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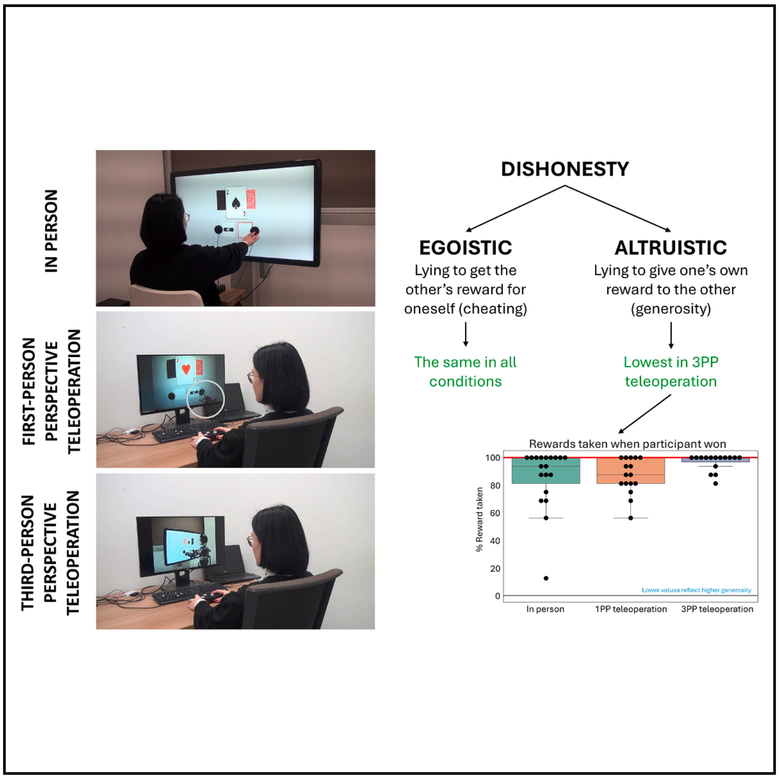
Non-immersive robot teleoperation does not reliably affect egocentric dishonesty but can influence altruistic dishonesty

Graphical abstract



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In brief

Health sciences; Cognitive neuroscience; Robotics

Highlights

- The study investigated non-immersive screen-based humanoid robot teleoperation
- Robot teleoperation induced modest embodiment and high sense of agency
- Teleoperation did not reliably increase egocentric dishonesty (cheating)
- 1 PP compared to 3 PP teleoperation increased altruistic dishonesty (generosity)

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Article

Non-immersive robot teleoperation does not reliably affect egocentric dishonesty but can influence altruistic dishonesty

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SUMMARY

Robot teleoperation enables action through an artificial body while physically elsewhere. We examined whether non-immersive, screen-based teleoperation of the humanoid robot iCub induces embodiment, the sense that the robot's body feels like one's own, and whether embodiment affects dishonest behavior compared to acting with one's real body. Participants performed a task either in person or via teleoperation in a first-person (1 PP) or third-person (3 PP) perspective. Both teleoperation modes produced a small but significant sense of embodiment and high agency over the robot, with stronger location illusion in 1 PP than 3 PP. Overall, embodiment and perspective did not influence dishonesty aimed to increase one's reward, i.e., egocentric dishonesty. However, in 3 PP, the egocentric dishonesty correlated positively with specific embodiment experiences: feeling out of one's body, having more than one body, and sensing one's actions affected by the robot. Moreover, participants were also more generous, showing altruistic dishonesty, toward their partner in 1 PP than in 3 PP. Results are discussed in relation to embodiment and moral decision-making.

INTRODUCTION

Teleoperation literally means controlling or operating at a distance.[1] Robot teleoperation can become invaluable when it is not possible to act in person for safety or practical reasons. Some examples involve space missions, operations in nuclear or biologically contaminated zones, natural disaster areas, as well as performing remote medical procedures.[2] Other, more morally questionable examples involve teleoperation in the context of warfare. In such cases, teleoperation dramatically increases the safety of the person operating a weapon, such as a remotely controlled drone. While teleoperation can increase the safety and efficiency of operators, it also physically detaches them from the consequences of the actions carried out through teleoperation.

At the same time, controlling a robotic body, especially a *humanoid* one, from a first person perspective can elicit the feeling of "embodying" the robot itself.[3,4] Embodiment is a psychological phenomenon where an individual perceives an external body or body part(s) as their own real body.[5,6] The experience of embodiment arises from several core components[7–9] including the following: the sense of (bodily) ownership (SoO), i.e., the feeling that the "external body" is one's own; the sense of agency (SoA), i.e., the feeling of being in control over the actions and movements performed by the "external body"; and the sense of location (SoL), reflecting where we experience ourselves to be located in space. The spatial overlap and the motor congruency between one's corporeal body and the external (artificial) body are fundamental mechanisms underlying the feeling of embodiment. For instance, seeing a body part where we expect to see our own body part can elicit the feeling that what we are seeing is our own body.[10,11] Also, seeing this body perform the same actions we are doing while doing them gives rise to feelings of control over the external body and can lead to the experience of embodying it.[12,13]

Research has extensively shown that the characteristics of the artificial body and the extent to which we embody it can shape different facets of our cognition, like the perception and attitudes toward one's own real body,[14] the performance at a cognitive task,[15] the likelihood of adopting prosocial behavior toward members of an ethnic minority,[16,17] and, perhaps most critically, moral decisions.[18] The influence of embodiment on moral decisions is particularly relevant, as many applications of teleoperation involve the need to make morally loaded decisions.

Figure 1. Illustration of the experimental setup

During the experiment, the door to the room with the iCub robot was closed.

Therefore, understanding how different forms or degrees of embodiment might bias such decisions is of utmost importance.

Previous research on the relationship between embodiment and morality has shown that different aspects of embodiment can have distinct, and even opposite, effects on moral behavior.[19,20] On the one hand, heightened SoO has been linked to increased egocentric decision-making. For example, individuals with amplified bodily signals (e.g., hunger and thirst) exhibit increased dishonesty when self-interest is at stake.[21] Similarly, participants in the ultimatum game prioritized selfish offers when bodily self-awareness was increased by highlighting interoceptive cues (e.g., self-heartbeat perception[22]) or delivering painful stimuli via laser stimulation,[23] suggesting that SoO may amplify self-serving motivations. On the other hand, SoA appears to favor ethical behavior: individuals report a stronger sense of agency when performing moral acts (e.g., helping others) and diminished agency during immoral actions, such as harming others.[24,25] This might be driven by the fact that the SoA is one of the factors taken into account when attributing responsibility.[25]

The influence of embodiment on moral decision-making has been investigated using immersive virtual reality. For instance, Scattolin et al.[18] asked participants to play a card game where they were free to lie to other players, to take high or low amounts of reward (money) associated with each round. Participants completed the game through a virtual avatar, under three conditions: one in which they saw an intact virtual body from a congruent, first-person perspective (1 PP) (i.e., where they would expect to see their real body), a second one where the virtual hands were detached from the rest of the virtual body seen from a 1 PP, and finally a third one where they saw an intact avatar from an incongruent, third-person perspective (3 PP) (i.e., looking at the virtual body from an outside perspective). Participants embodied the virtual avatar significantly less in the 3 PP condition compared to the two 1 PP conditions. Crucially, only when participants experienced less embodiment, they showed a significantly higher tendency to take the money from the other players when the round involved high, rather than low, rewards. The authors explain these results by arguing that lower embodiment could make it easier for individuals to distance themselves from the implications of dishonest actions performed by a virtual body. Similarly, Pyasik and Pia[26] found that seeing an avatar cheat from a 3 PP (vs. 1 PP) reduced participants' physiological reactivity to dishonesty.

Previous studies investigating the relationship between embodiment and dishonesty aimed to provide a high level of embodiment. However, what remains unexplored is whether these findings generalize to situations in which the level of embodiment is much lower. The goal of the current study was to investigate whether different forms of non-immersive embodiment of a teleoperated humanoid robot would influence moral decision-making. To achieve this, we designed a study inspired by previous research on this topic that used virtual embodiment. Specifically, we adapted the experimental setup from Scattolin et al.[18] to involve robot teleoperation rather than controlling a virtual avatar (Figure 1). Additionally, we decided to employ non-immersive, screen-based teleoperation over a humanoid robot, as compared to fully immersive virtual reality from the previous study.

The main task of participants was to play a card game (Temptation to Lie Card Game[18,27,28]). In this game, participants were shown a card, which, they were told, was selected earlier by another participant. Their task was to assess whether the previous participant won or not and decide whether to give the reward to that participant or lie about the card's outcome. Importantly, deciding not to give away the reward meant that participants could keep it for themselves. This created three possible scenarios: to truthfully report the card's outcome, to take the reward even when the other participant won (cheating—egoistic lie), or to give away the reward even if the other person lost (generosity—altruistic lie). Moreover, in line with a previous study,[18] the reward could be either high or low, introducing the potential of modulation of the tendencies to simply report the card's outcome, cheat, or show generosity depending on the amount of reward that was at stake. Figure 2 illustrates an example of a single trial from the experiment.

The experiment aimed to determine whether non-immersive, screen-based teleoperation of a humanoid robot using first-person and third-person visual perspectives leads to different levels of embodiment of the robot and whether embodying a teleoperated robot increases the likelihood of engaging in morally questionable behavior (cheating by taking a monetary reward that should be given to another participant), compared to acting through one's real body. Therefore, in our study, participants took part in the card game in three different conditions, with the order of conditions counterbalanced across participants.

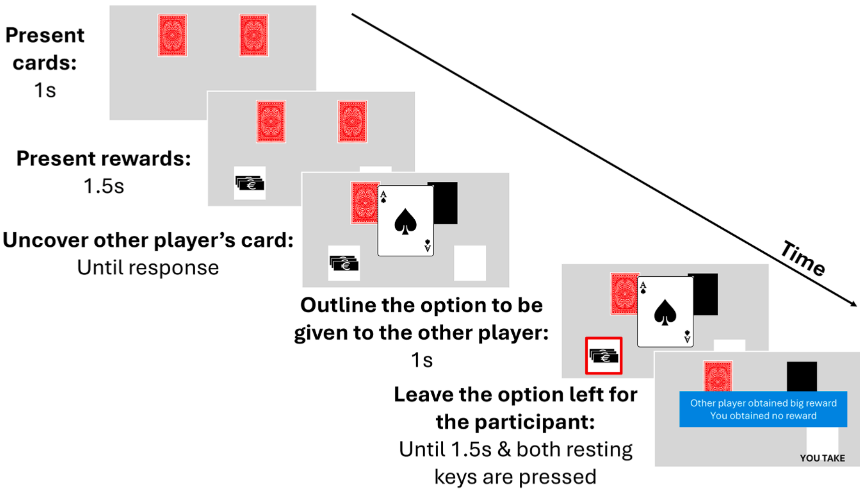

Figure 2. Example of a single trial from the experimental procedure (card game)
Participants saw the back of two cards. After 1 s, one of them was turned around to display the card picked by the other participant. The card could be either a red heart or a black spade, and participants were instructed at the beginning of the experiment which symbol corresponded to their partner's win or loss. Below the cards, participants saw two white boxes—one empty and one with a representation of the reward at play, which could be either small or large (shown here is an example of a high reward play). Participants' task was to decide which of these boxes should be given to the other person and which they should keep for themselves. This introduced the temptation to be dishonest (give no reward even if another person won) or the possibility to be generous (give away one's own reward).

First, participants performed the task in person by physically sitting in front of a big screen with response buttons attached to it (Figure 3A). Second, they completed the task using a 1 PP screen-based robot teleoperation. In this case, participants sat in front of a computer in the room next door and observed the game through the camera located in the eyes of a humanoid robot iCub.[29] To respond, participants released a button on a button box placed on the desk in front of them. Releasing the button triggered the robot's hand to move and press the same screen buttons participants used in the in-person condition (Figure 3B). This was intended to make participant's action during teleoperation similar to the one performed during in-person condition, but with the robot, not the participant, pressing the button on the screen. Finally, participants performed the same task using the 3 PP-screen-based robot teleoperation in which they observed the robot's actions from a camera situated behind and to the left of the robot (Figure 3C).

After each experimental block, participants evaluated their level of robot embodiment by using the Avatar Embodiment Questionnaire (AEQ).[30] The items were adapted to either the in-person or the robot teleoperation conditions. Table 1 presents the items from the questionnaire.

Concerning robot embodiment, we expected participants to report a higher level of bodily ownership, sense of agency, and sense of location when performing the task in person (using their own corporeal body) than when using 1 PP robot teleoperation (contrast 1). This prediction is based on the assumption that people should experience a stronger embodiment of their real bodies than of external bodies (at least as long as they do not experience depersonalization[31–34] or extreme forms of avatar-embodiment). Second, we expected embodiment values to be higher in the 1 PP teleoperation condition than in the 3 PP teleoperation condition (contrast 2), as shown by previous studies showing that 1 PP typically leads to stronger embodiment than 3 PP.[11,35]

We expected embodiment differences to be reflected in the moral behavior of participants. Specifically, we predicted that participants would show more cheating (i.e., a higher tendency to take the reward, when it should go to the other person), when experiencing lower embodiment, for instance when completing the task by teleoperating a robot from the 1 PP compared to when doing it in person (contrast 1). This prediction builds on the theoretical assumption that lower levels of embodiment facilitate a sense of separation from undesirable aspects of situations or events, such as their moral implications,[36] which could end up facilitating egoistic choices. Moreover, we hypothesized that the tendency for dishonest behavior would be stronger when participants teleoperate the robot from a 3 PP relative to 1 PP (contrast 2). This was based on previous findings by Scattolin et al.,[18] showing lower embodiment and altered moral behavior in 3 PP compared to 1 PP.

RESULTS

The influence of gender on the results

We did not observe any effect of gender on the results; therefore, all data are reported collectively across genders.

Sense of body ownership, sense of agency, and sense of location across experimental conditions

First, we tested whether different experimental conditions (performing the task in person, through 1 PP teleoperation, and through 3 PP teleoperation) affected sense of ownership of the robot, sense of agency, and sense of self-location, as measured by questions asked at the end of each block (questions from the Avatar Embodiment Questionnaire). We did these analyses by performing Friedman's test, a non-parametric equivalent of a one-way repeated measures ANOVA, which was followed by two planned contrasts. The first contrast was between the in-person condition and the 1 PP teleoperation, as in both cases participants performed the task from the first-person perspective. The second contrast compared two types of teleoperation.

The main effect of the experimental condition in Friedman's test was significant for all three aspects of bodily self-consciousness: sense of ownership (question 1: $\chi 2 = 40.5$, $p < 0.001$), sense of agency (question 4: $\chi 2 = 13.9$, $p = 0.001$; although in question 5 it was not: $\chi 2 = 2.2$, $p = 0.338$), and sense of location ($\chi 2 = 32.1$,

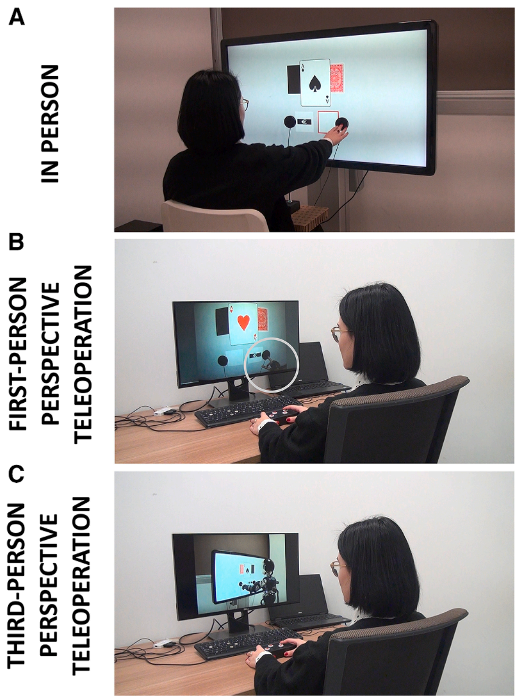

Figure 3. Photographs of the setup illustrating three experimental conditions

(A) In person condition, (B) 1PP robot teleoperation, (C) 3PP robot teleoperation. The gray circle in (B) shows the robot hand (the circle is presented for illustration purposes only).

Table 1. Questions from the Avatar Embodiment Questionnaire (AEQ)

Number	Question
1	I felt as if the robotic/corporeal body was my body
2	It felt as if the robotic/corporeal body was someone else's
3	It seemed as if I might have more than one body
4	It felt like I could control the robotic/corporeal body as if it was my own body
5	The movements of the robotic/corporeal body were caused by my movements
6	I felt as if the movements of the robotic/corporeal body were influencing my own movements
7	I felt as if the robotic/corporeal body was moving by itself
8	I felt as if my body was located where I saw the robotic/corporeal body
9	I felt out of my body
10	I felt as if my real body were drifting toward the robotic/corporeal body or as if the robotic/corporeal body were drifting toward my real body

Participants responded using a continuous visual analog scale. Adapted from Gonzalez-Franco and Peck.[30]

$p < 0.001$). The subsequent contrasts using the Wilcoxon's test revealed a significantly higher rating for the in-person condition than 1 PP teleoperation (contrast 1) of sense of ownership ($W = 59$, $p < 0.001$), sense of agency (question 4: $W = 178.5$, $p = 0.001$), and sense of location ($W = 137$, $p < 0.001$). When comparing two types of teleoperation (contrast 2), we did not detect a significant difference in sense of ownership ($W = 380$, $p = 0.513$) and sense of agency ($W = 442$, $p = 0.708$). However, participants reported that they "felt as if my body was located where I saw the robotic body" significantly more when controlling the robot from the first than the third-person perspective ($W = 277$, $p = 0.029$). See Figure 4 for illustration of the results.

Other questions investigating robot embodiment (questions 3 and 9)

For the full results from the used questionnaire, we refer the readers to the Figures S1–S10. Here, we report the results from two additional questions.

First, in response to question 3 "It seemed as if I might have more than one body" participants responded significantly more positively when teleoperating a robot from the first-person perspective than when doing the task in person (contrast 1: $W = 178.5$, $p = 0.001$), while the difference between two types of teleoperation was not significant (contrast 2: $W = 317$, $p = 0.141$). In the in-person condition, the responses were close to zero (median = 1), while in the 1 PP and 3 PP teleoperation, they were increased (21 in both conditions).

Question 9 was "I felt out of my body." Here, again, participants reported significantly higher values in 1 PP teleoperation than in the in-person condition ($W = 238$, $p = 0.013$). In the latter, the median response was 0, while the median response in 1 PP and 3 PP teleoperation were 19 and 20, respectively. The two types of teleoperation did not significantly differ from one another ($W = 377$, $p = 0.657$).

The tendency to keep the reward (cheating and generosity)

The percentage of trials in which participants decided to keep the reward is a bounded variable that takes values between 0 and 1. Moreover, it is highly non-normally distributed (as indicated by significant results of the Shapiro-Wilk test and a QQ plot reported in the Table S2 and Figure S13). Due to this, we performed the analyses using non-parametric statistics, which are much more robust in cases when assumptions of normality are violated. However, no non-parametric method exists that can replace a repeated-measures ANOVA that involves more than one factor.

Due to this methodological limitation, instead of performing a $2 \times 2 \times 3$ ANOVA, we performed Friedman's test, a non-parametric equivalent of a one-way ANOVA, treating all 12 specific within-subject combinations of factors as levels of a single factor. Such an approach allowed us to test whether there is evidence of significant variation between all these 12 specific conditions, but it did not allow us to attribute it to specific main or interaction effects. This test yielded a statistically significant effect ($\chi 2 = 353.2$, $p < 0.001$).

We followed this analysis with specific tests for each main effect. The Wilcoxon test comparing the effect of outcome (whether participant or the other player won the round) was significant ($W = 3$, $p < 0.001$), indicating that participants were significantly more likely to take the reward if they won than if

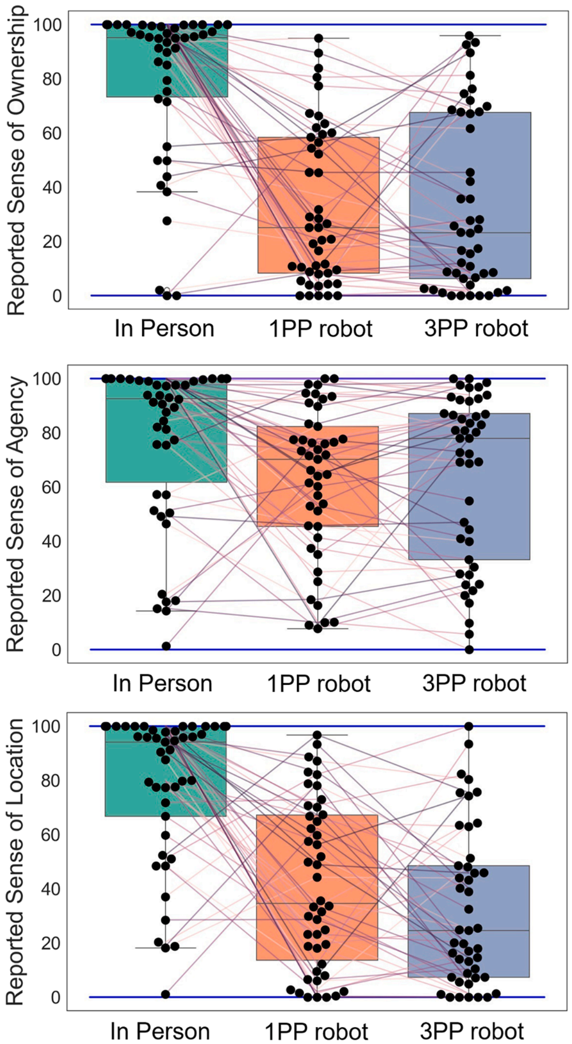

Figure 4. Boxplots and scatterplots illustrating the results from the Avatar Embodiment Scale across experimental conditions

The results show sense of ownership (question 1), sense of agency (question 4), and sense of location (question 8).

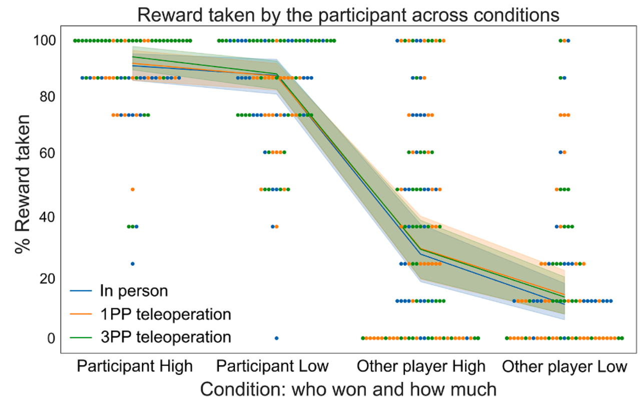

Figure 5. The results of the experiment comparing the tendency to take the reward in the card game across experimental conditions (within-subject analysis)

Data are represented as mean ± 95% confidence intervals. The results on the left reflect trials in which the participant won, so values lower than 100% indicate that participants exhibited generosity. Data on the right reflect trials in which participants lost, so they reflect the percentage of trials in which participants decided to take the reward that did not belong to them.

the other player won. For the reward (high versus low), Wilcoxon's test was also significant (W = 92.5, $p < 0.001$), showing that participants were significantly more likely to take the reward if it was high than low. However, we did not find evidence of the significant effect of Control (in-person, 1 PP teleoperation, and 3 PP teleoperation) on the tendency to take the reward ($\chi 2 = 2.61$, $p = 0.271$). Figure 5 illustrates the results. We also present the results of the standard ANOVA in the Table S4 and descriptive statistics for each condition in Table S3. This analysis yielded very similar results and did not find any significant effect involving the form of control.

We also conducted additional analyses in which we included the data from only the first experimental block that each person completed. As such, these results would be less affected by potential order or carryover effects[37] or demand characteristics.[38–40] We performed three such analyses using Kruskal-Willis test, a non-parametric equivalent of a one-way ANOVA (between-subjects) with factor Control. The analysis for the overall tendency to take the reward did not reveal a significant effect of Control ($\chi^2(2) = 1.504$, $p = 0.471$; Figure S11). Similarly, there was no significant effect of Control on the tendency to take the reward in trials when the other player won, i.e., the tendency to show egocentric dishonesty ($\chi^2(2) = 1.359$, $p = 0.507$; Figure S12). However, there was a significant main effect of Control in trials in which participants won ($\chi^2(2) = 6.142$, $p = 0.046$). Planned contrasts using the U-Mann Whitney test (a non-parametric equivalent of a standard t test) revealed that the difference between the in-person and the 1 PP teleoperation conditions (contrast 1) was not significant (U = 171.5, $p = 0.514$). However, the difference between the 1 PP and the 3 PP teleoperation (contrast 2) was significant (U = 60.5, $p = 0.012$), indicating that participants were less willing to take the reward in the 1 PP than the 3 PP condition, reflecting increased generosity (Figure 6).

Additional correlational analyses

In addition to the main analyses, we also conducted exploratory correlational analyses. For these analyses, we were primarily interested in the relationship between the tendency to cheat in the card game and the responses given to the Avatar Embodiment Questionnaire and other questionnaires. These analyses revealed several interesting findings.

First, to investigate the correlations between behavior in the card game and AEQ ratings, we used the percentage of trials in which participants decided to take the reward even if the other player won under four different conditions: (1) high reward during 1 PP teleoperation, (2) low reward during 1 PP teleoperation, (3) high reward during 3 PP teleoperation, and (4) low reward during the 3 PP teleoperation. Then, we calculated Spearman's rho correlations (we used non-parametric correlation because of nonnormal distribution of the results) between these scores (1 PP high/low and 3 PP high/low reward) and AEQ answers.

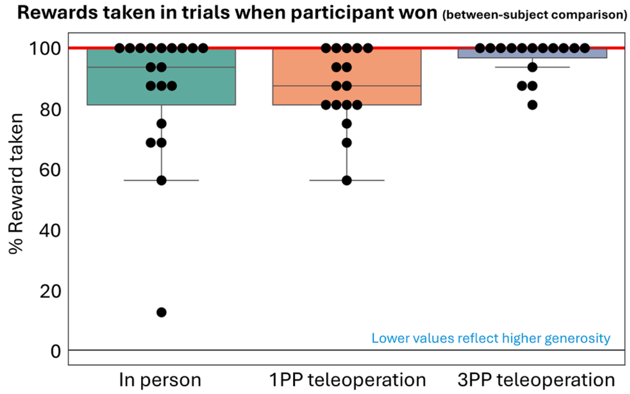

Figure 6. Boxplots and scatterplots showing the results of the between-subject analysis of the data from only the first blocks on the tendency to give the reward to the other player in trials in which the participant won

It means that not taking the reward was reflecting generosity toward the other player (altruistic lying).

We found that no correlations were significant for the 1 PP teleoperation. However, we did find significant correlations in the 3 PP condition, although only when the reward was low. The tendency to cheat in these trials positively correlated with answers to question 3: "It seemed as if I might have more than one body" (rho = 0.321, p = 0.032), question 6: "I felt as if the movements of the robotic body were influencing my own movements" (rho = 0.428, p = 0.003), and question 9: "I felt out of my body" (rho = 0.416, p = 0.004).

Moreover, the tendency to cheat in the low-reward 3 PP teleoperation was also negatively correlated with the general sense of agency, as measured by the positive agency scale in SoAS (rho = −0.450, p = 0.002). This scale also negatively correlated with the tendency to cheat when the reward was low in the 1 PP teleoperation (rho = 0.311, p = 0.035).

DISCUSSION

In the present study, we investigated whether non-immersive teleoperation of a humanoid robot through 1 PP and 3 PP influences the embodiment of the robot and, crucially, whether embodiment in turn influences the tendency to cheat. Based on previous research, we predicted that teleoperation of the robot might lead to increased tendency to engage in dishonest behavior compared to acting in person (see Figure 7A for illustration of our predictions). Similarly, if embodiment is higher during 1 PP teleoperation compared to 3 PP teleoperations, then the tendency to behave dishonestly would be lower in teleoperation than in 3 PP teleoperation. In the subsequent sections, we first discuss our results in relation to the process of robot embodiment, and then we discuss the results concerning moral decision-making.

Embodiment of a humanoid robot during two types of screen-based teleoperation

The first goal of the experiment was to investigate to what extent teleoperating a humanoid robot via a screen-based 1 PP of the robot (the view from the robot's eyes) or a screen-based 3 PP view of the robot (from behind it) influences robot embodiment. We found that on most questions investigating embodiment, these two perspectives led to similar results. The sense of embodiment of the robot body was typically low. The answers to the question "I felt as if the robotic body was my body," which measured participants' sense of ownership, were at the median level of 23–25 points out of 100. Similar values were given in response to the question, "It seemed as if I might have more than one body", with a median of 20–21 points. Albeit not high in absolute terms, ratings to this question were significantly higher than what participants reported after completing the task in the in-person condition, where the median value was 2.5 points. We also observed a similar pattern in response to the question "I felt out of my body," with values close to zero for the in-person condition (median = 1.2) and increased values for both types of teleoperation (median 1 PP = 14.8, 3 PP = 17.2). These results suggest that our manipulation elicited some level of robot embodiment, which was accompanied by an experience of detachment or displacement from their real body.[6] Still, for most of the participants, these effects were low in magnitude. This contrasts with previous results by two of the authors using the same task in immersive virtual reality,[18] in which the 1 PP control over a digital avatar elicited median responses of 79.7 and the 3 PP condition of 63.7 points (out of 100).

In contrast to the sense of (bodily) ownership, participants typically reported high levels of sense of agency over the actions of the teleoperated robot. The level of SoA was estimated using two questions from the avatar embodiment questionnaire. In question 5, "The movements of the robotic/corporeal body were caused by my movements," most participants reported ceiling level SoA in all experimental conditions, with median values between 92 and 97 and no significant difference between conditions. The second question, probing the sense of agency, "It felt like I could control the robotic/corporeal body as if it was my own body," led to a different pattern of results. Unsurprisingly, participants reported very high values in the "in-person" condition (92.6). In contrast, ratings provided after the 1 PP teleoperation were significantly lower (70.3). Ratings in the 3 PP condition were similar but showed slightly, but not significantly, higher level (77.9). This pattern is similar to the one from the previous VR study[18]: median responses to question 5 were between 98 and 100 and to question 4 were between 81 (3 PP) and 86 (1 PP).

The last component of embodiment that we investigated, sense of location, was the only one that significantly differed between the two types of teleoperation. For 1 PP robot teleoperation, the median response to the question "I felt as if my body was located where I saw the robotic body" was 34.6. In contrast, for the 3 PP teleoperation, it was 24.7. This was the only aspect of embodiment that significantly differed between the two employed teleoperation perspectives. However, compared with the study using a VR setup,[18] the rating for this question from the 1 PP perspective was low, as in the VR 1 PP condition participants' answers were around 90. Interestingly, the ratings participants provided in both our teleoperation conditions are much closer

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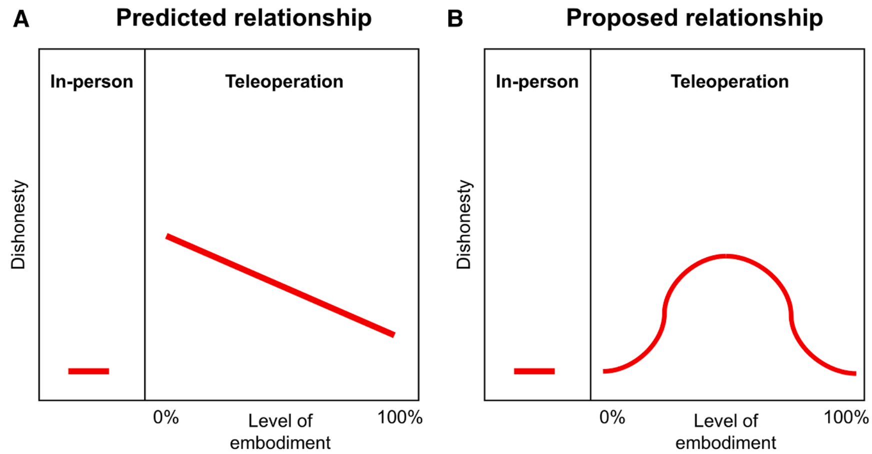

Figure 7. Two forms of relationship between embodiment and dishonesty (cheating)

The relationship that we predicted (A) and the relationship that we propose based on comparison of our results with previous research (B).

to what participants in the VR study reported for the 3 PP condition: 38.5.

Overall, these results show that while screen-based teleoperation preserved a sense of agency, it did not lead to a strong embodiment of the robot. While research typically shows that embodiment is stronger in a 1 PP than in a 3 PP,[18] our participants showed similar levels of embodiment in the two teleoperation conditions, regardless of the perspective from which they saw the robotic body. One possible reason why we did not find higher levels of embodiment in the 1 PP perspective compared to the 3 PP perspective might be that participants could not fully see the robot's body from the 1 PP. In fact, the camera mounted in the robot's eye pointed toward the computer screen, while the robot's hands became visible shortly before each button press and until the robot's lowering of the hand. This limited visibility might also explain the lower embodiment ratings we observed compared to reported when using immersive virtual reality, where participants are free to look around by simply moving their head. This not only allows full visibility over the virtual body but also contributes to the feeling of immersion in the virtual scenario, thereby strengthening the illusion of being inside a new body. In our study, it is possible then that the limited view participants had over the robotic body may have made it more difficult for participants to fully embody the robotic body, despite having a congruent perspective (1 PP) over it. Another key difference between the present study and those using immersive virtual reality is that in the latter, participants' real bodies are completely hidden from view and only virtual avatars are visible. This is not true here, where participants always had complete visibility over their own real body, possibly preventing them from fully experiencing the illusion of being within the robotic body. An additional difference is that in VR studies embodiment procedures driven by actions (e.g., touching virtual balls with the virtual hand) are induced. All these factors could have contributed to perceiving the robot's body as equally extraneous to their bodily self, regardless of the perspective from which they were experiencing it.

To summarize, screen-based robot teleoperation elicited only a modest robot embodiment and shift in self-location, compared to embodiment over a digital avatar using a VR setup. However, it did not lead to a strong decrease in the sense of agency, both in comparison to the in-person condition or to previous studies using VR. Future research with teleoperation systems that lead to stronger immersion via the use of head-mounted displays, tactile gloves, and other technologies,[41,42] also including brain-computer interfaces,[43] should investigate how strongly the level of robot embodiment can be increased.

Dishonest behavior during non-immersive robot teleoperation

The second, and main, goal of our study was to investigate the tendency to engage in egoistic dishonest behavior when teleoperating a robot in a non-immersive setup, compared to when acting in person. Previous research with VR found evidence that embodying a virtual avatar using the 3 PP can influence the tendency to display dishonest behavior compared to embodying an avatar from a 1 PP.[18] In our study, we did not find evidence of such an effect when comparing third-person and first-person teleoperation of a humanoid robot. These two conditions also did not lead to a significant increase in dishonest behavior compared to performing the task in person. We did, however, observe evidence of an effect of visual perspective (1 PP vs. 3 PP) on participants' generosity (altruistic lying)—an effect that we did not predict but which we will discuss later.

Lack of effect on cheating stands in contrast to previous results obtained using virtual reality.[18] One explanation for the discrepancy in findings might be that our task was not convincing enough to the participants, and therefore, they did not adequately engage cognitive processes responsible for moral cognition. However, we find this explanation very unlikely. While the mode of performing the task (in-person, 1PP/3 PP teleoperation) did not affect the results, the two other factors from our model yielded results that reflected the expected modulation of moral decision-making. First, in most of the trials, participants took the reward when the displayed card showed that they won and did not take the reward when the other person won. This confirms that they generally understood and followed the task instructions. Crucially, we found a significant and strong effect of reward size on participants' moral behavior: participants were more likely to "steal" other participants' reward if it was high and they were more likely to give away "their" reward if it was low. This indicates that participants were evaluating the available options and engaged in dishonest behavior mostly when a potentially higher reward was to be gained. Similarly, when they engaged in generous behavior, they were much more likely to do it when the loss for them was low rather than high—again demonstrating an interplay between moral behavior and the potential cost and reward.

This suggests that the difference in obtained results might be due to differences in the form and level of embodiment experienced by participants in the current and the previous study. As discussed in the previous section, our results show that screen-based teleoperation does not lead to high embodiment of a robotic body. In our study, the reported robot embodiment was at around 25%. This differs from Scattolin et al.,[18] where participants reported high embodiment over a virtual body—around 80 points (out of 100) in the first-person perspective conditions and around 65 in the third-person perspective condition. At the same time, Scattolin et al.[18] found that participants took significantly more money from others only in the 3 PP condition when rewards were high rather than low. The authors interpreted this result as evidence that lower feelings of embodiment might elicit a sense of detachment from the meaning of actions performed through the virtual body, which might facilitate dishonesty. In other words, if individuals do not identify with a virtual body, they may feel less responsible for the (dishonest) actions performed through it. Following this logic, one might speculate that if the sense of body ownership is even lower, participants should be even more likely to behave dishonestly when operating through a robot that they do not identify with, as in the present study.

However, our results did not confirm this inference. Instead, we found that very low level of embodiment of an external body led to similar level of dishonesty as performing the task in person. What can explain such, apparently paradoxical, result? Our results do not allow us to conclusively answer this question, and more research is needed. However, we propose a very speculative potential explanation. Such results could be observed if the relationship between embodiment and dishonesty is non-linear, with only intermediate levels of embodiment encouraging dishonesty, while high and low embodiment preventing it (Figure 7B). The intermediate level of embodiment can present a situation in which a person is simultaneously inhabiting an external body and remaining in one's real one. This creates a situation in which an external body might serve as a form of "mask": a distinct actor that can take part of the blame for morally questionable behavior. In contrast, in case of a convincing multisensory 1 PP embodiment, one gets fully psychologically transported into an external body. As such, any action performed through the external body is much more immediate, and therefore it might be relatively more difficult to relinquish the sense of responsibility. This mechanism could explain the difference between null result in our study and positive findings in Scattolin et al.,[18] although validation of this proposal requires further empirical data.

Nevertheless, it is possible that strong 1 PP embodiment might lead to more dishonest behavior than what a person would do when acting in person. In fact, a large body of evidence shows that the characteristics of the virtual body we illusorily identify with can influence our behavior.[44–48] This phenomenon, known as the "Proteus effect",[48,49] shows that individuals may change their behaviors and attitudes not only in accordance with the observable, physical characteristics of the embodied avatar but also with its non-physical characteristics. For example, research has shown that embodying a virtual body resembling figures like Einstein, Freud, or a human-like Christian God can improve planning and problem solving, change one's outlook on personal problems, and increase feelings of strength and invulnerability compared to embodying neutral avatars.[15,50–52] In light of this evidence, we can hypothesize that embodying an avatar that is generally perceived as possessing an evil moral character might lead to an increased tendency to cheat compared to when embodying an avatar with a good moral character (cf.[53]). In other words, the Proteus effect might influence decision-making in ways that differ from those of pure embodiment, but it might also moderate the relationship between embodiment and moral behavior. Future research should therefore address this issue.

This interpretation finds additional support in the correlational data from our experiment. While at the group level we did not find evidence of increased cheating during robot teleoperation, we discovered that during 3 PP teleoperation, participants who were more likely to cheat (when the reward was low) were also more likely to report that they felt having more than one body. Moreover, they were also more likely to say that they felt out of their body and that movements of the robotic body were influencing them, suggesting that they delegated some agency and responsibility for the action and its consequences to the robot.

In our study, participants retained a strong sense of agency over their actions, which was at approximately 80 points (question 4) or 90 points (question 5) in both conditions involving teleoperation. A sense of agency is one of the crucial factors at play when attributing moral responsibility. Research on moral behavior has shown that a diminished sense of agency facilitates immoral actions, as it is strongly correlated with moral disengagement,[54] a psychological process through which individuals deny responsibility for immoral actions to reduce guilt and self-condemnation. For instance, moral disengagement is frequently reported under coercion, as the felt lack of agency facilitates individuals to distance themselves from the consequences of their actions (e.g., "I was just following orders").[24,55] Therefore, in the current study, the constancy in participants' moral behavior might be explained by the strong sense of agency reported in all experimental conditions. This is further supported by our correlational results showing that the sense of agency (treated as a trait) was negatively correlated with the tendency to cheat when teleoperating the robot, although only when the reward was low.

Previous research found that being located at a greater physical distance might increase the likelihood of immoral behavior.[19,20] In our study, participants reported a significantly higher sense of being located at the robot's position when operating in 1 PP than 3 PP. This did not, however, translate to increased tendency to engage in egocentric dishonesty. One might argue that even if in both types of teleoperation participants treated the robot as a tool through which they acted, the experienced physical distance from the place where the consequences have their effect might still make participants more likely to cheat. However, we did not find evidence for this, which might be due to several factors. First, participants knew that the robot was located just a few meters away from them in the room next door, so in the physical proximity. Second, while the difference in the sense of self-location between the two teleoperation conditions was statistically significant, it was nevertheless small in absolute terms: only about 10%. Moreover, in both cases the sense of being located at the robot's location was generally low, with responses at 25% (3 PP) and 35% (1 PP). Therefore, the difference between both conditions might have been too small to reliably affect dishonesty in the form of egocentric lying.

However, while we did not find evidence that embodiment in our setup affects cheating, which was the main goal of our study, we did find evidence that the perspective of teleoperation (1 PP or 3 PP) affected generosity. Specifically, in our analysis using the between-subject design, we found that participants were significantly more likely to lie altruistically to give the reward to their partner when teleoperating the robot from the 1 PP than the 3 PP. At the same time, the difference between generosity in the 1 PP teleoperation and the in-person condition did not significantly differ, and they were both at a comparable level. This suggests that generosity can be influenced by the visual perspective, as both the in-person and 1 PP teleoperation were performed from the first-person view. Furthermore, in both these conditions, we found a stronger sense of location, which is an important component of our bodily self-consciousness,[56,57] which led us to hypothesize that participants might have experienced a heightened bodily awareness compared to the 3 PP condition. As higher bodily awareness has been linked to more responsible behavior[25,54] and stronger moral identity,[36] it is possible that this might have had an effect on the participants' more generous behavior in the two 1 PP conditions, leading them to behave more prosocially. This result, however, was present only when the data were analyzed using the between-subject design, suggesting that it might be very sensitive to order and carryover effect or demand characteristics.[37,39]

Taken together, our results suggest that the weak embodiment experienced during non-immersive teleoperation may be insufficient to reliably influence the tendency to engage in morally negative behaviors toward others, as such actions constitute a clear violation of social norms. However, it may be strong enough to modulate generosity (altruistic lying), which is generally regarded as a prosocial behavior and may therefore be more susceptible to such manipulations.

Overall, inspired by earlier work using virtual reality, we employed a non-immersive robot teleoperation protocol to test the impact of teleoperation on embodiment and dishonest behavior. We found that our setup, in which participants controlled the robot through a screen-based system (as contrasted with head-mounted displays frequently used in previous work with immersive virtual reality), led to a modest embodiment of the robot. Importantly, we did not find evidence that people are more likely to engage in dishonest behavior under such circumstances, although we did find that certain aspects of embodiment in the 3 PP teleoperation correlated with it in our group. We propose that dishonest behavior might require an intermediate level of embodiment: the level that is high enough to experience ownership over an external body, and low enough so that the external body does not "fully take over" and become perceptually transparent. Our results have potentially important practical implications. Previous studies found that embodiment, as well as physical distance, can facilitate immoral behavior. Our findings show that this effect can be limited and potentially highly context-sensitive. This can be perceived as an optimistic finding, as it suggests that people's moral decisions might remain relatively unaffected by teleoperation, at least as long as the level of embodiment is low (and sense of agency is high). At the same time, we found evidence that people were more generous toward the other person by engaging in altruistic dishonesty when they controlled the robot through 1 PP than 3 PP, suggesting that if dishonesty is not associated with violation of social norms, it might be easier to affect it through manipulation of aspects of embodiment. However, more research is needed on this topic to determine whether these findings generalize onto other contexts, including real-life situations. In the near future, we can expect an explosion of new products allowing operating through teleoperation. Further tuning of systems combining virtual reality head-mounted displays with haptic feedback to teleoperate robots from a distance (e.g., the iCub3 Avatar System[42]) could soon lead to the true embodiment of a robot over one's own physical body, presenting again the question whether and how this will affect our moral behavior in demanding scenarios.

Limitations of the study

There are several limitations of our study. First, we decided to use screen-based teleoperation, rather than teleoperation through a head-mounted display (HMD). Using an HMD would likely lead to a larger level of embodiment of the robot and might lead to a different pattern of results (as predicted by the model proposed above). Future studies should empirically validate this prediction. However, we believe that investigating setups eliciting low levels of embodiment remain important for both theoretical and practical reasons. On the theoretical level, embodiment is a continuum, rather than a single discrete state. As such, there is a need to investigate not only the extreme situations (very strong embodiment or none in immersive setups) but also situations in between. While previous studies similar to ours employed a 3 PP view to reduce embodiment,[18] screen-based teleoperation is a qualitatively different way of obtaining low embodiment. As such, it can—and as the comparison between the current and previous study shows—affect other cognitive processes differently. Therefore, to achieve full understanding of the relationship between embodiment and moral decision-making, it is important to investigate various forms of embodiment. Second, from the practical perspective, strong embodiment and fully immersive teleoperation might not always be preferred for all applications. First, using HMDs can lead to some symptoms of motion sickness.[58–60] It can be especially the case for teleoperation of humanoid robots, like iCub that was used in our study, which are characterized by relatively large delays and discrepancies between one's bodily movements and movements of the robot body.[41,61] However, these problems will likely be reduced or even removed in future, and there is already a large number of teleoperation setups that do not cause such symptoms. More importantly, even when such teleoperation becomes fully technologically feasible, screen-based teleoperation might still remain a more convenient and affordable form of teleoperation for many use cases. Strong embodiment and immersion might not be preferable if the robot displays a large degree of autonomy,[62–65] and screen-based teleoperation makes it easier to multitask and share workload between the human and the robot. It might also be preferable when operating multiple semi-autonomous robots at the same time, as it can allow easier monitoring of all of them simultaneously.

The second limitation of our study pertains to the fact that our results might not be fully and directly applicable in real-life scenarios, because we used a very minimal and abstract way to investigate dishonesty (and generosity): a simple card game. While such games have been successfully used to investigate moral decisions in many past studies,[18,28,66,67] they are nevertheless quite distant approximations for real-life scenarios (for a review see[68]). More work investigating the predictive validity of such research in real-life applications is needed.

Finally, in our study we used the Avatar Embodiment Questionnaire[30] to measure different aspects of embodiment. Due to low internal reliability of the scales proposed by the authors, we decided to use individual items rather than composite scales. While some of these questions map in a reasonably straightforward way onto distinct aspects of embodiment, others might bear more complex or context-dependent implications in the setting of this study. Take, for example, the item "It seemed as if I might have more than one body." In immersive virtual reality studies, high agreement with this statement is typically interpreted as evidence of reduced embodiment of the digital avatar, based on the assumption that the virtual body has not fully replaced participants' real one. In line with this, Gonzalez-Franco and Peck[30] treat this as a reverse-coded item in their composite ownership scale. In our case, however, we argue that this interpretation may not fully apply to our experimental design. In the in-person condition, where only the participant's physical body is visible and involved in the task, low agreement with this item is indeed expected. However, our two teleoperation conditions (i.e., 1 PP and 3 PP) place participants in a uniquely different situation: both their own physical body and the robotic one are simultaneously visible. In this context, feeling as if having more than one body" could imply some degree of embodiment of the robotic body, while maintaining that toward one's real body. This seems to be supported by our data, which show that ratings on this item are increased in both teleoperation conditions compared to the in-person one. Importantly, ratings to this item did not differ significantly between the 1 PP and 3 PP teleoperation conditions, even though previous research shows that 1 PP generally elicits stronger embodiment. If the item were to reflect reduced embodiment (as is assumed in immersive VR studies), we would expect higher agreement in the 3 PP condition than in the 1 PP condition. The absence of such a difference supports our interpretation: in this context, the item may not signal disembodiment but rather the simultaneous identification with two distinct bodies.

RESOURCE AVAILABILITY

Lead contact

Requests for resources should be directed to and will be fulfilled by the lead contact, Agnieszka Wykowska (agnieszka.wykowska@iit.it).

Materials availability

This study did not generate new unique materials.

Data and code availability

- The full dataset has been deposited at Zenodo and is publicly available as of the date of publication. DOIs are listed in the key resources table.
- The code for replication of all analysis has been deposited at Zenodo and is publicly available as of the date of publication. DOIs are listed in the key resources table.
- Any additional information required to reanalyze the data reported in this paper is available from the lead contact upon request.

STAR★METHODS

Detailed methods are provided in the online version of this paper and include the following:

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AUTHOR CONTRIBUTIONS

M.W., conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, validation, visualization, writing—original draft, and writing—review & editing; M.S., conceptualization, methodology, writing—original draft, and writing—review & editing; L.P., conceptualization, methodology, writing—original draft, and writing—review & editing; D.D.T., data curation, resources, software, and validation,; S.M.A., conceptualization, methodology, supervision, and writing—review & editing; A.W., conceptualization, funding acquisition, methodology, project administration, resources, supervision, and writing—review & editing.

DECLARATION OF INTERESTS

The authors declare no competing interests.

SUPPLEMENTAL INFORMATION

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STAR★METHODS

KEY RESOURCES TABLE

REAGENT or RESOURCE	SOURCE	IDENTIFIER
Deposited data		
Data from 50 human participants and code for replication of analyses	This paper, Zenodo	Zenodo: https://doi.org/10.5281/zenodo.15075412
Software and algorithms		
PsychoPy (version 2022.2.4)	Peirce et al.[69]	https://www.psychopy.org/
JASP (version 0.19.3)	JASP Team (2025)	https://jasp-stats.org/
scipy	Virtanen et al. (2020)	https://scipy.org/

EXPERIMENTAL MODEL AND STUDY PARTICIPANT DETAILS

Participants

50 participants completed the experiment. Four participants were excluded from the analysis. Two of them knew they couldn't be paid due to the regulations at the Italian Institute of Technology at the time of testing. As a result, and unlike all other volunteers, these participants had no incentive to maximize their monetary reward during the experiment. The other two participants were excluded because they failed to understand the experimental task, as indicated by their questions during the experiment and reports after the experiment.

The final sample included 46 participants, with 26 females and 20 males (we did not find any significant influence of gender on results). Their average age was 24.2 (*Median* = 23, *SD* = 3.9), ranging from 19 to 36. 40 participants were right-handed, and 6 were left-handed.

All participants gave informed consent after reading the general information about the study and before starting the experiment. The study was approved by the local ethical committee (Comitato Etico Regione Liguria, protocol 280/2019 from 11/28/2019, code IIT_S4EMB). The data were collected at the Italian Institute of Technology, IIT in Genoa, Italy in accordance with the standards from the Declaration of Helsinki. At the end of the experiment all participants were debriefed and told that they could withdraw their data from the experiment. No participant decided to withdraw their data.

METHOD DETAILS

Procedure

The experimental task was based on previous work,[18,27] but involving teleoperating a humanoid robot (Figure 1). After their arrival to the lab, participants were told they would play a card game with other people, who had been in the lab earlier and had been tasked with repeatedly picking one of two covered cards (thus, participants believed that they played against the recorded choices of previous participants who had come earlier). One of the cards was associated with a win, the other with a loss. However, these other players (about whom we instructed participants that they participated earlier) were never allowed to look at their picks. Participants were then told that it was their task to see whether these other people had picked the winning or losing card and, at every round, decide whether to give the financial reward associated with the winning card to the other person. Importantly, refusing to give the reward to the other player meant that the participant would take the reward for that trial. All people involved in the game would be compensated based on what the participant gave to each person, not on the actual outcome of other players' picks. This introduced the temptation to cheat, as participants were told that all rewards they decided to keep in the game would increase their own payout from the experiment. Participants were also told that the people they played with would not be informed of whether they responded honestly or not. These circumstances generated the temptation for participants to cheat and falsely indicate that the other player lost, even when they won. This belief manipulation followed the exact procedure used in.[18,27]

Each trial of the card game started with two cards presented to the participants for 1 s on the upper side of the screen (Figure 2). Both cards were presented with their backs up. Afterward, the participants were shown the reward symbols in the bottom half of the screen. One of the reward symbols was always an empty white box and indicated no reward. The other reward was either low (indicated by one banknote) or high (indicated by three banknotes). After 1.5 s, one of the cards was uncovered to show participants which card the other player had picked. At this point, the participant's task was to evaluate whether the card was a ''winning'' or a ''losing'' card. For half of the participants, the winning card was the red ace of hearts, and for the other half, it was the black ace of spades. If the other player had picked the winning card, then they were supposed to get the reward. After the card was uncovered participants had to decide whether the other player should receive a reward. Giving the reward to the other player meant that the participant would not obtain any reward in that trial. And vice versa: indicating that the other player should get no reward meant that the participant obtained it.

Depending on the experimental condition, participants played the card game as follows.

1. In the "In person" condition, they responded by releasing their finger from a response box button and pressing the button on the same side of the screen (Figure 3, upper panel).
2. In the "1 PP teleoperation" condition, participants similarly released their finger from a button, but it was iCub who performed the action of pressing the button on the screen. This action was observed by the participants via a camera located in the iCub's left eye (Figure 3, middle).
3. In the "3 PP teleoperation" condition, the procedure was the same as in the 1 PP teleoperation condition, except that participants observed the iCub's action through a camera positioned behind and to the right of the robot (Figure 3, lower panel).

In both teleoperation conditions, the movement of the robot arm lasted 2 s. Once the button on the screen had been pressed, the selected option was outlined with a red frame, providing feedback for the participant's selection (Feedback A). In teleoperation conditions, the robot started moving its hand back toward the starting position 500 ms after the appearance of the red frame. The return movement also lasted 2 s, and 1 s after the start of the return movement, a second feedback was displayed on the screen for 1.5 s, telling participants what reward they obtained themselves (Feedback B).

The experiment consisted of 3 blocks, one for each experimental condition. Each block involved 32 trials (there were 16 trial types, and each trial type was displayed twice). The order in which each participant completed each experimental condition was specified before the experiment started, to make sure that the order of experimental conditions was counterbalanced across participants.

After finishing the main task, participants filled out seven questionnaires (see below). After that, they completed an additional task in which they had to repeatedly press space to fill "a battery" displayed on the screen (this task was based on a similar procedure used in[70,71]). Filling each battery led to a small financial reward. The purpose of this task was to make sure that all participants were in reality paid the same amount of money at the end of the experiment, a condition required by the ethical protocol. Therefore, participants who made less dishonest choices in the main task had to complete more trials in the extra task than more dishonest participants.

At the end of the experiment, participants were fully debriefed. They learned why it was necessary to use deception in the experiment and were given the choice to withdraw their data if they wished (no participant requested withdrawal of the data).

Questionnaires

Avatar embodiment questionnaire (AEQ)

After completing each block, participants answered 10 self-report questions. The questions represented three scales proposed by[30]: (1) body ownership, (2) agency and motor control, and (3) location of the body. Participants responded to these questions using a continuous visual analog scale (VAS). The responses on the VAS scale were coded as 0 for the leftmost response and as 100 for the rightmost response. Each scale consisted of 3 or 4 questions, and the authors proposed how to calculate a score for each aspect of bodily self-consciousness. However, our analyses revealed that these scales demonstrated very low internal reliability (Cronbach alpha with values lower than 0.48, sometimes reaching even negative values). Because of this, we decided to analyze these results by looking at individual items rather than scales. Specifically, we used question 1 as a measure of SoO ("I felt as if the robotic/corporeal body was my body"), questions 4 and 5 as two measures of SoA ("It felt like I could control the robotic/corporeal body as if it was my own body", "The movements of the robotic/corporeal body were caused by my movements"), and question 8 for SoL ("I felt as if my body was located where I saw the robotic/corporeal body"). Additionally, we also tested responses to two questions, which allowed for keeping their formulation to be strictly identical regardless of the experimental condition: question 3 ("It seemed as if I might have more than one body") and question 9 ("I felt out of my body").

Other questionnaires

After the experimental part of the study was finished, participants completed additional questionnaires: InStance Test,[72] Moral Identity Questionnaire,[73] Moral Foundation Questionnaire,[74] Godspeed Questionnaire,[75,76] Body Consciousness Questionnaire,[77] Sense of Agency Scale[78] and Monetary Intelligence Scale.[79]

Physical robot setup

The experiment employed an iCub humanoid robot[29] positioned in an upright stance facing a large interactive screen, on which task instructions and stimuli were displayed. The robot was controlled in joint space to ensure high repeatability of its pointing behaviors across experimental trials. Specifically, joint positions were pre-programmed to consistently indicate one of two target buttons, placed symmetrically on the screen surface - one on the left side and the other on the right.

Apparatus and stimuli

The experimental setup was implemented within a dedicated local area network (LAN), encompassing three primary units: the iCub robot, the experimental machine (responsible for task management, stimulus presentation, and data logging), and the participant's machine (used by the participant). Participants remotely controlled the robot under the two distinct teleoperation conditions described above (FFP and 3 PP). In FFP condition, participants, seated in a separate room, viewed real-time visual feedback directly streamed from one of the robot's eye cameras. The video feed enabled participants to perceive the environment and targets from the robot's own visual perspective, thus experiencing the interaction through the robot's eyes. Alternatively, in the 3 PP condition, visual feedback was provided through an external camera positioned behind, and to the left of the robot. This external viewpoint offered participants a comprehensive view of the robot's interactions with the screen, the spatial arrangement of the buttons, and the overall context of the task environment. Both video streams were encoded and transmitted via the LAN with minimal latency to ensure synchronized interaction and immersive teleoperation experience for the participant. The experiment was programmed in PsychoPy 2022.2.4 and run on the experimental machine. Moreover, the experimental script was integrated with Python wrappers of YARP[80] to trigger robot actions based on participants' responses.

QUANTIFICATION AND STATISTICAL ANALYSIS

Data analysis

Data was preprocessed using custom scripts in Python. Final analyses were conducted with Python using the *scipy* package version 1.13.1. Additional analyses testing assumptions of the model were performed using JASP 0.19.3, a free software for performing statistical analyses. Raw data, as well as preprocessed data used to perform statistical analyses is available under the following link: https://zenodo.org/records/15075413.

The target sample size of 50 was chosen to be the same as in the previous study using the same experimental paradigm.[18] Sensitivity analysis conducted using G*Power 3.1.9.7 showed that such sample would allow us to detect an effect size of f = 0.146 (F-test for repeated-measures ANOVA with 12 measurements comprising the $3 \times 2 \times 2$ design, alpha = 0.5, power = 0.95).

The final sample consisted of 46 participants, as four participants were excluded. Two of them knew they couldn't be paid due to the regulations at the Italian Institute of Technology at the time of testing. As a result, and unlike all other volunteers, these participants had no incentive to maximize their monetary reward during the experiment. The other two participants were excluded because they failed to understand the experimental task, as indicated by their questions during the experiment and reports after the experiment.

Regarding embodiment, the experiment represented a one-way repeated measures design, with factor Control (In-person vs. 1 PP teleoperation vs. 3 PP teleoperation) followed by planned contrasts comparing in-person vs. 1 PP teleoperation (contrast 1) and 1 PP with 3 PP teleoperation (contrast 2). The dependent variables were answers to the items from the Avatar Embodiment Questionnaire.[30]

Moral decision-making data represented a three-way $3 \times 2 \times 2$ repeated measures design with factors Control (In-person vs. 1 PP teleoperation vs. 3 PP teleoperation) $\times$ Outcome (the other player wins vs. the other player loses) $\times$ Reward (high vs. low). The main dependent variable was the percentage of trials in which participants indicated that the reward should be given to themselves rather than to the other player.

When analyzing the data we tested the assumption of normality using the Shapiro-Wilk test of normality for all dependent variables (Table S2). The percentage of trials in which participants took the reward in the main experimental task was non-normally distributed in all 12 conditions (all ps<0.001). A QQ-plot provides additional evidence to the deviation from normality, especially when looking at extreme values (Figure S13). Regarding embodiment, answers to all 10 questions in all three experimental conditions were significantly non-normally distributed (all $p \leq 0.037$, Table S1). Considering these results, we used non-parametric statistics in all of our analyses. Specifically, we used the Python functions *scipy.stats.wilcoxon* to calculate the results of the Wilcoxon test – a non-parametric equivalent to a repeated-measures *t* test, and *scipy.stats. friedmanchisquare* to calculate the results of the Friedman's test – a non-parametric equivalent to a repeated-measures 1-way ANOVA. There exists no non-parametric substitute for repeated-measures ANOVA with more than one factor so when analyzing the percentage of rewards taken instead of performing a $2 \times 2 \times 3$ ANOVA, we performed Friedman's test treating all 12 specific within-subject combinations of factors as levels of a single factor. Such an approach allowed us to test whether there is evidence of significant variation between all these 12 specific conditions, but it did not allow us to attribute it to specific main or interaction effects. Our approach was then to follow this analysis, if significant, with specific tests for each main effect performed, either using a Wilcoxon test (for comparisons between two levels, i.e., Outcome: whether the participant or the partner won, and Reward: high vs. low) or a Friedman's test (for Control, which has three levels).

The experimental task, as well as the main reported analysis used a within-subject design. This was motivated by the fact that this form of analysis was also used by[18] in a study that we attempted to replicate as closely as possible. The second reason was that such analysis has higher statistical power than a between-subject design. However, a within-subject design can be prone to (i) carryover effects, where the effects from the earlier experimental condition can linger and influence the results in the later conditions, (ii) order effects, where the order of presentation of conditions might influence the results,[37] and (iii) demand characteristics, in case participants realize what is the goal of the study and begin to act in accordance with what they believe is the behavior expected from them.[38–40] To make sure that our results were not influenced by these factors we conducted an additional between-subject analysis of percentage of reward taken in the main task. This analysis was performed only using data from the first experimental block from each participant. Because the order of conditions was counterbalanced we had similar number of participants in each condition (16 for in-person, 15 for 1 PP teleoperation, and 15 for 3 PP teleoperation – the differences are caused by participant exclusions). We performed three specific analyses which were of main theoretical interest: a one-way analysis comparing the factor Control (in-person, 1 PP teleoperation, 3 PP teleoperation) for (1) all trials, (2) only trials in which participant won, and (3) only trials in which participant lost. Each analysis was performed with the Kruskal-Willis test, which is a non-parametric equivalent of a one-way between-subjects ANOVA, using the Python function *scipy.stats.kruskal*. In case of significant main effect we followed these analyses with planned contrasts using the U-Mann Whitney test, a non-parametric equivalent of the independent samples *t* test. The analyses were performed using the Python function *scipy.stats.wilcoxon*. Details about the results of the inferential statistics can be found in the results section, Figures 4, 5, and 6, and in the supplemental information. Alpha was set at 0.05.

Supplementary materials

Supplementary Materials provide results of additional analyses of the data.