort condition reflected a unimodal or bimodal distribution. While a unimodal distribution would suggest that participants' behavior is produced by the same process, a bimodal distribution would suggest that participants' behavior is produced by different processes. The results revealed a bimodal distribution (see Fig. 4). To test whether the central tendency of the two subsets credibly differed from zero - meaning that the behavior of both subsets was influenced by their partner's effort, we conducted a Bayesian analysis. This revealed that the difference of the effort investment between the High and Low Partner effort conditions credibly differed from zero for each subset. These results provide support that participants' behavior reflect the operation of two distinct processes: while a subset of participants pursued rewards in the current task optimally, another subset of participants incurred costs to match their partner's effort.

2. Experiment 2

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

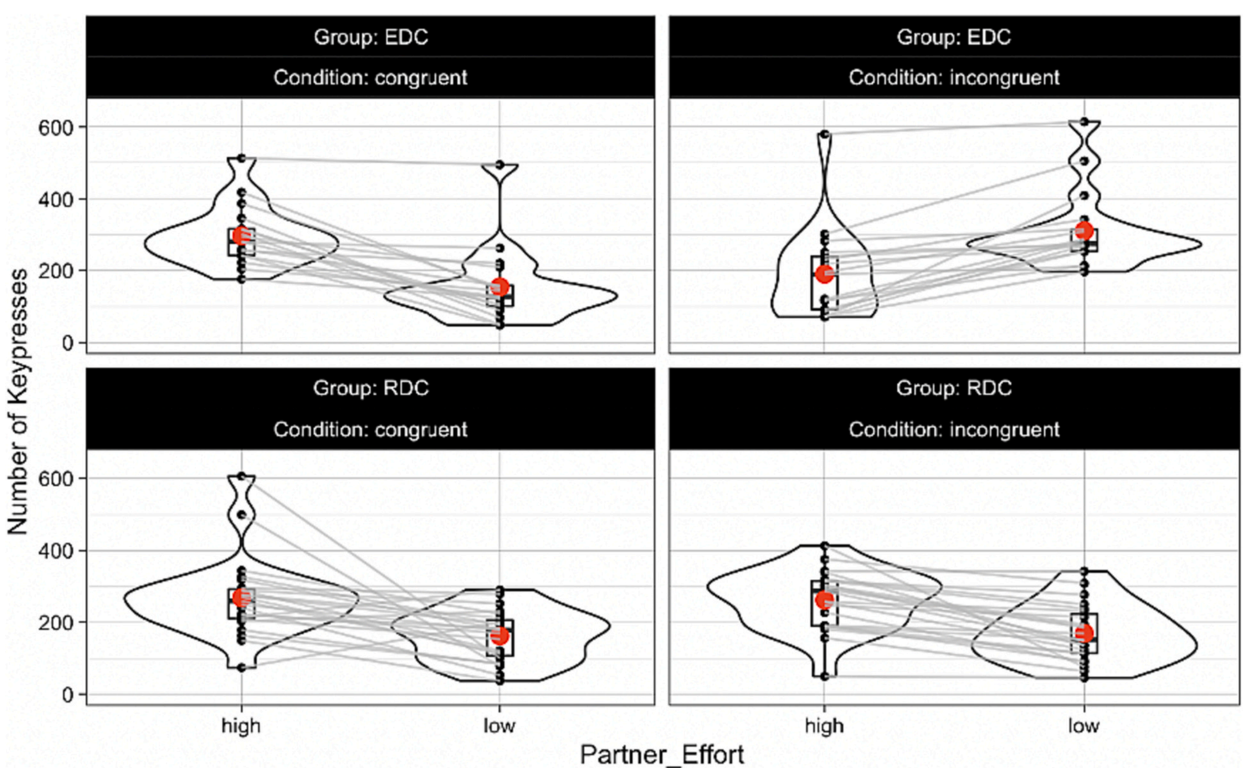

Fig. 3. Participants' effort investment in the form of keypresses across conditions, split into two groups. The environment-directed effort calibration group (EDC) exhibits a change from effort matching to inverse effort matching when the reward structure is incongruent rather than congruent. The relationship-directed effort calibration group (RDC) exhibits no such change. Each black dot represents one participant's effort investment in the respective condition, and the gray line connects each participant's effort investment in the High and Low Partner's Effort conditions within the respective Congruence of reward structure condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

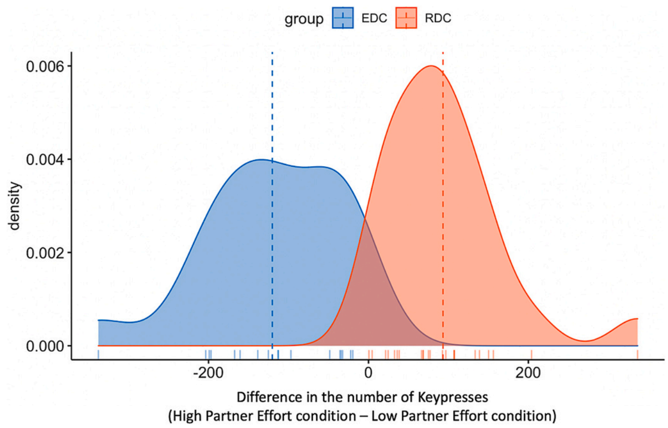

Fig. 4. Distribution of the difference of participants' effort investment between the High and Low Partner effort condition within the context of the incongruent condition depicted on a density plot. The environment-directed effort calibration group (EDC, depicted in blue) is below zero because they invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The relationship-directed effort calibration group (RDC, depicted in orange) is above zero because they invested more effort in the High Partner Effort condition than in the Low Partner Effort condition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

2.1. Method

2.1.1. Participants

Using G*power (Faul et al., 2009), we determined that a sample size of 40 participants provides 80% power to detect an effect size of f = 0.1876 or greater in a repeated measures ANOVA with a 5% false-positive rate. We followed the pre-registered exclusion criteria: accordingly, we excluded 20 participants who failed the belief manipulation check at the end of the experiment (2 participants said that „My partner thought that the available reward value was always the opposite for them and for me."; 15 participants said that „My partner thought that the available reward value was in one block the same, in another block the opposite for them and for me."; 3 participants said that „I don't remember what my partner thought about the available reward value.") and we excluded 2 participants who were accidentally disturbed during the experiment by another participant. The sample includes forty individuals (25 female, $M_{age} = 26.45$ years, $SD_{age} = 7.11$ years). We did not exclude any data point from the analysis. Participants carried out the experiment in pairs; members in each pair did not know each other prior to participation. Participants were recruited through (removed for double-blind review), were naïve to the purpose of the study, and reported normal or corrected to normal vision. All participants gave their informed written consent prior to the experiment and received gift vouchers for their participation. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by (removed for double-blind review).

2.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to that of Experiment 1.

2.1.3. Procedure

The procedure was identical to that of Experiment 1 except that at the end of the experiment, participants had to answer belief manipulation check questions regarding their partner's belief about the congruence of reward structure.

2.1.4. Design

The design was identical to that of Experiment 1 except that participants believed that their (virtual) partner always believed that they were in a congruent reward structure. The dependent measure was identical to that of Experiment 1.

2.1.5. Data preparation and analysis

See the reproducible scientific report and SOM for details.

2.2. Results

To examine the effect of Partner's Effort and Congruence on participants' effort investment in the form of keypresses, we planned to perform a repeated measures ANOVA and a Bayesian analysis, and pre-registered them as the planned analyses. Prior to conducting this analysis, we performed a Shapiro-Wilk test on all four conditions and two of them showed evidence of non-normality (High Congruent ($M = 309$, $Mdn = 287$, $SD = 101$), $W = 0.858$, $p = 0.000139$; Low Congruent ($M = 167$, $Mdn = 158$, $SD = 76.8$), $W = 0.961$, $p = 0.184$; High Incongruent ($M = 241$, $Mdn = 242$, $SD = 96.1$), $W = 0.921$, $p = 0.00836$); Low Incongruent ($M = 243$, $Mdn = 240$, $SD = 82.2$), $W = 0.972$, $p = 0.429$) (see Fig. 5). Because the assumption of normality was not met, we could not perform a repeated measures ANOVA as we had pre-registered. We analyzed the data with Bayesian methods with the pre-registered model. We used a generalized linear mixed model, in which the predicted value is described as negative binomial distributed around a linear combination of categorical predictors (Partner's Effort, Congruence, random effect of participant and random slopes of condition nested within participant) mapped to the central tendency of the predicted value via the exponential function. The results revealed a main effect of Partner Effort, a main effect of Congruence, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Congruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and no simple effect of Partner Effort in the Incongruent condition. The results also revealed a simple effect of Congruence in the High Partner Effort condition, that is, participants invested more effort in the Congruent condition than in the Incongruent condition, and a simple effect of Congruence in the Low Partner Effort condition, that is, participants invested more effort in the Incongruent condition than in the Congruent condition.

Although in the Incongruent condition we did not find any difference between the High and Low Partner's Effort conditions at the group level, participants' effort investments in the Incongruent condition suggested that there is a difference at the individual level. Specifically, there appears to be a subset of participants who invested more effort in the Low Partner Effort condition than in the High Partner Effort condition (Environment-directed effort calibration group) - that is, there appears to be a subset of participants who pursued rewards in the current task optimally, while there appears to be a distinct subset of participants who invested more effort in the High Partner Effort condition than in the Low Partner Effort condition (Relationship-directed effort calibration group) - that is, there appears to be a subset of participants who incurred costs to match their partner's effort (see Fig. 6).

To probe this, as an exploratory analysis, we analyzed the data of both subsets of participants separately by applying the same pre-registered Bayesian model. The results of the Environment-directed effort calibration group revealed a main effect of Partner Effort, no main effect of Congruence, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Congruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and a simple effect of Partner Effort in the Incongruent condition, that is, participants invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The results also revealed a simple effect of Congruence in the High Partner Effort condition, that is, participants invested more effort in the Congruent condition than in the Incongruent condition, and a simple effect of Congruence in the Low Partner Effort condition, that is, participants invested more effort in the Incongruent condition than in

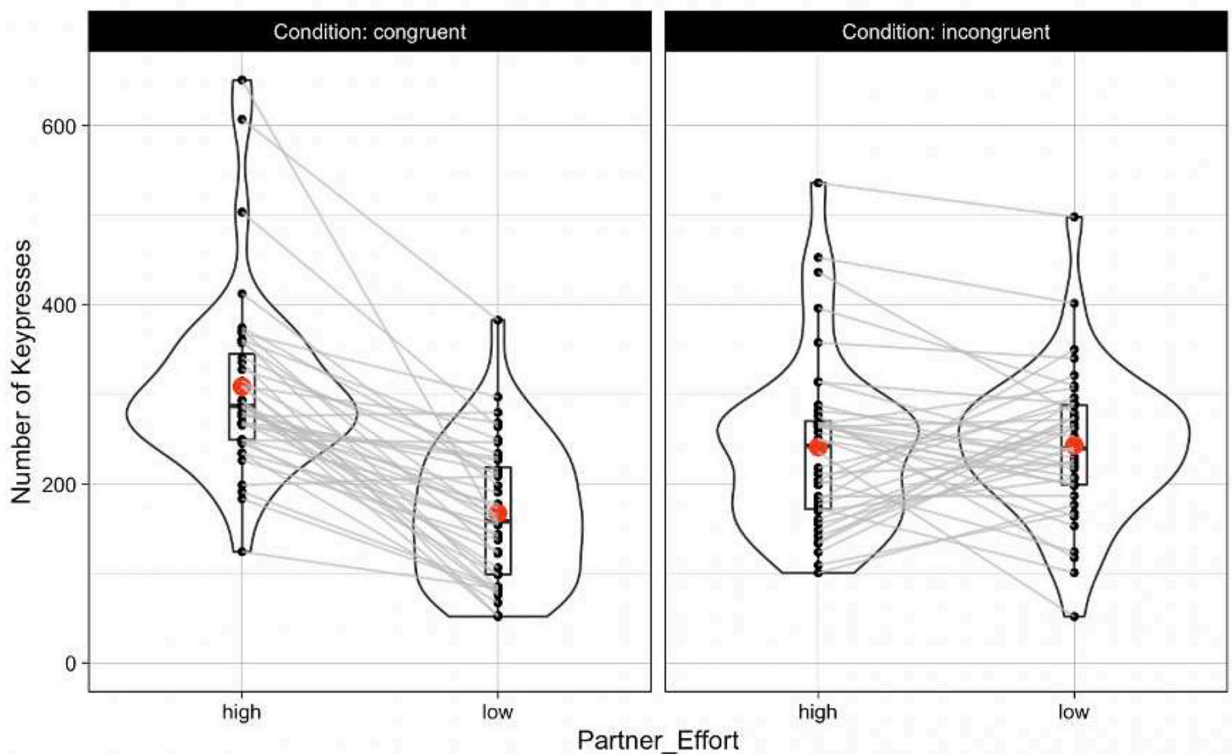

Fig. 5. Participants' effort investment in the form of keypresses across conditions. Each black dot represents one participant's effort investment in the respective condition and the gray line connects one's effort investment in the High and Low Partner's Effort conditions within the respective Congruence condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means.

the Congruent condition. The results of the Relationship-directed effort calibration group revealed a main effect of Partner Effort, a main effect of Congruence, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Congruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and a simple effect of Partner Effort in the Incongruent condition, that is, participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition. The results also revealed no simple effect of Congruence in the High Partner Effort condition, and a simple effect of Congruence in the Low Partner Effort condition, that is, participants invested more effort in the Incongruent condition than in the Congruent condition.

To further probe the conjecture that the behavior of the two groups was produced by different processes, as an exploratory analysis, we examined whether the distribution of the difference of participants' effort investment between the High and Low Partner effort condition reflected a unimodal or bimodal distribution. While a unimodal distribution would suggest that participants' behavior is produced by the same process, a bimodal distribution would suggest that participants' behavior is produced by different processes. The results revealed a bimodal distribution (see Fig. 7). To test whether the central tendency of the two subsets credibly differed from zero - meaning that the behavior of both subsets was influenced by their partner's effort, we conducted a Bayesian analysis. This revealed that the difference of the effort investment between the High and Low Partner effort conditions credibly differed from zero for each subset. These results provide support that participants' behavior reflect the operation of two distinct processes: while a subset of participants pursued rewards in the current task optimally, another subset of participants incurred costs to match their partner's effort.

3. Experiment 3

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

3.1. Method

3.1.1. Participants

Using G*power (Faul et al., 2009), we determined that a sample size of 20 participants provides 80% power to detect an effect size of d = 0.66 or greater in a paired-sample *t*-test with a 5% false-positive rate. We followed the pre-registered exclusion criteria: accordingly, we excluded 9 participants who failed the belief manipulation check at the end of the experiment (2 participants said that „My partner thought that the available reward value was always the same for them and for me."; 5 participants said that „My partner thought that the available reward value was in one block the same, in another block the opposite for them and for me."; 2 participants said that „I don't remember what my partner thought about the available reward value.") and we excluded 1 participant because we reached the target sample size of 20. The sample includes twenty individuals (14 female, $M_{age} = 26.5$ years, $SD_{age} = 3.713$ years). We did not exclude any data point from the analysis. Participants carried out the experiment in pairs; members in each pair did not know each other prior to participation. Participants were recruited through (removed for double-blind review), were naïve to the purpose of the study, and reported normal or corrected to normal vision. All participants gave their informed written consent prior to the experiment and received gift vouchers for their participation. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by (removed for double-blind review).

3.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to that of Experiment 1.

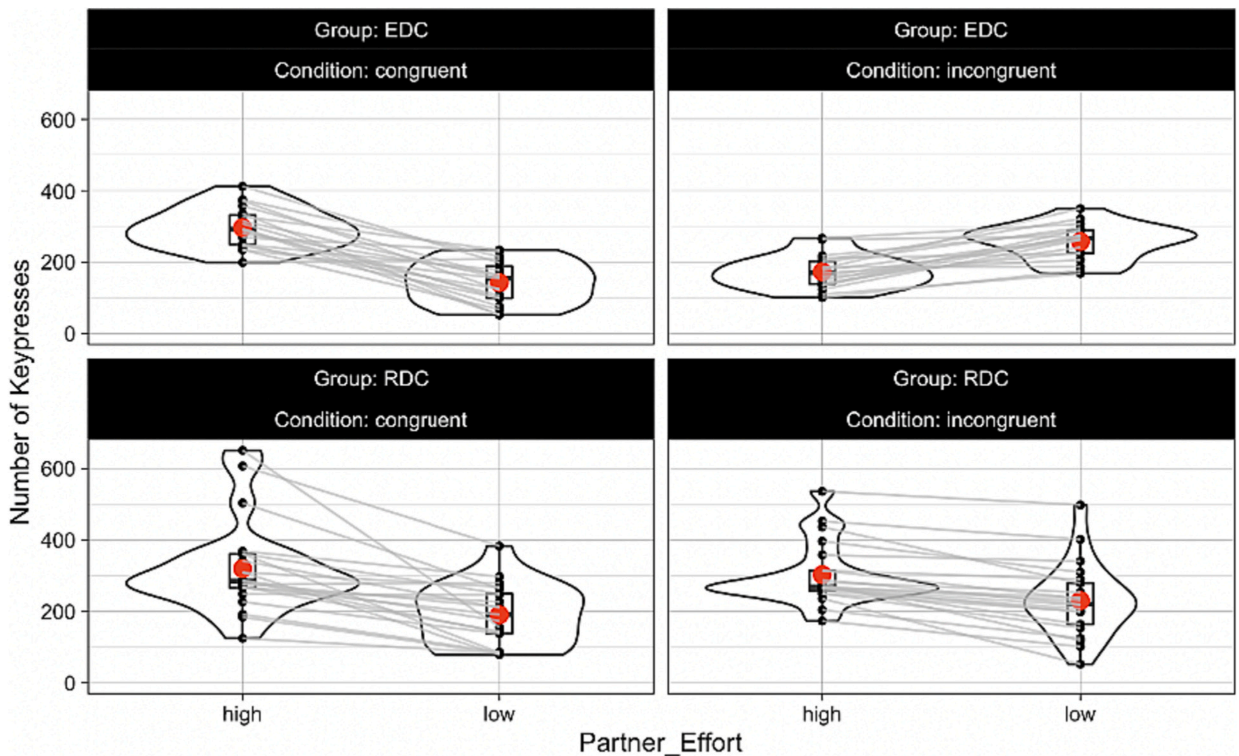

Fig. 6. Participants' effort investment in the form of keypresses across conditions, split into two groups. The environment-directed effort calibration group (EDC) exhibits a change from effort matching to inverse effort matching when the reward structure is incongruent rather than congruent. The relationship-directed effort calibration group (RDC) exhibits no such change. Each black dot represents one participant's effort investment in the respective condition, and the gray line connects each participant's effort investment in the High and Low Partner's Effort conditions within the respective Congruence of reward structure condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

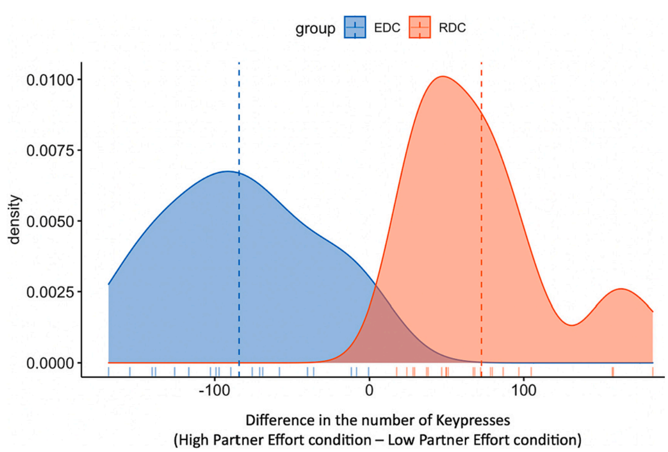

Fig. 7. Distribution of the difference of participants' effort investment between the High and Low Partner effort condition within the context of the incongruent condition depicted on a density plot. The environment-directed effort calibration group (EDC, depicted in blue) is below zero because they invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The relationship-directed effort calibration group (RDC, depicted in orange) is above zero because they invested more effort in the High Partner Effort condition than in the Low Partner Effort condition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.1.3. Procedure

The procedure was identical to that of Experiment 1 except for two modifications. After the tutorials, participants had a familiarization phase with 4 trials in the Congruent condition and 4 trials in the Incongruent condition (they were counterbalanced and identical to the conditions of the Congruence manipulation of Experiment 1). Then, in the test phase, participants had 10 trials in the Uncertain condition.

3.1.4. Design

In a within-subject design experiment, participants were informed that their partner always believed that they were in an incongruent reward structure and that the partner believed that the participants had the same belief as them (i.e., partner). Moreover, participants were informed that, in fact, they would never know whether they were in a Congruent or Incongruent condition (Uncertain condition). We manipulated the virtual partner's effort investment: sometimes their partners invested a high level of effort (High Partner Effort condition), and sometimes they invested a low level of effort (Low Partner Effort condition). The dependent measure was identical to that of Experiment 1.

3.1.5. Data preparation and analysis

See the reproducible scientific report and SOM for details.

3.2. Results

To examine the effect of Partner's Effort on participants' effort investment in the form of keypresses, we planned to perform a paired-sample *t*-test and a Bayesian analysis, and pre-registered them as the planned analyses. Prior to conducting this analysis, we performed a Shapiro-Wilk test on the difference of participants' effort investment between the conditions and it did not show evidence of non-normality (High Partner Effort (M = 308, Mdn = 305, SD = 109); Low Partner Effort (M = 260, Mdn = 264, SD = 125); W = 0.922, p = 0.108) (see Fig. 8). Because the assumption of normality was met, we could perform

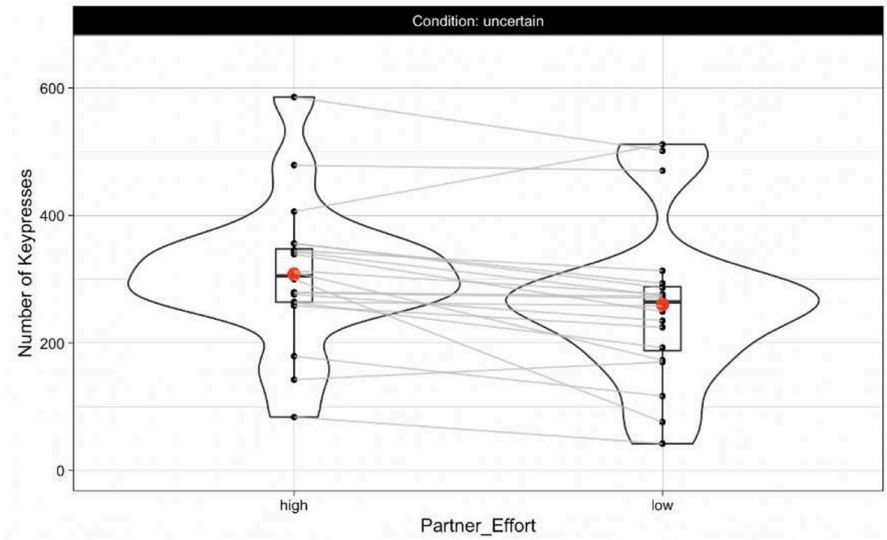

Fig. 8. Participants' effort investment in the form of keypresses across conditions. Each black dot represents one participant's effort investment in the respective condition and the gray line connects one's effort investment in the High and Low Partner's Effort conditions. In each boxplot, horizontal lines indicate medians, and red circles indicate means.

a paired-sample *t*-test as we had pre-registered. The results revealed a significant effect of Partner Effort, $t(19) = 3.27$, $p < 0.00407$, $d = 0.73$. We also analyzed the data with Bayesian methods with the pre-registered model. We used a generalized linear mixed model, in which the predicted value is described as negative binomial distributed around a linear combination of categorical predictors (Partner's Effort, random effect of participant and random slopes of condition nested within participant) mapped to the central tendency of the predicted value via the exponential function. The results revealed an effect of Partner Effort.

4. Experiment 4

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study.

4.1. Method

4.1.1. Participants

Using G*power (Faul et al., 2009), we determined that a sample size of 40 participants provides 90% power to detect an effect size of $f = 0.2$ or greater in a repeated measures ANOVA with a 5% false-positive rate. Eventually we tested 48 participants. We followed the pre-registered exclusion criteria: accordingly, we excluded 6 participants who failed the belief manipulation check at the end of the experiment (4 participants said that „My partner thought that the available reward value was always the opposite for them and for me."; 1 participant said that „My partner thought that the available reward value was in one block the same, in another block the opposite for them and for me."; 1 participant said that „I don't remember what my partner thought about the available reward value."). The sample includes twenty-one pairs of individuals (31 female, $M_{age} = 24.57$ years, $SD_{age} = 3.4$ years). We did not exclude any data point from the analysis. Participants carried out the experiment in pairs; members in each pair did not know each other prior to participation. Participants were recruited through (removed for double-blind review), were naïve to the purpose of the study, and reported normal or corrected to normal vision. All participants gave their informed written consent prior to the experiment and received gift vouchers for their participation. The experiment was conducted in accordance with the Declaration of Helsinki and was approved by (removed for double-blind review).

4.1.2. Apparatus and stimuli

The apparatus and stimuli were identical to that of Experiment 1.

4.1.3. Procedure

The procedure was identical to that of Experiment 2 except that at the end of the experiment, participants were measured on two secondary tasks: 1) we measured participants' explicit judgment on fairness using two hypothetical scenarios in which we manipulated whether a joint action partner prefers equity in terms of effort and gains over utility maximization for the team or vice-versa; 2) and we measured participants on a 10-item version of Singelis' Self-Construal Scale (D'amico & Scrima, 2016), in which participants rated statements on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). See SOM for details on the secondary tasks.

4.1.4. Design

In a within-subject design experiment, we manipulated 1) partner's effort (High and Low) and 2) participants' belief about the identity of the partner (Human partner and Computer partner). Moreover, instead of manipulating the Congruence of reward structure, participants were tested in an incongruent reward structure –that is, participants were led to correctly believe that when their partner has high reward for a trial, then they have low reward, and when their partner has low reward for a trial, then they have high reward. Moreover, participants were informed that their partner always believed that they were in a congruent reward structure. In each condition, there were 5 trials and we measured participants' number of keypresses before quitting.

4.1.5. Data preparation and analysis

See the reproducible scientific report and SOM for details.

4.2. Results

We were interested in investigating how people's tendency to invest effort changes depending on whether they interact with a human partner or a computer. To examine the effect of Partner's Effort and Partner identity on participants' effort investment in the form of keypresses, we planned to perform a repeated measures ANOVA and a Bayesian analysis, and pre-registered them as the planned analyses. Prior to conducting this analysis, we performed a Shapiro-Wilk test on all four conditions and one of them showed evidence of non-normality (High

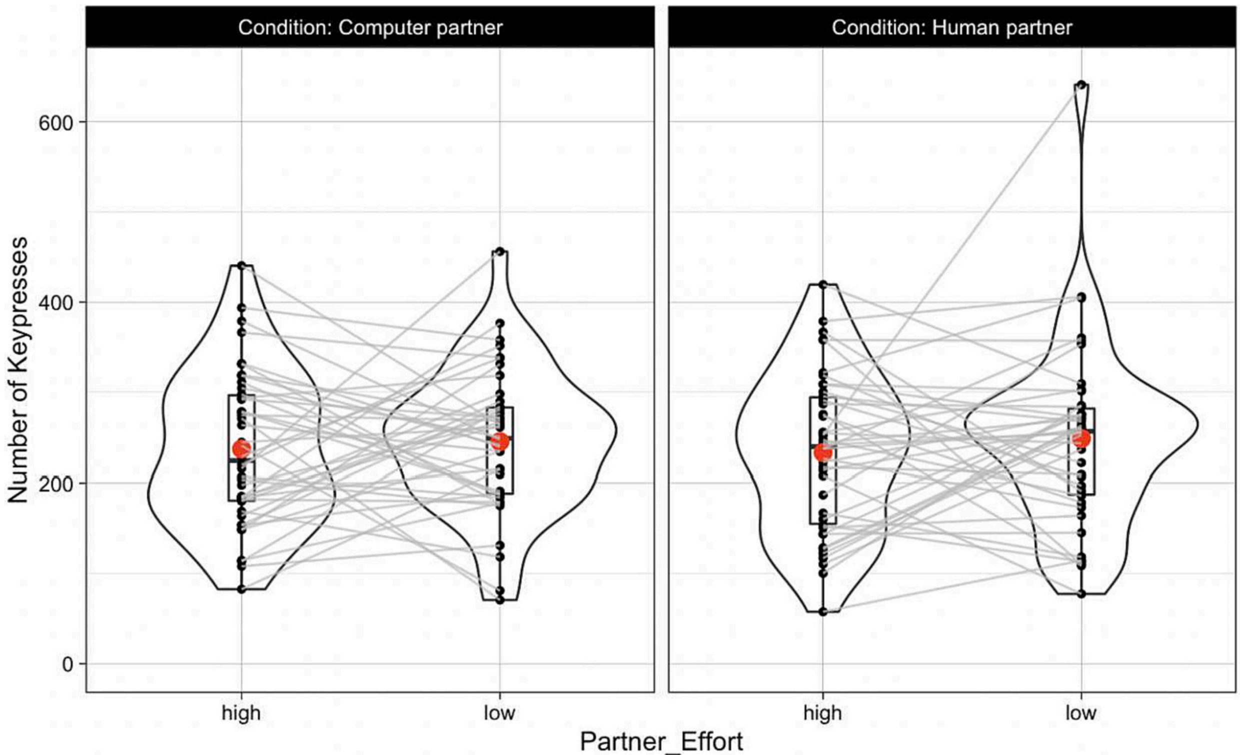

Fig. 9. Participants' effort investment in the form of keypresses across conditions. Each black dot represents one participant's effort investment in the respective condition and the gray line connects one's effort investment in the High and Low Partner's Effort conditions within the respective Partner identity condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means.

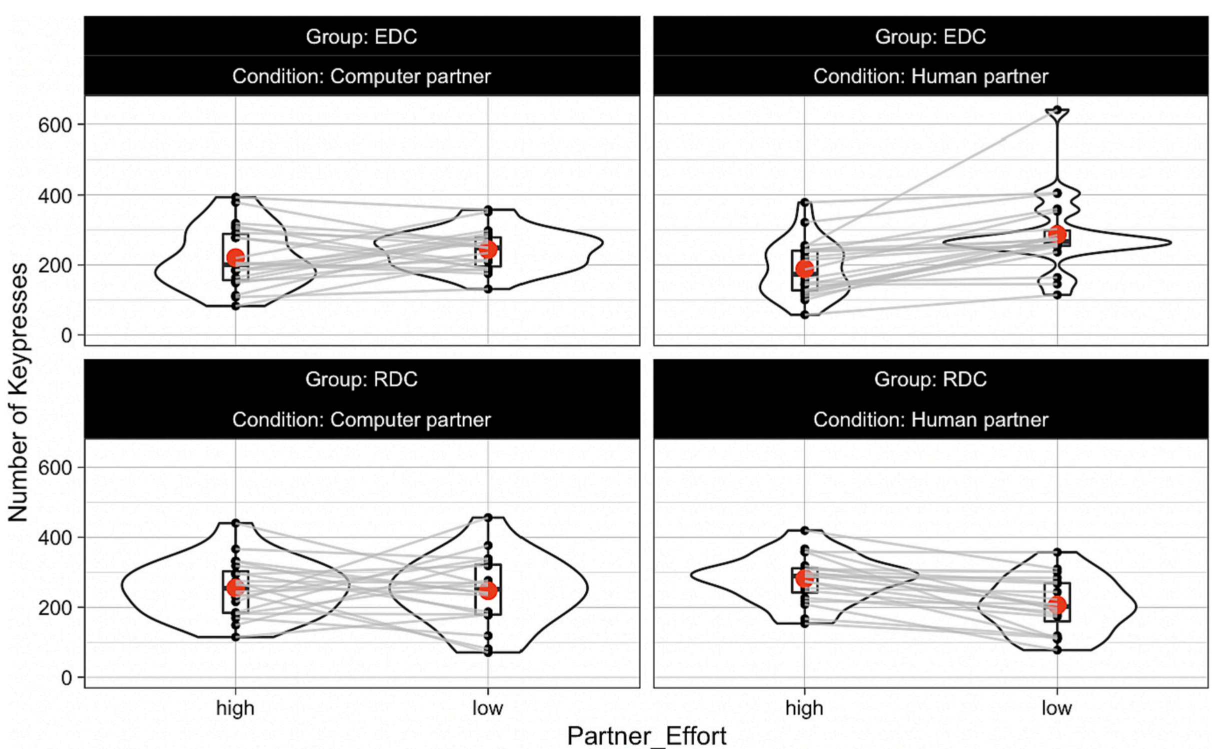

Fig. 10. Participants' effort investment in the form of keypresses across conditions, split into two groups. Both the relationship-directed effort calibration group (RDC) and the environment-directed effort calibration group (EDC) exhibit a change of behavior when the partner is believed to be a computer algorithm rather than a human partner. Each black dot represents one participant's effort investment in the respective condition, and the gray line connects each participant's effort investment in the High and Low Partner's Effort conditions within the respective Partner identity condition. In each boxplot, horizontal lines indicate medians, and red circles indicate means. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Human partner ($M = 233$, $Mdn = 240$, $SD = 86.3$), W = 0.981, $p = 0.691$; Low Human partner ($M = 249$, $Mdn = 257$, $SD = 101$), W = 0.902, $p = 0.00163$; High Computer partner ($M = 237$, $Mdn = 224$, $SD = 84.5$), W = 0.977, $p = 0.542$); Low Computer partner ($M = 245$, $Mdn = 249$, $SD = 78.5$), W = 0.983, $p = 0.776$) (see **Fig. 9**). Because the assumption of normality was not met, we could not perform a repeated measures ANOVA as we had pre-registered. We analyzed the data with Bayesian methods with the pre-registered model. We used a generalized linear mixed model, in which the predicted value is described as negative binomial distributed around a linear combination of categorical predictors (Partner's Effort, Partner identity, random effect of participant and random slopes of condition nested within participant) mapped to the central tendency of the predicted value via the exponential function. The results revealed no main effect of Partner Effort, no main effect of Partner identity, and no interaction.

Although we did not find any difference between the High and Low Partner's Effort conditions at the group level, participants' effort investments suggested that there is a difference at the individual level. Specifically, there appears to be a subset of participants who invested more effort in the Low Partner Effort condition than in the High Partner Effort condition (Environment-directed effort calibration group) - that is, there appears to be a subset of participants who pursued rewards in the current task optimally, while there appears to be a distinct subset of participants who invested more effort in the High Partner Effort condition than in the Low Partner Effort condition (Relationship-directed effort calibration group) - that is, there appears to be a subset of participants who incurred costs to match their partner's effort (see Fig. 10).

To probe the conjecture that the behavior of the two groups was produced by different processes, we examined whether the distribution of the difference of participants' effort investment between the High and Low Partner effort condition within the context of a human partner reflected a unimodal or bimodal distribution. While a unimodal distribution would suggest that participants' behavior is produced by the same process, a bimodal distribution would suggest that participants' behavior is produced by different processes. The results revealed a bimodal distribution (see Fig. 11). To test whether the central tendency of the two subsets credibly differed from zero - meaning that the behavior of both subsets was influenced by their partner's effort, we conducted a Bayesian analysis. This revealed that the difference of the effort investment between the High and Low Partner effort conditions

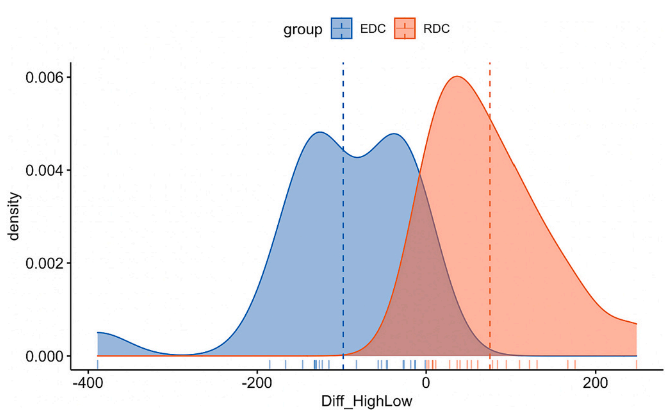

Fig. 11. Distribution of the difference of participants' effort investment between the High and Low Partner effort condition within the context of the Human partner condition depicted on a density plot. The environment-directed effort calibration group (EDC, depicted in blue) is below zero because they invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The relationship-directed effort calibration group (RDC, depicted in orange) is above zero because they invested more effort in the High Partner Effort condition than in the Low Partner Effort condition. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

credibly differed from zero for each subset. These results provide support that participants' behavior reflect the operation of two distinct processes: while a subset of participants pursued rewards in the current task optimally, another subset of participants incurred costs to match their partner's effort.

To probe whether the behavior of the two groups changes differently depending on whether they interact with a human partner or a computer, we analyzed the data of both subsets of participants separately by applying the same pre-registered Bayesian model. The results of the Environment-directed effort calibration group revealed a main effect of Partner Effort, no main effect of Partner identity, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Human partner condition, that is, participants invested more effort in the Low Partner Effort condition than in the High Partner Effort condition, and a simple effect of Partner Effort in the Computer partner condition, that is, participants invested more effort in the Low Partner Effort condition than in the High Partner Effort condition. The results also revealed a simple effect of Partner identity in the Low Partner Effort condition, that is, participants invested more effort in the Human partner condition than in the Computer partner condition, and a simple effect of Partner identity in the High Partner Effort condition, that is, participants invested more effort in the Computer partner condition than in the Human partner condition. The results of the Relationship-directed effort calibration group revealed a main effect of Partner Effort, no main effect of Partner identity, and an interaction. Moreover, the results revealed a simple effect of Partner Effort in the Human partner condition, that is participants invested more effort in the High Partner Effort condition than in the Low Partner Effort condition, and no simple effect of Partner Effort in the Computer partner condition. The results also revealed a simple effect of Partner identity in the Low Partner Effort condition, that is, participants invested more effort in the Computer partner condition than in the Human partner condition, and no simple effect of Partner identity in the High Partner Effort condition.

To address to what extent people's tendency to match their partner's effort or to invest effort efficiently is reflected in people's explicit beliefs about fairness, we examined how participants rated others' behavior in the scenarios as a function of Group (RDC/EDC) and Vignette (utility maximization for the team/effort matching) with Bayesian methods with the pre-registered model (see Fig. 12 and **Table 1**). We used a generalized linear model, in which the predicted value is described as categorical distributed around a linear combination of nominal predictors (Group, Vignette, random effect of participant) mapped to a probability value via a thresholded cumulative normal function.

Statement 1: *The actor's choice was fair*. The results revealed no main effect of Group, no main effect of Vignette, and no interaction.

Statement 2: *The actor made the right choice*. The results revealed no main effect of Group, a main effect of Vignette, and no interaction.

Statement 3: *In the actor's position I would have made the same choice*. The results revealed no main effect of Group, a main effect of Vignette, and no interaction.

To address whether people's tendency to match their partner's effort or to invest effort efficiently is reflected in people's self-construal, we examined how participants rated their feelings of connectedness to and separateness from social situations on Singelis' Self-Construal Scale as a function of Group (RDC/EDC) and Subscale (independent/interdependent) with Bayesian methods with the pre-registered model (see Fig. 13 and **Table 2**). We used a generalized linear model, in which the predicted value is described as negative binomial distributed around a linear combination of categorical predictors mapped to the central tendency of the predicted value via the exponential function. Accordingly, a linear combination of categorical predictors (Group, Subscale, Subjects) mapped to the central tendency parameter via the exponential function. The results revealed a main effect of Group, no main effect of Subscale, and no interaction.

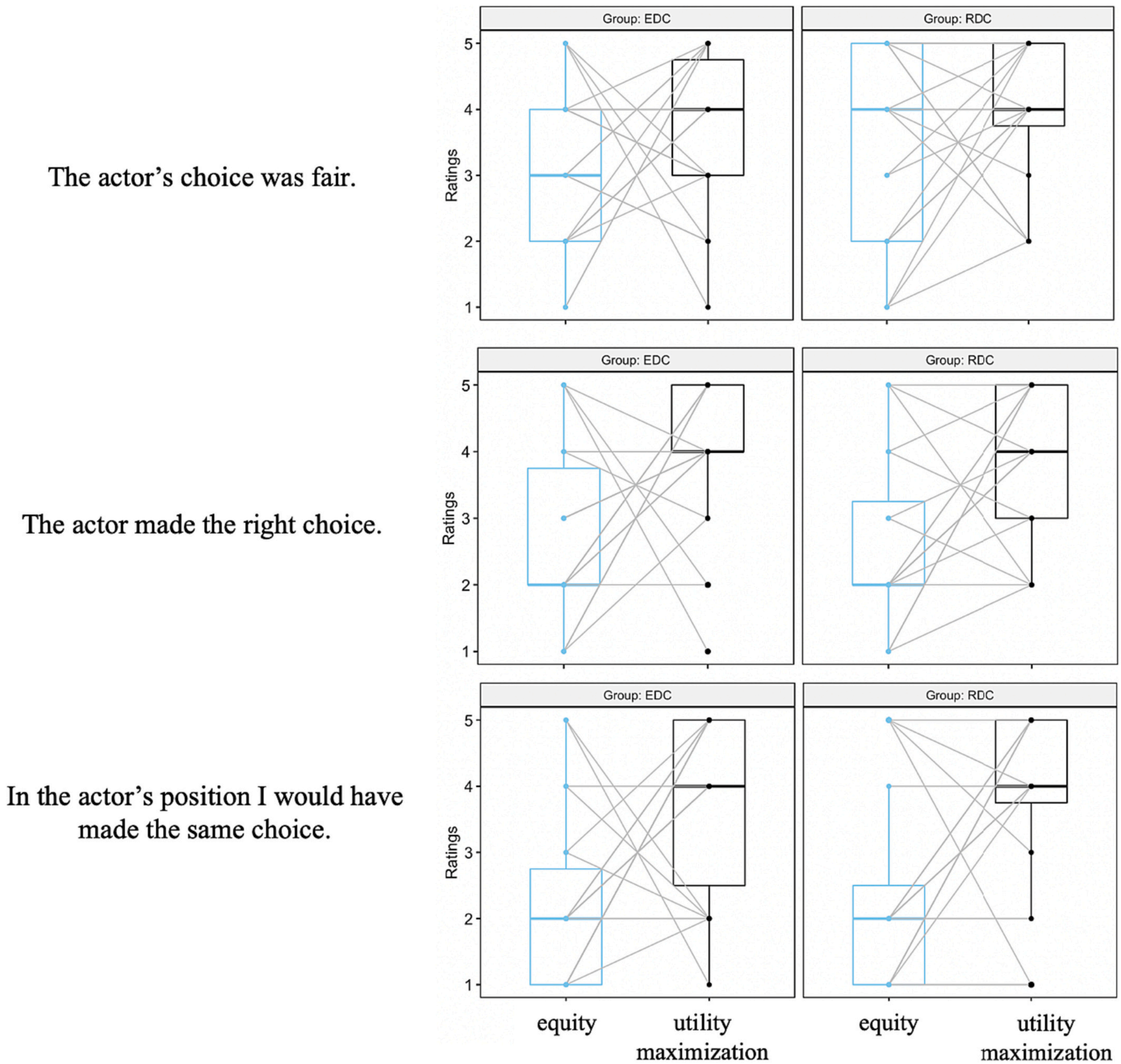

Fig. 12. We depicted how participants from the two groups (RDC/EDC) rated their agreement with statements related to the two hypothetical scenarios, in which an actor prefers equity in terms of effort and gains over utility maximization for the team, or vice-versa, on a Likert scale (1–5) (where 1 means "strongly disagree" and 5 means "strongly agree").

5. General discussion

A growing body of empirical work suggests that the perception or anticipation of a partner's effort modulates effort-based decision-making in the context of joint action (Chennells & Michael, 2018; Jackson & Harkins, 1985; Strachan & Török, 2020; Székely & Michael, 2018; Székely & Michael, 2023; Török, Pomiechowska, Csibra, & Sebanz, 2019). In the current study, we investigated the hypothesis that people calibrate their effort investment in joint action with the ultimate goal of attracting and keeping good collaboration partners (*The relationship-directed effort calibration hypothesis*) and that the proximal psychological motive that drives them to do so is a preference for fairness (*The equity through effort calibration hypothesis*). Across four experiments, we tested these hypotheses and differentiated them from alternative explanations of why people match their partners' effort. Specifically, in Experiments 1 and 2, we differentiated the relationship-directed effort calibration hypothesis from the hypothesis that people may use their partner's effort costs as information to infer the value of opportunities afforded by their environment, which may lead them to adjust their effort investment as a function of the inferred value (The *environment-directed effort calibration hypothesis*). In Experiment 1, we found that while one subset of participants pursued rewards in the current task optimally, another subset of participants incurred costs to match their partner's effort. While the former provides support for the environment-directed hypothesis, the latter provides support for the relationship-directed hypothesis. However, with respect to each of these subsets, there is an alternative explanation which we did not control for: namely, that participants within the different subsets exhibited the observed

Table 1
Median and IQR for the ordinal ratings at each level of the factors for all three statements.

The actor's choice was fair.		
Vignette	*Group*	
	EDC	RDC
Equity in terms of effort and gains	3 (2)	4 (3)
Utility maximization for the team	4 (1.75)	4 (1.25)

The actor made the right choice.		
Vignette	*Group*	
	EDC	RDC
Equity in terms of effort and gains	2 (1.75)	2 (1.25)
Utility maximization for the team	4 (1)	4 (2)

In the actor's position I would have made the same choice.		
Vignette	*Group*	
	EDC	RDC
Equity in terms of effort and gains	2 (1.75)	2 (1.5)
Utility maximization for the team	4 (2.5)	4 (1.25)

patterns in order to appear competent (*The appearance of competence hypothesis*). Experiment 2 was designed to control for this alternative explanation of the subset that exhibited environment-directed effort calibration – i.e., this subset of participants may have inferred that their partner was aware that the reward structures were incongruent in the Incongruent condition, and may accordingly have invested greater effort in the Low Partner Effort condition and less effort in the High Partner Effort condition in order to demonstrate competence and efficiency to their partner. To address this, in Experiment 2, participants were informed that their partner always believed that they were in a congruent reward structure, and we found clear support for both the relationship-directed and the environment-directed hypotheses. Having found evidence for the relationship-directed hypothesis in Experiments 1 and 2, we next turned our attention to the proximal psychological motives underpinning these effects, and specifically to testing the hypothesis that when people expect to share the reward of the joint task equally, people ensure fairness by calibrating their effort investment such as to reduce inequity with respect to joint action partners' effort investment (The equity through effort calibration hypothesis). Experiments 1 and 2 do not directly support this hypothesis because they were not designed to rule out the appearance of competence hypothesis. To address this, Experiment 3 provided further evidence of relationship-directed effort calibration, but in a context in which it could uniquely be explained by the equity through effort calibration hypothesis – i.e. in which the appearance of competence hypothesis could be ruled out.

Experiment 4 was designed to test the link between one's tendency to match a partner's effort and one's exposure on the cooperation partner market. We hypothesized that if people match their partner's effort with the ultimate goal of attracting and keeping good collaboration partners, then people should match their partner's effort when they interact with a human partner, but that they should not do so when they interact with a computer. To address this, participants were led to believe that they played with two separate partners (a Human partner and a Computer partner) in an incongruent reward structure, and they were informed that both of their partners believed that they were in a congruent reward structure. We predicted that those participants who matched a human partner's effort would not do so within the context of an interaction with a computer partner. Moreover, we predicted that those participants who pursued rewards in the current task optimally – that is, who invested more effort in the Low Partner Effort condition than in the High Partner Effort condition within the context of an interaction with a human partner – would invest effort similarly within the context of an interaction with a computer partner. This is because the optimal level of effort investment is not altered if one's partner is a computer. We found clear support for both predictions - further corroborating the

Table 2
Median and IQR for the ordinal ratings at each level of the factors.

Subscale	*Group*	
	EDC	RDC
Independent	10 (5.25)	10 (5)
Interdependent	11 (2.75)	9 (5.5)

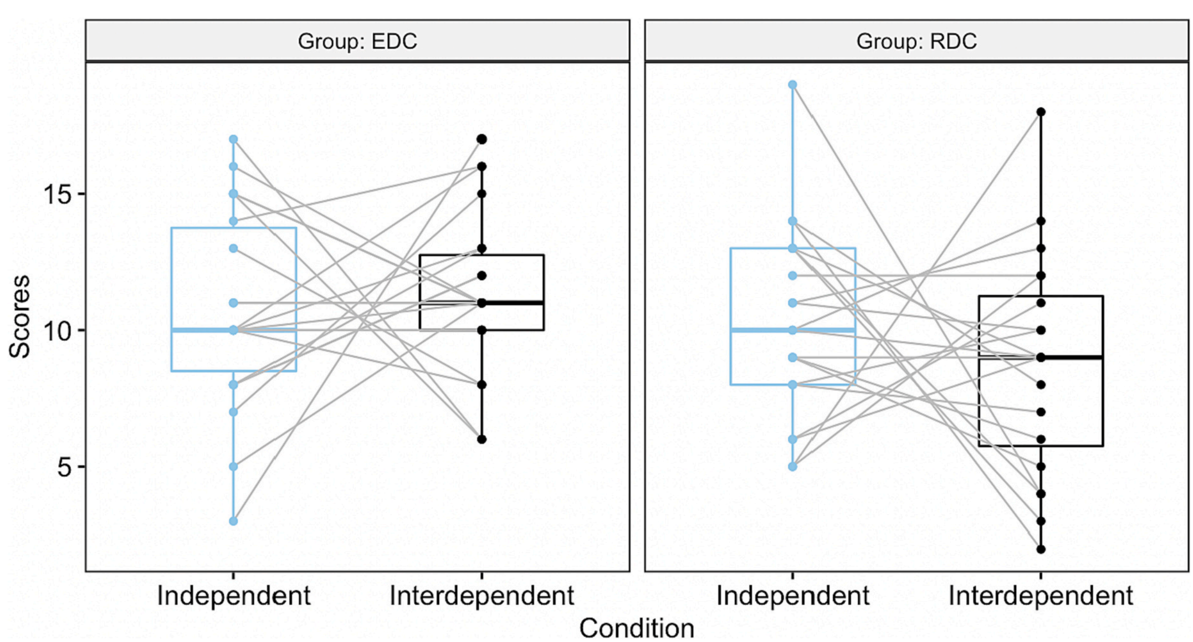

Fig. 13. We depicted how participants rated their agreement with statements expressing independence or interdependence with respect to others on a Likert scale (1–5) (where 1 means "strongly disagree" and 5 means "strongly agree").

relationship-directed effort calibration hypothesis.

In addition, in Experiment 4, we also investigated to what extent people's tendency to match their partner's effort or to invest effort efficiently is reflected in people's explicit beliefs about fairness. To address this, we measured participants' explicit judgments about fairness using two hypothetical scenarios. In the scenarios, we manipulated whether a joint action partner preferred equity (in terms of effort and gains) over utility maximization for the team, or vice-versa. We predicted that those participants who matched their partner's effort on the primary task of Experiment 4 would judge an agent who acted in accordance with equity as more fair than an agent who acted in accordance with utility maximization for the team. In contrast, we predicted that those participants who invested effort efficiently on the primary task would make the opposite judgment.

The results showed no evidence that people's tendency to match their partner's effort or to invest effort efficiently is reflected in their explicit beliefs about fairness. Neither group of participants exhibited a substantial difference with respect to their judgments about the fairness of agents who acted equitably (in terms of effort and gains) and agents who maximized utility for the team. Interestingly, however, both groups of participants stated that they themselves would maximize utility rather than acting equitably (in terms of effort and gains) in a similar situation, and that doing so would be the right course of action. This is surprising: although previous research (Batson, Kobrynowicz, Dinnerstein, Kampf, & Wilson, 1997; Lönnqvist, Irlenbusch, & Walkowitz, 2014) has shown that people sometimes endorse more altruistic fairness preferences when their own payoff is not at stake than when it is, the current research is the first, to our knowledge, to provide evidence that people sometimes act more equitably than they explicitly endorse – and that they may not even be aware of doing so. One possible interpretation is that people's spontaneous actions reflect a basic sense of fairness with respect to effort investment which diverges from their explicit judgments about fairness. A second possible interpretation (compatible with the first) is that participants who matched their partner's efforts were more strongly motivated by equity in the primary task because they perceived it as a situation in which their actions might influence their value as cooperation partners, whereas their judgments about the vignettes were performed from a detached, hypothetical perspective. Future research may further explore the spontaneous sense of fairness expressed in people's behavior, and its relation to explicit beliefs about fairness.

To address whether people's tendency to match their partner's effort or to invest effort efficiently is reflected in people's self-construal, we examined how participants rated their feelings of connectedness to and separateness from social situations on Singelis' Self-Construal Scale. Here, we did not have clear predictions. On the one hand, one could speculate that those who invest effort efficiently care less about the joint outcome than about their own gains, whereas those who match a partner's effort care more about equity than about the sheer quantity of rewards or efficiency. On this interpretation, one should expect that the effort matchers would be more interdependent in their self-construal than those who invest effort efficiently. According to a second interpretation, in contrast, one could speculate that within the context of the task, those who match their partner's effort are willing to incur costs to themselves and to the dyad as well. In other words, they are willing to reduce their partner's payoff for individual reputational gain. On this interpretation, one should expect the effort matchers to be more independent in their self-construal than those who invest effort efficiently and increase their partner's payoff the most. Both of these interpretations remain speculative, however, given that our results do not provide evidence for either of them.

This research offers evidence for functional explanations of why the perception of a partner's effort modulates effort-based decision-making in joint action and thereby contributes to attaining a fuller understanding of the role of effort and effort perception in human cooperative interactions. First, our findings provide evidence that people have a tendency to achieve equity through effort calibration even at a *cost* to themselves and their partner. Moreover, our findings also provide a valuable addition to existing research on how people prioritize overall efficiency versus considerations of fairness. For example, Strachan and Török (2020) found evidence that people prioritize joint efficiency over fairness in joint action. However, in their experiments the effort costs were small for participants, and the authors identified the possibility that fairness may affect decision-making more when there are substantial action costs. The current research supports this conjecture by providing evidence that when the costs are higher, some participants are more strongly motivated by fairness than by efficiency considerations. Moreover, by identifying distinct subgroups that appear to be more strongly motivated by the one than the other, they raise the intriguing possibility that there may be substantial individual differences with respect to the relative strength of these motives. Further research is needed in order to catalogue and to explain these individual differences.

Second, our findings provide evidence that people use others' investment of effort to infer the value of opportunities afforded by their environment, and that they adjust their effort accordingly. These findings are consistent with a large body of work on naïve utility calculus suggesting that human beings from early infancy assume that other agents act to maximize subjective utility (Jara-Ettinger et al., 2016).

It is important to acknowledge several limitations of the current study. First, only Experiment 4 directly addresses the link between the tendency to match a partner's effort and partner selection, and the results raise interesting questions for future research. On the one hand, we found that participants who matched their human partner's effort were less inclined to match a computer partner's effort – as one would expect if their tendency to match a partner's effort was motivated by a concern about maintaining their value as cooperation partners. On the other hand, we show that some participants matched a computer partner's effort. While this latter finding may be surprising, we believe that it is in fact consistent with Baumard et al. (2013)'s account of the evolution of fairness. In their account, competition among cooperative partners leads people to strategically share the costs and rewards of cooperation equally. With time, this eventually leads to the selection of a disposition to be intrinsically motivated to cooperate fairly. This is so because, at the psychological level, it may be a more cost-effective way of securing a good collaborative reputation than constantly engaging in the cost-benefit analyses of the implications of various sharing behaviors. Therefore, if the tendency to achieve equity through effort calibration is indeed an evolved mechanism of partner choice, then people may have an intrinsic preference to match their partner's effort. If so, then changes in partner market conditions may not lead to substantial short-term changes in people's tendency to match their partner's effort. That said, the link between one's tendency to match their partner's effort and partner selection should be further investigated.

Second, the task itself did not implement a real partner market: participants could not choose their partners or leave their partners and do the task with someone else. In a way, this makes our results even more striking: although there was no partner to attract and no need to actively maintain one's partner, one subset of participants matched their partner's effort even when they incurred a cost in doing so. This is consistent with the hypothesis that the preference for equity through effort calibration may be intrinsic and not necessarily strategic. However, it must be noted that the experimental situation itself was embedded in a real partner market: participants were first introduced to another participant in the waiting area, whom they were told would be their partner for the experiment, and they were informed that their jointly earned rewards would be evenly divided between them and this partner. Participants could defect by going through the trials with no effort investment or by quitting the experiment.

Third, we focused on the amount of effort people invest in joint action. However, the amount of effort is just one aspect of how an agent contributes to a joint action. For example, agents may vary in the quality of their efforts –that is, in their level of competence. Moreover, agents' contribution itself may vary in their pivotality – that is, with respect to the contribution's importance in terms of the final outcome. Future research should investigate whether and how equity through effort calibration may be sensitive to specific features of cooperation partners such as their level of competence or the pivotality of contributions.

Open practices

This project was pre-registered prior to data collection [Experiment 1: *https://osf.io/up2sw/?view_only=1ac485fbb976436fad28c1a40b3d2a95*; Experiment 2: https://osf.io/zt5d3/?view_only=b49366807cb94be7a786b8e7b9847941; Experiment 3: https://osf.io/rptw9/?view_only=c1540add34744cd285e251ee6c47600f; Experiment 4: https://osf.io/avmcw/?view_only=d4c7d84966d5464f9d8de277c1ed035a]. The reproducible scientific reports (data and analysis code) are available in an online repository here [https://osf.io/cj64t/?view_only=a3697e5d4a1847ea92095af20e40cc59].

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CRediT authorship contribution statement

Marcell Székely: Conceptualization, Data curation, Formal analysis, Methodology, Project administration, Software, Visualization, Writing – original draft. **Stephen Butterfill:** Conceptualization, Writing – review & editing. **John Michael:** Conceptualization, Funding acquisition, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Data availability

The reproducible scientific reports (data and analysis code) are available in an online repository here [https://osf.io/cj64t/?view_only=a3697e5d4a1847ea92095af20e40cc59].

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jesp.2024.104601.

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