How the sense of body ownership shapes honesty: Evidence from behavioural, clinical and immersive virtual reality studies

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Table of contents

1 General introduction

Honesty entails adherence to moral and social norms despite the personal benefits that would derive from non-compliance (Xu & Ma, 2015). As such, honesty is highly valued across cultures and religions. However, and in spite of all this, dishonest behaviors are common and occur at all societal levels (Mazar & Ariely, 2006). Crucially, dishonesty comes with significant consequences. For example, the special report on fraud in the European Union showed that, in 2017, fraud cost the EU about €390.7 million. Similarly, the cost of illegal software download in the United States was of about US$59 billion in 2010. However, the consequences of dishonesty are not only of economic type but may also affect interpersonal cognition (J. J. Lee et al., 2019) and lead to even more dishonesty (Welsh et al., 2015). Considering all this, clarifying what can bias behaviors towards honesty or dishonesty is paramount.

At the personal level, two opposite views of honesty have emerged (Burton, 1963). On the one hand, honesty is seen as a stable trait which determines each individual's behavior in a variety of situations. On the other hand, it is conceived as highly dependent on contextual factors and on the evaluations that the person makes of each situation. In line with both these views, investigations that tried to identify the determinants of (dis)honesty have focused on dispositional features of the individual as well as factors defining each situation specifically. This effort shows that personality traits like conscientiousness and agreeableness may favor honesty (S. D. Lee et al., 2020), while manipulativeness (Kashy & DePaulo, 1996), creativity (Gino & Ariely, 2012), impulsivity and psychopathy (S. D. Lee et al., 2020) may reduce it. Similarly, honesty is reduced in situations where personal payoffs are involved and can be increased (Gerlach et al., 2019), when anonymity is maintained (C. B. Zhong et al., 2010), in association with feelings of entitlement (Poon et al., 2013; Schurr & Ritov, 2016), when the individual finds him/herself in unfavorable situations (Panasiti et al., 2011) or feels anger (Motro et al., 2018; Panasiti & Ponsi, 2017). On the other hand, if dishonest behaviors represent a threat for one's own reputation (Panasiti et al., 2016) or individuals feel guilty (Motro et al., 2018; Panasiti & Ponsi, 2017) and have enough time to ponder over alternative courses of action (Shalvi et al., 2012), then the tendency to act honestly increases. We are aware that this excursus is far from capturing the extensive research on the topic of moral behavior and the complex picture it presents, nonetheless these results highlight just how vast is the number of elements that can shape the moral decision-making process, either favoring honesty or dishonesty. For example, it is possible that the behavior of individuals is influenced by larger-scale factors as well, like the prevalence of dishonesty in their society. However, evidence for this effect doesn't seem to be conclusive, with studies supporting the role of societies in shaping the conduct of single individuals (Gächter & Schulz, 2016) and others suggesting that the two occur independently (Mann et al., 2016).

Considering all this, it is clear that the role of contextual factors at the individual and societal level should not be overlooked. Yet, what appears to be needed is an understanding of whether and how each individual's percept of the physical body can bias towards more honest or dishonest choices.

1.1 Embodied (dis)honesty

Embodied cognition theories posit that information coming from the body can affect different aspects of cognition and a variety of psychological functions (Barsalou, 2008). Indeed, evidence appears to support this role of the body in areas like memory (Arminjon et al., 2015), language (L. E. Williams et al., 2009; Zwaan, 2014), mathematical reasoning (Nathan et al., 2020) and even in the decision-making process (Bartol & Linquist, 2015). Crucially, bodily signals also impact social cognition. For example, facial mimicry can facilitate the recognition of emotions in others (Stel & Van Knippenberg, 2008). Also, the illusion of having a body of a different ethnicity can diminish the racial bias towards individuals of that ethnicity (Maister et al., 2015). Considering the diverse areas of cognition impacted by signals coming from the body, it is possible that bodily states can also affect morality.

Indeed, literature seems to suggest the existence of this type of relation. For example, motor resonance is reduced when observing immoral actions, especially when individuals display high levels of harm avoidance (Liuzza et al., 2015). Also, acting immorally appears to elicit a desire for physically cleanness (C.-B. Zhong & Liljenquist, 2006). Interestingly, this desire for cleanness applies specifically to the body part that carried out the immoral action. Specifically, if lies are communicated using hands (i.e., by writing an email) or through speech (i.e., by leaving a voice mail), individuals showed higher preference for hand and mouth washing products, respectively (S. W. S. Lee & Schwarz, 2010). This evidence supports a role of the body when processing immorality and its aftermaths. However, it is yet not clear how being aware of the physical body can affect the process underlying one's own moral decisions.

The conscious experience of the body, or corporeal awareness, is the organized, dynamic representation of multiple information into a single, unified sense of physical selfhood (Berlucchi & Aglioti, 1997, 2010). However, this unique percept is believed to result from the integration of two different but highly interdependent constructs. Corporeal awareness, or bodily self-consciousness (BSC), relies on the feeling of having a physical body and that all of its parts belong to oneself, i.e. sense of body ownership (Blanke, 2012). The other constituent of corporeal awareness is the feeling that the owned body can be deliberately moved and controlled, or sense of agency (Haggard, 2017). If BSC indeed has an influence over the process behind (dis)honest decisions, it is possible that, considering its dual nature, this influence may differ when considering one or the other component.

The work presented here aims at clarifying the relationship between consciousness of the body and morality, with a particular focus on the role of body ownership. Specifically, we investigated whether enhancements and reductions of the sense of body ownership can bias the process leading to (dis)honest behaviors. We predicted that the relation between the sense of body ownership and (im)morality might follow one of two alternative paths. In the first of these alternative hypotheses, we argue that a low sense of body ownership can make individuals less attentive to their own needs and therefore less dishonest. According to the second hypothesis, low feelings of ownership over a body may help separate the self from negative attributes, such as immorality, and therefore favor dishonest behaviors.

1.2 Two alternative hypotheses

1.2.1 The "Grace" hypothesis.

According to Greene and Paxton's "Grace" hypothesis (2009), individuals who behave honestly are the ones that do not feel tempted by the rewards (or more generally, the positive outcomes) they may acquire through immoral behaviors. In line with this, honesty may result from a reduced sense of body ownership. In fact, feeling that the body does not belong to oneself may lessen the push to satisfy its needs and desires.

In support of this, when information from the body of individuals is made salient, this increases outcome-based choices. For example, individuals make more unfair offers to others in Ultimatum Games and accept more of these offers from others when they are listening to their own heartbeat or when in pain (Lenggenhager et al., 2013; Mancini et al., 2011). Interestingly, these bodily signals appear to reverse the general tendency to refuse unfair offers, despite the personal losses that this behavior entails (Nowak et al., 2000). In other words, increased attention towards the body appears to favor self-oriented choices, that is, choices aimed at maximizing personal outcomes. Crucially, bodily states can also determine how tempting specific types of rewards are (Paulus, 2007a, 2007b) and thus increase the tendency to act dishonestly (E. F. Williams et al., 2016).

Considering that signals coming from the body can increase the awareness of having a body itself (Tsakiris et al., 2011), research presented so far seems to suggest that heightened sense of body ownership may bias moral decision-making towards choices that bear an advantage for the self. However, this effect may be modulated by how tempting the rewards associated with these choices are.

1.2.2 The separation hypothesis.

According to Lee and Schwarz (2021), individuals engage in a variety of embodied mechanisms through which they can achieve separation from negative attributes, like dishonesty. In the case of immorality, these mechanisms are activated when congruency between the idea one has of the self and actual behaviors is at stake (Mazar et al., 2008). In fact, the desire to preserve a moral image does not imply that individuals always behave ethically. On the contrary, they allow themselves some dishonesty. Crucially, the decision whether to behave immorally or not depends on how easy it is to re-interpret immoral behaviors as reflective of a moral self (Mazar et al., 2008). Embodied procedures of separation may facilitate this and allow maintenance of a moral image while giving oneself permission to act immorally.

Here we propose that conditions of reduced body ownership may serve as ways to achieve separation of the self from negative attributes. For example, low sense of body ownership has been associated with less negative emotions (like fear) (Bourdin et al., 2017; Hofer et al., 2017), with dampened sensitivity to pain (Martini et al., 2014) and with reduced responses to motor errors (Pezzetta et al., 2018). Oppositely, feeling ownership over a negatively connoted body may facilitate attribution of the same negative characteristics to the self. This perceived association between the self and negativity may favor subsequent separation strategies. In line with this, a sense of ownership over a verbally abusing robot appears to elicit more reparation behaviors, like apologies, towards the victim of the slur (Aymerich-Franch et al., 2020). Considering all this, it is possible that a low sense of body ownership may succeed in separating the individual from immoral behaviors (Scattolin et al., 2021). Accordingly, if individuals feel detached from immorality, they may allow themselves even more dishonesty without having to reconsider their own moral image. In line with this, it is possible that reductions of the sense of body ownership favor the occurrence of dishonest behaviors.

1.3 Aim of the present work

With this series of studies, we aimed at clarifying whether the sense of body ownership biases the decision-making process towards honesty or dishonesty. To this aim, we first used a correlational approach to explore the sense of ownership towards the physical body and its association with morality and moral behavior (study 1, Chapter 2). In the following study, we used an experimental approach and actively manipulated the sense of ownership towards a virtual avatar while participants were performing moral decisions (study 2, Chapter 3). Then, we selected a clinical population characterized by a chronic and specific reduction of the sense of ownership towards one of their limbs (Body Integrity Dysphoria) and assessed their moral behavior when (dis)honest choices had to be communicated with the owned or the disowned limb (Study 3, Chapter 4).

In the first study, participants were asked to complete a series of questionnaires assessing components of bodily self-consciousness (i.e., body ownership and sense of agency) as well as variables that could modulate their relations with morality. Also, we were interested in understanding if specific components of BSC could predict the moral identity and behavior of participants in similar or opposite ways. For this reason, morality was measured via a self-report (Moral Identity) and via a short task that we developed specifically for the purpose of this study (Moral Behavior). In our Spot the Difference Task (STDT), we asked participants to compare two pairs of images and to report how many differences they could find in a certain amount of time. While the images within each pair differed for 5 details, participants had the opportunity to (falsely) report having identified up to 10 differences. Consequently, instances in which participants reported finding more than five differences indicated that they had lied. In the reward condition, the participants would receive an additional payment (vs. no additional payoff in the no reward condition) if they reported a number of differences between 6 and 10, that is, they had selected any of the response options above 5. We subtracted the actual number of differences between images (i.e., 5) from the number each participant reported (i.e., from 0 to 10) and we used this value as a measure of (dis)honest behavior. Notably, investigating the relation between sense of agency and morality (as well as the role of potentially modulating variables) was a secondary aim of this study. Consequently, the findings concerning this component of BSC have also been discussed in detail. Finally, a version of this chapter has been made public in the form of preprint and is available at this DOI: https://doi.org/10.31234/osf.io/tcu23

In the second study, participants saw a virtual body either from a congruent perspective, with hands attached or visually separated from the rest of the virtual arms, or from an incongruent viewpoint, that is, from a third person perspective. To investigate the impact of reduced body ownership over moral decision-making, participants were asked to play the Temptation to Lie Card Game (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016) against other individuals. The game was completed within the virtual environment and each trial was associated either with a high or low reward. Crucially, participants could freely decide whether to lie or behave honestly, knowing that all players involved in the game would be paid based on what they decided to communicate.

In the third, and last of our studies, we recruited a group of participants with Body Integrity Dysphoria (BID), that is, a condition where individuals' sense of ownership over a limb is reduced. We asked participants to play the Temptation to Lie Card Game and to provide their responses using the owned or the disowned limb to press a food-pedal.

2 Morality in the flesh: on the link between bodily self-consciousness, morality and (dis)honest behavior

2.1 Introduction

Corporeal awareness, or bodily self-consciousness (BSC) (Berlucchi & Aglioti, 1997), is based on two main pillars, namely the feeling of having and owning a body (sense of ownership) (Blanke, 2012), and that of being able to initiate and control said body's movements (sense of agency) (Haggard, 2017). The notion that bodily signals may impact higher-order psychological functions is at the core of embodied cognition theories (Barsalou, 2008). What remains largely unknown is whether, or how, different aspects of BSC can influence morality and moral decision making. The question of whether, and if so how, awareness of body signals may bias our moral decisions towards dishonesty (e.g., by increasing the temptation from personal rewards) or honesty (e.g., by heightening our sense of responsibility) is central to many religious systems where morality typically plays a fundamental role. However, systematic research on whether body ownership and agency – two inherently linked yet distinct constructs (Tsakiris et al., 2010) – exert different influences on morality is scarce. It is possible, for example, that an increased sense of ownership over the body is associated with higher levels of dishonesty. Indeed, when signals from the body become more prominent, people appear to indulge in different types of self-serving behaviors, such as making more egoistic offers to others during Ultimatum Games (Lenggenhager et al., 2013; Mancini et al., 2011) or cheating in exchange for rewards (E. F. Williams et al., 2016). This effect might be driven by the interoceptive component of body ownership which conveys the reward value assigned to certain stimuli and thus may influence consequent decisions (Paulus, 2007a, 2007b; E. F. Williams et al., 2016). In line with this hypothesis, an increase in rewards sensitivity (as signaled by enhanced activity in the nucleus accumbens during reward anticipation) seems to be associated with more frequent dishonest behaviors (Abe & Greene, 2014). Conversely, sense of agency may be correlated positively with morality and honest behaviors. For instance, existing literature on intentional binding shows that implicit agency is increased when performing moral actions (Moretto et al., 2011) and reduced when performing immoral ones (i.e., inflicting pain upon others) (Caspar et al., 2018). Interestingly, the effect of agency on morality might be moderated by such variables as moral disengagement and sense of power. Moral disengagement refers to different mechanisms through which personal responsibility over immoral deeds is withdrawn and is often associated with higher deception, even at the risk of one's own reputation (Panasiti et al., 2011). Tellingly, moral disengagement is associated with a reduced sense of agency (Bandura, 2001). As such, heightening one's sense of agency may reduce moral disengagement, and thus increase morality. On the other hand, studies indicate that the perceived sense of power (i.e., the capacity to influence others) (Anderson et al., 2012) may be associated with increased sense of agency, as inferred from intentional binding (Obhi et al., 2012), and to reduced morality, as indexed by increased egoistic and unethical behaviors (Lammers et al., 2015).

Importantly, both bodily representations and morality are quintessentially important for the notion of self. Indeed, people perceive that changes in morality-related characteristics alter one's true self more significantly than changes to personality traits, or even memory loss (Strohminger et al., 2017; Strohminger & Nichols, 2014). However, previous investigations on whether the moral self (i.e., the tendency and ability to care about one's own and others' ethical conduct) (Krettenauer, 2011) can predict actual behaviors has led to contrasting results. Mounting evidence supports the belief that people act in accordance with their moral identity in an effort to confirm their perceived sense of self (Stets & Carter, 2011), and that behaviors congruent with this self-concept are more likely to occur when moral values are actively considered (e.g., by being asked to list the Ten Commandments) (Mazar et al., 2008) or when such values are perceived as central features of the self (Effron & Conway, 2015). However, other studies have shown that relying on people's self-assessment as moral agents may lead to inaccurate predictions of their behavior (Ellemers et al., 2019). Indeed, once a moral or immoral concept of self is made salient, people may employ subsequent behaviors to reduce inconsistencies with, and therefore preserve, their moral image (Sachdeva et al., 2009). For instance, moral behaviors are more likely to follow negative actions as an attempt to compensate, and thus avoid having to reconsider one's identity – an effect known as moral cleansing (West & Zhong, 2015). Conversely, once people have proven that they are not immoral, they feel allowed, or licensed, to act less morally (Effron & Conway, 2015).

To further explore these ideas, we conducted an online study to collect self-report measures concerning several variables of interest that allow for the investigation of the possible link(s) between components of BSC and morality. Notably, the participants' morality was not only measured using a questionnaire (Moral Identity), but also by employing a Spot the Difference Task (STDT), which we specifically designed for the study of (dis)honest behaviors in online contexts.

2.2 Methods

We pre-registered our methods and analysis plan on the Open Science Framework (see https://osf.io/scbnw).

We used RStudio, version 1.3.959 (RStudio Team, 2020), to analyse the data: correlations and normality of residuals were computed using functions cor.test and shapiro.test of the stats package (version 4.0.2) (R Core Team, 2020), respectively. To perform the multiple linear regression and generalized linear mixed effect models regression analysis, we used package lme4 version 1.1-23 (Bates et al., 2015), which was also employed to determine effect sizes. Robust linear regressions were computed using package MASS, version 7.3 – 51.6 (Venables & Ripley, 2002), while robust linear mixed effect models were performed using package robustlmm, version 2.3 (Koller, 2016). All analyses were two-tailed.

2.2.1 Participants

We recruited our participants via Prolific (http://www.prolific.co/), and they took part in the study from December 2018 to February 2019 – before the widespread effects of the COVID-19 pandemic could bias their responses. In line with general data replicability recommendations (Asendorpf et al., 2013), our sample is consistent with two a priori sample size estimations. We performed these two power analyses for General Linear Models via R software (*pwr* package) with $\alpha = .05$, a small effect size (.02) and power of 0.8. The results indicate that 550 and 647 responses were needed for 3 and 5 predictors, respectively.

A total of 705 participants took part in the study, 47 of whom were excluded from the final dataset (the full data for both reasons and occurrences are reported in Supplementary Table 1, Chapter 8). Our final sample included 658 participants (females = 314) between the ages of 18–66 (M = 29.37, SD = 9.68), who declared compliance with the requirements of the study (i.e., not having any neurological or psychiatric condition, nor taking any psychiatric drugs). Italian was the first language of all the participants. All of the participants gave their informed consent and were paid for their participation. The methods and procedures of this study were approved by the Ethic Committee of the IRCCS Fondazione Santa Lucia (Rome), and were in accordance with the Declaration of Helsinki.

2.2.2 Materials

We asked the participants to complete a series of questionnaires measuring different components of BSC, with the intent of assessing their possible link with moral identity and behaviour, as well as exploring which other variables could modulate this relation. All questionnaires, and the online behavioural task, were developed using PsyToolkit (version 2.5.4) (Stoet, 2017). Additional information on the measures used in the study can be found in Appendix A (Chapter 8).

2.2.3 Morality measures

Moral identity. We assessed the Moral identity of participants using the internalization factor of the Moral Identity Measure (Aquino & Reed, 2002) (e.g., 'Being someone who has these characteristics is an important part of who I am'; $\alpha = .79$).

(Im)moral behavior. To assess the (im)moral behavior of our participants, we used a version of the STDT in which participants were presented with pairs of images in the middle of the screen, and asked to find as many differences as possible within 45 seconds. A countdown was displayed on the top center of the screen. Numbers from 0 to 10 were shown on the bottom, as the participants were informed that 10 differences existed between the image pairs. Once the countdown had ended, the participants were instructed to click on the number corresponding to the differences they had found. Notably, we never asked the participants to provide information as to which differences they had identified.

All participants completed the task twice under two different conditions (no reward and reward), the order of which was randomized. Each condition was completed with one of two possible image pairs. We used a web search to obtain these, and other, images. We based the selection of the two image pairs employed in the STDT on a validation study (see Appendix A, chapter 8 for a full description). For every participant, each image pair was randomly assigned to only one experimental condition.

In the no reward condition, participants gained €0.10 for completing the task; in the reward condition, further to the aforementioned €0.10, participants received an additional €0.30 for each difference above 5 they reported finding, plus a further €10 if, at the end of data collection, they were among those who found the highest number of differences. Crucially, the images in each pair only differed in five details, so any response above this number was considered a lie. In other words, although we told participants that the differences between images were always 10 and while they could report finding as many as this number, in reality each pair included only 5 differences (se supplementary table 2 in Chapter 8 for a detailed description of all existing differences). To prevent our participants from understanding this essential aspect of the task, we informed them that, given the same amount of time, most people found only 5 of the total 10 differences. We referred to the performance of others to tacitly suggest that some of the differences were not easy to spot and thus persuade participants that this was the reason they could not find all of them. This also provided a plausible explanation for the additional payoff, as this would go only to those individuals who had performed particularly well and, presumably, had more actively engaged in the task.

Lies were calculated by subtracting the actual number of differences from the responses (results smaller than, or equal to, zero were coded as zero). Participants also had the opportunity to enter their responses after the countdown had ended. Indeed, both the images and response options continued to be displayed after the countdown. Any response given after 45s was considered a Reaction Time (RT) Lie. We computed RT Lies with a similar calculation to that of lies: the time participants were given to complete the task (45s) was subtracted from their response time (results smaller than, or equal to, zero were coded as zero).

By way of example, and due to copyright regulations, Figure 1 shows a mock pair of images specifically created by the authors for the purpose of exemplifying the STDT.

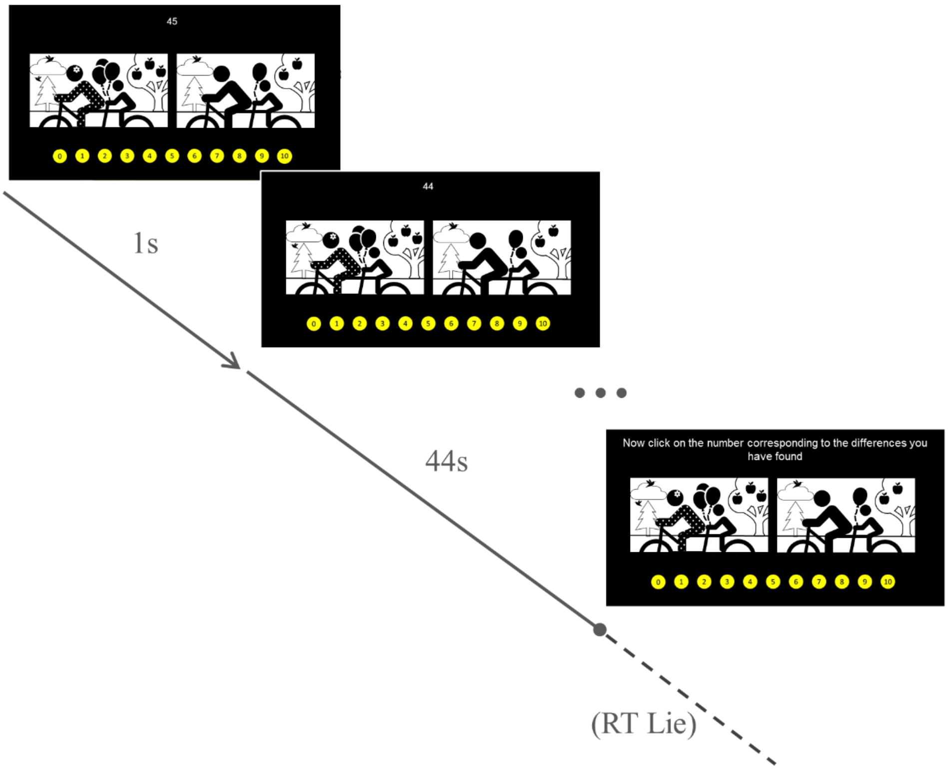


Figure 1 Example of Spot The Difference Task (STDT) trial. The task was composed of two trials, which were completed by all participants under two different conditions – no reward and reward. In both of the STDT trials, participants were asked to compare a pair of images in order to find as many differences as they could in 45 seconds. Participants were told that the images contained 10 details, yet the majority of people could only find 5 in the given timeframe. In the reward condition (vs. no reward condition) participants obtained €0.30 for each difference above 5 they reported finding. At the end of the data collection process, the participants who identified the highest number of differences received an additional €10. Crucially, and unbeknownst to the participants, only five differences existed between the images. Any response above five could then be considered a Lie. A countdown signalling the remaining time (in seconds) was displayed on the top-centre of the screen. At any time, participants could indicate the number of identified differences by clicking on the corresponding number within the yellow dots. Crucially, once the countdown hit zero, the participants could still compare the two images, as these remained on-screen until a response was provided. The dashed line represents a possible delayed response. The additional time that participants took to find differences and provide a response was used as a measure of a more implicit type of dishonesty (RT Lie). Due to copyright regulations, the above figure shows a mock pair of images not shown during the study. The images presented here were created by the authors for the sole purpose of exemplifying the STDT.

2.2.4 Body self-consciousness measures

We used two scales to measure sense of ownership, namely the private body subscale of the Body Consciousness Questionnaire (Miller et al., 1981) (e.g., 'I am sensitive to internal bodily tensions'; α = .65) and the ownership subscale of the Embodied Sense of Self Scale (Asai et al., 2016) (e.g., 'Sometimes the clothes I am wearing feel heavy', α = .73). As stated in the pre-registration, participants' responses to the two ownership questionnaires were to be combined into a single measure after reversing responses to the ESSS. In fact, while the BCQ measures interoceptive awareness, higher ESSS scores reflect a more anomalous sense of ownership, such as that observed in schizophrenia (Asai et al., 2016). Although we expected these two measures to be negatively correlated, their Pearson's correlation coefficient was positive (r = .16, 95% CI [.09, .24], p < .001; see Table 1), which indicated that the two could not be combined. Previous studies have suggested that interoception modulates the degree to which a virtual hand or body is perceived as belonging to the self (Aspell et al., 2013; Heydrich et al., 2018; Monti et al., 2020; Suzuki et al., 2013), thereby supporting the notion that – although not sufficient – inner body signals are necessary for sense of ownership (Blanke et al., 2015). Consequently, we only used BCQ scores in those models with body ownership as a predictor.

For sense of agency, we employed the positive agency subscale from Tapal and colleagues (2017) (e.g., 'I am in full control of what I do'). This showed positive internal consistency (α = .78).

2.2.5 Moderating variables

Considering that the task included a financial reward, we used the Monetary Intelligence Scale (Tang et al., 2018) as a measure of reward sensitivity, which consists of an Affective (α > .85), Behavioural (α > .7), and Cognitive (α > .85) sub-constructs. The 8-item

Propensity to Morally Disengage Scale (Moore et al., 2012) (α = .77) and Sense of Power Scale (Anderson et al., 2012) (α = .85) were used to assess moral disengagement and sense of power, respectively.

2.2.6 Procedure

The participants could complete all parts of the survey using any computer with an internet connection. We also provided them with general information regarding the study. In the consent page, participants had to check a box to indicate their agreement to participation – not doing so would bar them from completing the subsequent steps. Demographic information (i.e., age, sex, highest education degree received, subjective economic status) was collected prior to the STDT. To assess subjective economic status (SES), we asked the participants to place themselves along a Visual Analogue Scale, ranging from 'People who have the least money' to 'People who have the most money' (scores ranged from 0 to 100). This method was adapted from Adler et al. (2000) and Ostrove et al. (2000). Questionnaires followed the task. The order of conditions and pairs of images in the STDT was randomized, as was the order of questionnaires and the questions themselves. The Monetary Intelligence Scale and Sense of Agency Scale included one attention-check question each, namely 'answer "agree" to this sentence' and 'the answer to this question should be "disagree"'. The entire study could be completed in approximately 20 minutes.

2.3 Results

2.3.1 Moral Identity

We analysed moral identity by using two multiple linear regression models. First, we checked whether any demographic variable (i.e., Age, Sex, Education, Subjective Economic Status or SES) was associated with moral identity. Due to education being significantly correlated (*r* = .09, 95% confidence interval, or CI [.01, .16], *p* = .023; Table 1), we included it in both models as a covariate.

Table 1. Table reporting Pearson's correlation coefficients (r) between demographic variables (Age, Education, Subjective Economic Status or SES), two ownership questionnaires (Body Consciousness Questionnaire or BCQ, Embodied Sense of Self Scale or ESSS), and two morality measures (Moral Identity and Lies in the Spot The Difference Task). Values in square brackets represent 95% confidence intervals. Asterisks indicate significance (* p < .05, ***p < .001).

Variable	1	2	3	4	5	6
1. Age						
2. Education	.25*** [.17, .32]					
3. SES	-.17*** [-.24, -.09]	.13*** [.06, .21]				
4. BCQ	.07 [-.01, .14]	-.02 [-.10, .05]	-.09* [-.17, -.01]			
5. ESSS	-.04 [-.11, .04]	-.06 [-.14, .01]	-.09* [-.16, -.01]	.16*** [.09, .24]		
6. Moral Identity	.03 [-.05, .11]	.09* [.01, .16]	.00 [-.07, .08]	.15*** [.08, .23]	-.08* [-.16, -.01]	
7. Lies	.08* [.001, .15]	-.03 [-.11, .04]	-.01 [-.09, .07]	.03 [-.05, .10]	.09* [.01, .17]	-.10* [-.17, -.02]

The effect of sense of ownership on moral identity.

To investigate whether moral identity was predicted by body ownership, as well as if this effect was moderated by sensitivity to rewards, we entered these two variables and their interaction term as fixed factors in a model predicting moral identity. As residuals were significantly non-normal (*W* = 0.94, *p* < .001), we computed (and here present) a robust regression. Sense of ownership significantly increased moral identity (β = 0.03, 95% CI = [0.02, 0.04], t(653) = 4.46, p < .001), and the interaction between ownership and reward sensitivity was significant (β = -0.06, 95% CI = [-0.11, -0.01], t(653) = - 2.28, p = .023; Figure 2). While sense of ownership increases moral identity when reward sensitivity is low (β = 0.05, 95% CI = [0.03, 0.07], t(653) = 4.28, p < .001; Figure 2), the slope for high reward sensitivity is not significantly different from 0 (β = 0.02, 95% CI = [-0.01, 0.04], t(653) = 1.18, p = .238; Figure 2).

The effect of sense of agency on moral identity.

In the second model, moral identity was the dependent variable while sense of agency, moral disengagement, and sense of power were the independent variables. To analyse whether moral disengagement and/or sense of power could moderate the effect of agency, we entered two interaction terms as fixed factors (sense of agency × moral disengagement and sense of agency × sense of power). We performed a robust regression after a Shapiro-Wilk test showed a significant deviation of residuals from normality (W = 0.95, p < .001). The robust results show that sense of agency significantly increased moral identity (β = 0.12, 95% CI = [0.07, 0.17], t(651) = 4.98, p < .001), while moral disengagement was found to reduce it (β = - 0.15, 95% CI = [-0.21, -0.10], t(651) = -5.64, p < .001). The interaction between agency and moral disengagement was significant (β = 0.09, 95% CI = [0.04, 0.15], t(651) = 3.41, p < .001), and indicated that agency positively predicts moral identity only when moral disengagement is high (β = 0.17, 95% CI = [0.09, 0.26], t(651) = 3.87, p < .001; Figure 3). Also significant was the interaction between agency and sense of power (β = 0.07, 95% CI = [0.02, 0.11], t(651) = 2.77, p = .006; Figure 4), in that an increase of agency predicts higher moral identity when sense of power is high (β = 0.17, 95% CI = [0.09, 0.25], t(651) = 4.01, p < .001; Figure 4).

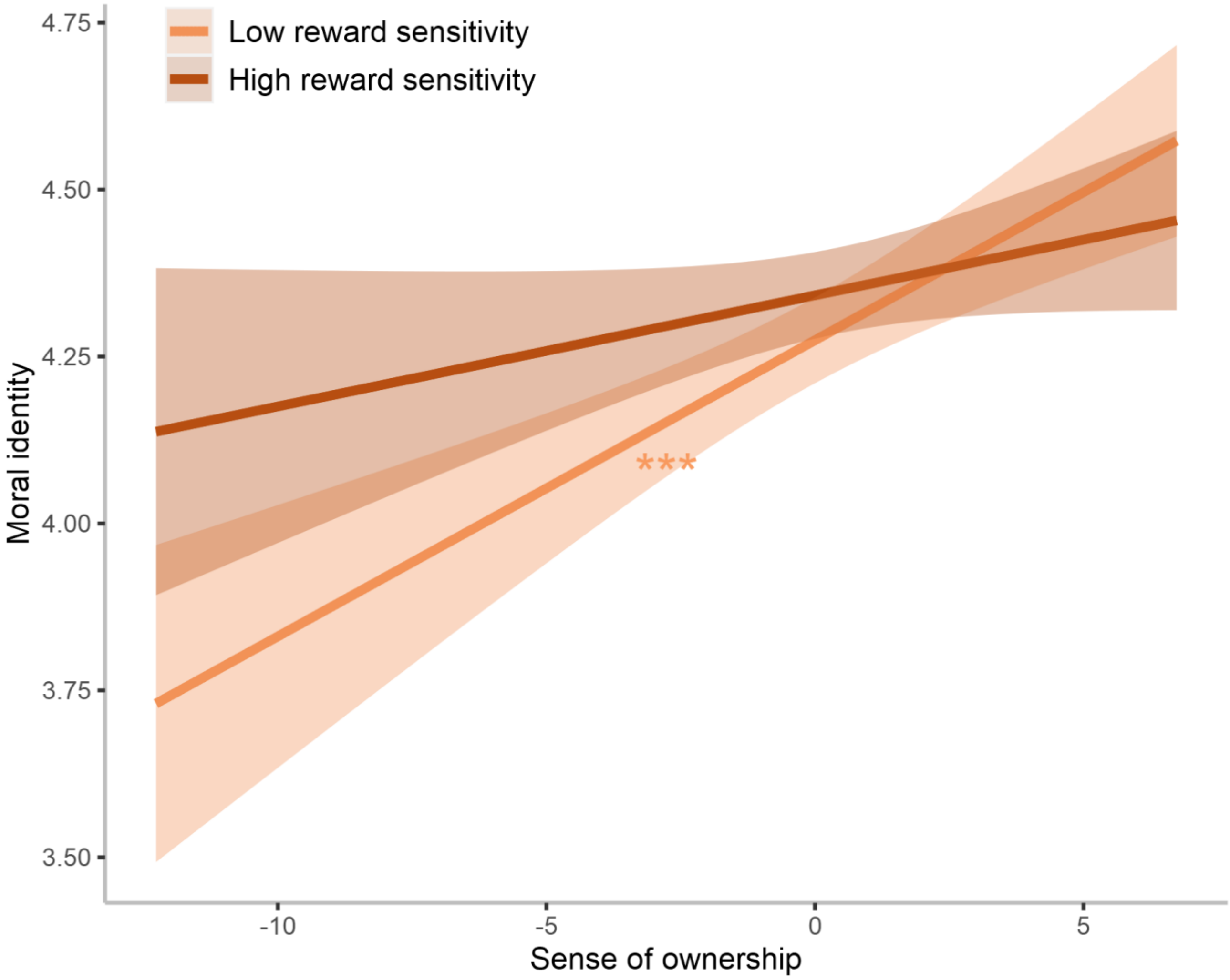


Figure 2. Moral identity scores as a function of ownership and reward sensitivity. The plot shows regression lines for 1SD below (Low Reward Sensitivity) and above (High Reward Sensitivity) the mean reward sensitivity score. The shaded bands represent 95% confidence intervals, and the asterisks indicate significance (***$p < .001$).

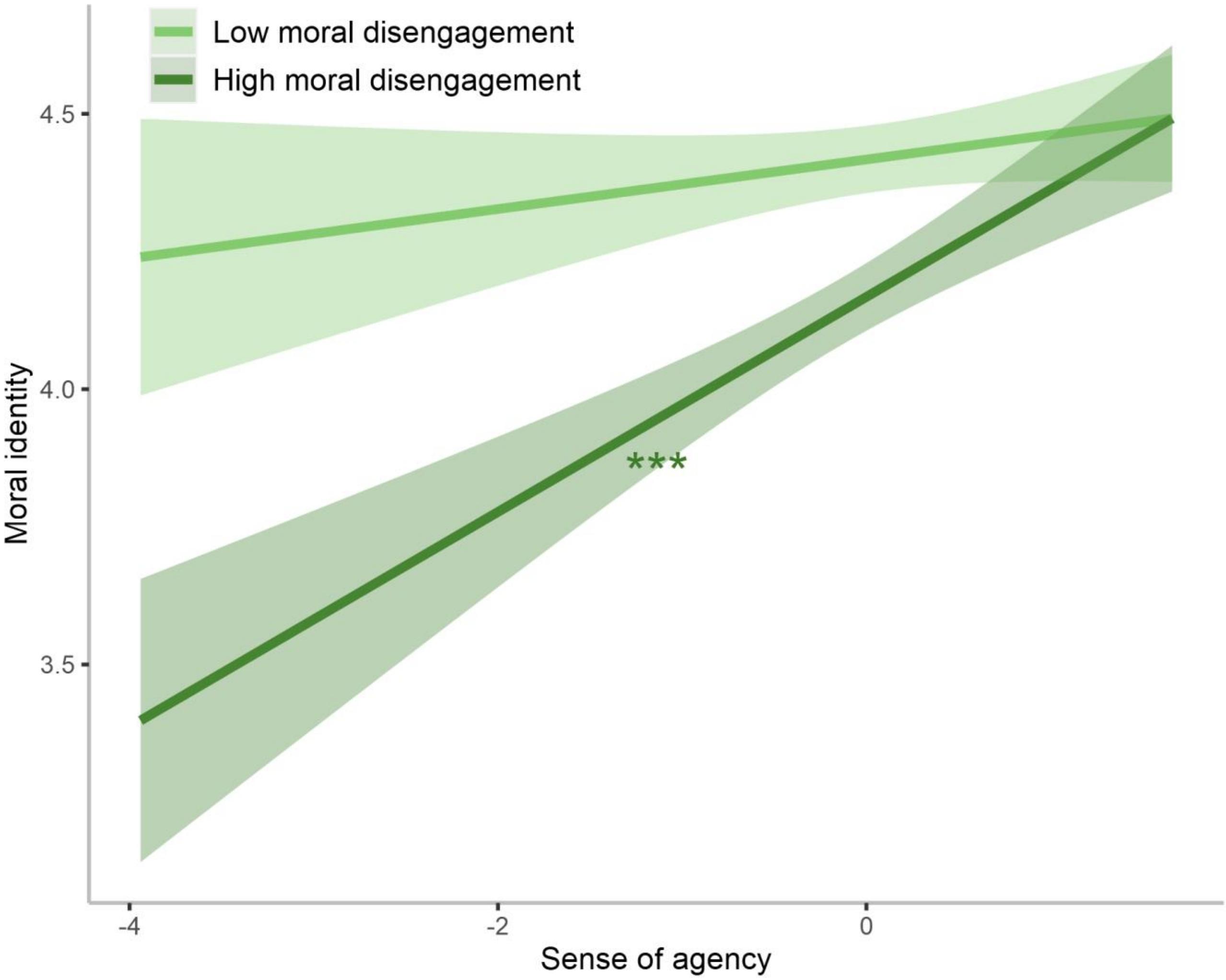


Figure 3. Moral identity scores as a function of agency and moral disengagement. The plot shows regression lines for 1SD below (Low Moral Disengagement) and above (High Moral Disengagement) the mean moral disengagement score. The shaded bands represent 95% confidence intervals and the asterisks indicate significance (***p < .001).

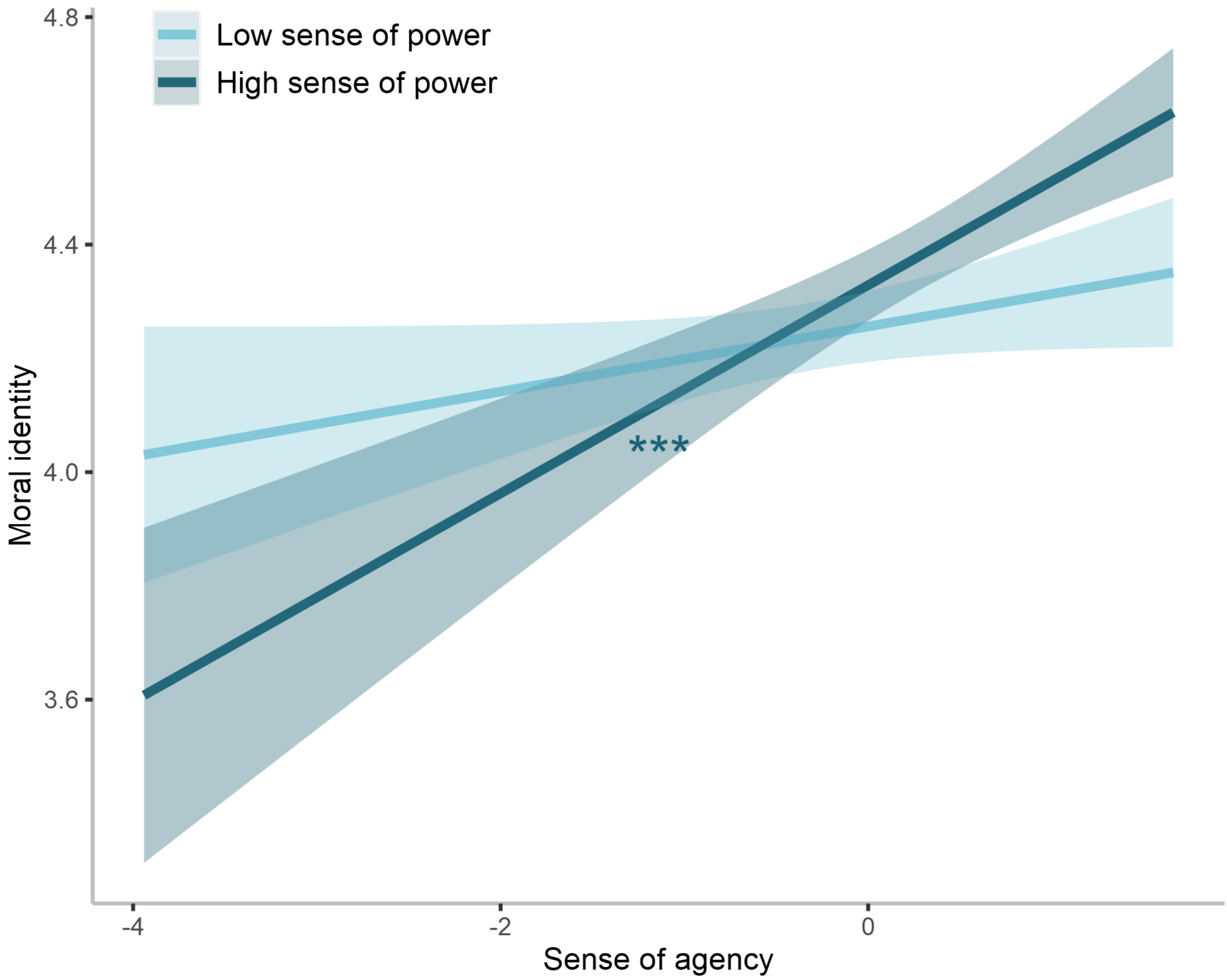


Figure 4. Moral identity scores as a function of agency and sense of power. The plot shows regression lines for 1SD below (Low Sense of Power) and above (High Sense of Power) the mean sense of power score. The shaded bands represent 95% confidence intervals and the asterisks indicate significance (***$p < .001$).

2.3.2 (Im)moral behavior

To ensure that the two pairs of images did not differ in terms of how many details the participants reported finding, we first ran a multiple linear mixed effect model. Lies were the predicted variable, while participants' identification number (ID) and the presented pair of images were entered as the random and fixed factor, respectively. This analysis revealed that the specific pair of images did not predict the number of differences reported by participants (β = 0.03, 95% CI = [-0.03, 0.10], $t(655.32) = .99$, $p = .323$).

We used three additional multiple linear mixed effect models to analyze lies, and thus investigate whether sense of ownership and agency can predict dishonest behavior, as well as whether other variables acted as moderators. In all of these analyses, participants' ID's were set as random factors, while their ages were included as fixed predictors (as it significantly correlated with the variable Lies; $r = .08$, 95% CI [.001, .15], $p = .049$; Table 1).

The effect of sense of ownership on (im)moral behavior.

In the first of these models, we entered body ownership, experimental condition (no reward coded as 0, reward coded as 1), reward sensitivity, and all of the interaction terms, as fixed predictors. Since a Shapiro-Wilk test showed that residuals did not follow a normal distribution ($W = 0.56$, $p < .001$), we entered the same model in a robust mixed regression analysis. Given the similarity of robust mixed regression results and multiple linear mixed effect model, only the latter – which allows post-hoc comparison testing for mixed effects models – will be reported here. Robust results can be found in Appendix A (Chapter 8). We observed that the condition (no reward/reward) increased the number of lies (β = 0.15, 95% CI = [0.09, 0.22], $t(652.41) = 4.50$, $p < .001$). The interaction between ownership, condition, and reward sensitivity is significant (β = -0.09, 95% CI = [-0.17, -0.01], $t(651.21) = -2.24$, $p = .025$; Figure 5). Indeed, in the reward condition, sense of ownership increased the number of lies in participants who scored low in reward sensitivity (β = 0.02, 95% CI = [0.01, 0.05], $t(1271.73) = 2.26$, $p = .024$; Figure 5).

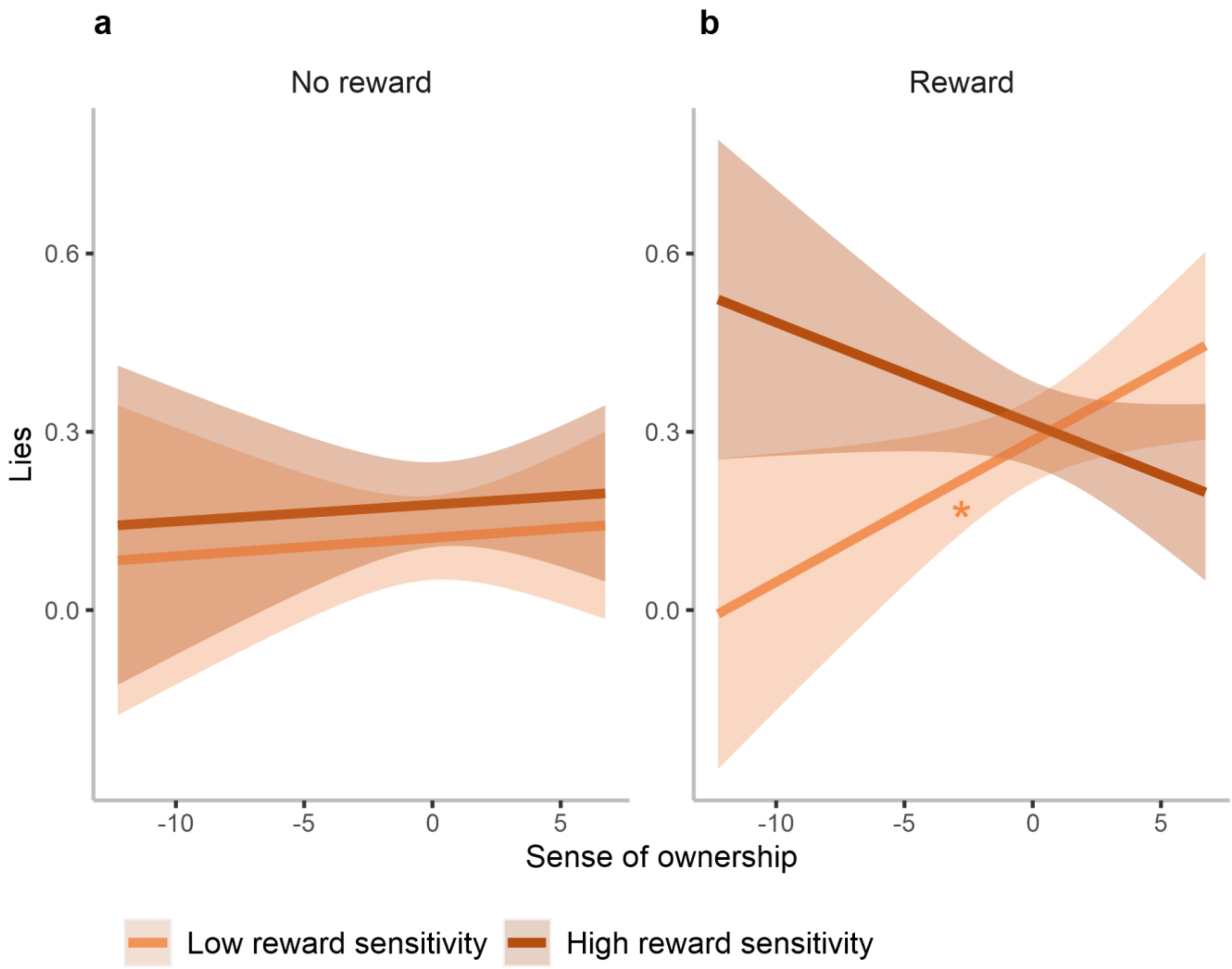


Figure 5. Lies as a function of ownership, reward sensitivity, and experimental condition. Panel **a** represents lies in the no reward condition, while the reward condition is displayed in panel **b**. The plot shows regression lines for 1SD below (Low Reward Sensitivity) and above (High Reward Sensitivity) the mean reward sensitivity score. The shaded bands represent 95% confidence intervals. Asterisks indicate significance (* $p < .05$).

The effect of sense of agency on (im)moral behavior.

We computed two models so as to examine the possible link between lies and sense of agency. Agency, experimental condition (no reward coded as 0, reward coded as 1), moral disengagement, and RT Lies were set as independent variables in one of these models. To investigate possible moderations, we included their interaction (agency × experimental condition × moral disengagement × RT lies) in this analysis. A Shapiro-Wilk test showed that the distribution of residuals was significantly non-normal ($W = 0.57$, $p < .001$), leading us to perform a robust regression analysis on the same model. The robust results show that the number of lies in the task increased in association with the experimental condition (no reward/reward) ($\beta = 0.001$, 95% CI = [0.00, 0.01], $t(662.10) = 2.46$, $p = .014$) and age ($\beta = 0.001$, 95% CI = [0.00, 0.01], $t(660.90) = 3.44$, $p < .001$). All other predictors were not significant.

In the last model, sense of agency, condition (no reward; reward), sense of power, RT Lies and all interactions between these (agency × experimental condition × sense of power × RT Lies) were fixed factors. We computed a robust multiple linear mixed effect model due to the significantly non-normal residuals ($W = 0.55$, $p < .001$). The robust analysis found that the number of reported differences increased in association with age ($\beta = 0.001$, 95% CI = [0.00, 0.01], $t(1064.29) = 3.46$, $p < .001$), yet no other predictor was significant.

2.4 Discussion

We have investigated whether two of the basic pillars of bodily self-consciousness (the sense of ownership and the sense of agency) are differentially related to moral identity and (im)moral behavior. Specifically, we tested if sensitivity to rewards could modulate the effect of body ownership, while concurrently exploring whether moral disengagement and sense of power could impact the effect of the sense of agency. To answer these questions, we conducted an online study where moral identity was measured by means of a questionnaire and (im)moral behavior was measured by a task that tempted participants to lie in exchange for a higher monetary reward.

Interestingly, we found that both sense of ownership and sense of agency strengthened moral identity. The relation between moral identity and sense of agency may possibly be explained through personal responsibility. In fact, sense of agency over the body entails feelings of responsibility over the outcomes of performed actions (Moretto et al., 2011). Feeling responsible for the effects of one's own behaviors may thus promote the occurrence of moral deeds (Bandura et al., 1996) and, by consequence, consolidate one's moral concept of the self. In line with this, acting dishonestly has been associated with decreased readiness potential – an electrocortical signal associated with the production of voluntary acts and strongly associated with a sense of responsibility (Panasiti et al., 2014). While the link between sense of agency and moral identity could well be rooted in feelings of responsibility, the positive relation between sense of ownership and moral identity appears to be less straightforward. However, this association may resemble that found between enhanced body ownership and positive attributes. Consider, for example, the enfacement illusion (Porciello et al., 2018), i.e., the inclusion of another person's face into an extended representation of one's own body. Crucially, this extension of the sense of body ownership is more likely to occur when the other person is considered as displaying desirable characteristics, such as niceness and physical attractiveness (Bufalari et al., 2014; Sforza et al., 2010). Therefore, it has been proposed that enhanced body ownership is observed in association with positive qualities, as doing so promotes the observer to attribute these qualities to themselves (Scattolin et al., 2021). The positive relation we found between sense of ownership and moral identity may be aligned to this, as increased ownership could facilitate the association between body and positive characteristics (like morality), that are consequently ascribed to the self.

Notably, we found that other variables modulate the relation between each specific component of BSC and morality. In particular, reward sensitivity appears to moderate the main effect of sense of ownership. We observed this both for moral identity and immoral behavior. An important result of our study is that awareness of one's own body can enhance moral self-image, which in turn may steer one towards dishonesty. Indeed, we found that, as the sense of ownership intensifies, low levels of reward sensitivity become associated with increased moral identity (Figure 2) and, concurrently, to increased deceptive behavior during the STDT (Figure 5). This (seemingly paradoxical) result may be in keeping with previous studies which indicate that, when people perceive themselves as highly moral, they feel more licensed to act less morally – an effect referred to as moral licensing (Effron & Conway, 2015; Sachdeva et al., 2009).

Interestingly, we observed no such pattern for high levels of reward sensitivity. Indeed, the above effect tended to occur when an enhanced sense of body ownership conveyed signals of low reward sensitivity. Our results suggest that being less sensitive to reward may have a paradoxical effect on reward-related behaviors. This supports the work of Capa and Bouquet (2018), who showed that participants with low sensitivity to reward perform better in working memory tasks when performance is associated with higher rewards, and when such benefits are presented subliminally. However, other implicit measures of reward sensitivity suggest a different association with (im)moral behavior. In a recent study from our group (Schepisi et al., 2020), participants were asked to play a game in which they were tempted to lie to people associated with different social characteristics for a monetary reward (Azevedo et al., 2017). Before the (im)moral choice was made, the tendency of participants to look at the game outcome before the information regarding their opponent's social status was measured. This served as an implicit measure of reward sensitivity: the weaker this measure was, the less participants behaved immorally towards low-status opponents (Schepisi et al., 2020).

Traditionally speaking, the way in which reward sensitivity influences reward-related behaviors (e.g., addiction) has been believed to be non-linear (Davis & Fox, 2008). Low sensitivity to reward encourages people to seek bigger rewards in order to boost a depressed dopamine system (Blum et al., 2000). Concurrently, similar reward-seeking behaviors are observed in association with hypersensitivity to rewards (Davis et al., 2007; Ponsi et al., 2021).

Another novel result is that a higher sense of agency seems to strengthen moral identity in people who employ justification strategies for their wrongdoings. This suggests that feeling in control of one's own actions can partly counterbalance the negative effect of moral disengagement. Bandura and colleagues (1996) argued that, when people are faced with multiple, alternative courses of action, they aim at behaving in accordance with their moral standards. To achieve their goals while simultaneously avoiding immoral behaviors, they can employ self-censure mechanisms when making decisions. Self-sanctions appear to be strongly activated when the sense of responsibility over one's own actions and outcomes is high, which is to say when justifying future detrimental behavior becomes difficult. Accordingly, our data suggest that sense of agency does increase moral identity, especially when moral disengagement is high. While sense of agency and moral disengagement appear to predict moral identity, their relation to behavior in a given task does not appear to be significant. One possible explanation for this is that anticipatory self-sanction mechanisms were activated once participants were presented with the opportunity of cheating in exchange for a higher pay-off. Therefore, self-sanctions may have prevented the use of moral disengagement strategies and consequently restrained deceptive behaviors.

Contrary to what we expected, agency boosted the effect of sense of power over moral identity. Simply put, sense of agency was associated with higher moral identity in participants who reported being able to influence others. This finding supports previous research, which has shown that feeling powerful is associated with a preference for deontological moral judgements (Lammers & Stapel, 2009), which may in turn enforce a moral concept of self. However, our study shows a lack of association between (im)moral behavior, sense of agency, and sense of power. This may be explained by the complex pattern of relations among these and other variables, as well as by the link between sense of power and opposite moral-thinking styles. A recent study (Fleischmann et al., 2019) found that sense of power is associated with opposite moral-thinking styles, which, in turn, have opposite effects over moral judgements. While some of these moral styles favor decisions focused on maximizing the outcomes, others are associated with an increase of deontological judgements. In light of all this, we can suggest that, during our task, the participants' sense of power may have activated different moral-thinking styles. It is possible that their opposing effects may have counteracted each other's bias towards (dis)honesty, ultimately leading to the absence of any relation between the senses of agency and power.

While it is our belief that the present study significantly expands the current knowledge on the role of body awareness into higher level cognitive functions, such as morality and moral decision-making, we acknowledge some limitations. Our participants always completed the task before being asked to respond to the questionnaire assessing moral identity. We made this choice so as to avoid the activation of any self-related concept of morality prior to performing the task, which might have influenced spontaneous behavior. Mazar and colleagues (Mazar et al., 2008) showed that cheating did not change participants' opinion regarding their honesty. As such, we believe that performing the task did not bias responses in the moral identity questionnaire. However, it could be argued that, as this questionnaire always followed the STDT, our results may reflect personal efforts to restore moral self-image by a figurative act of cleansing (Sachdeva et al., 2009; West & Zhong, 2015). Indeed, people often employ various strategies to try and dissociate themselves from immoral deeds (Bandura, 2001; C.-B. Zhong & Liljenquist, 2006). Dissociating immorality from the self prevents having to review one's own moral image in order to comprehend inconsistent behaviors and preserve one's moral reputation in the eyes of others (Ellemers et al., 2019). In this vein, it is possible that participants who lied more in our task may have been attempting to re-establish their concept of self by overestimating just how importantly they consider certain moral characteristics. Accordingly, studies indicate that those who are less interested in upholding their moral image may present themselves more truthfully in spite of immoral behaviors (Ellemers et al., 2019; Halevy et al., 2014), while the desire to maintain a moral facade may paradoxically lead to increased dishonesty or, in this case, to an inflated moral self (Ellemers et al., 2019).

Although we tested a large sample of people, all of them were Italian-speaking, thereby complicating the generalization of the results. The very cogent issue of whether culture can influence the way in which body ownership and agency – as well as moderating variables – impact morality and (dis)honest behavior ought be addressed in future studies. In particular, research should clarify whether cross-cultural differences in morality (Stankov & Lee, 2016) and moral behaviors (Graham et al., 2016) could be traced to possible differences in awareness of bodily signals (Ma-Kellams, 2014), or in the feelings of agency associated with pleasant or desirable outcomes (Barlas & Obhi, 2014).

In conclusion, we have demonstrated that different aspects of morality can be accounted for by different components of BSC. In fact, we observed increased moral identity in association with enhanced senses of ownership and agency. However, different variables appear to intervene in these relations: while the effect of sense of agency appears modulated by moral disengagement and sense of power, reward sensitivity moderated the effect of sense of ownership. When considering dishonest behaviors, our data suggest that these are predicted by increased sense of ownership, but only when reward sensitivity is low. Policies aimed at increasing corporeal awareness may strengthen the moral identity of individuals. At the same time, understanding which factors operate in synergy with BSC components during decision-making processes could help develop specific training programs. These would aid in promoting a reliance on mechanisms that could counterbalance the tendency to act immorally.

3 Reduced body ownership increases dishonesty: evidence from an immersive virtual reality study.

3.1 Introduction

The physical body is central to the experience of the world around us. It is by means of our senses that we get to perceive our surroundings and it is through processing of this sensory information that behavior within the environment is shaped. However, sensory signals are not only fundamental for the experience of the external world, but also for the emergence of corporeal awareness (Berlucchi & Aglioti, 2010). Information coming from different sensory modalities is continuously combined and results in the feeling of having a body, or sense of body ownership (Blanke, 2012). This feeling regards the body as a whole as well as the parts it consists of, which are all perceived as belonging to the self (Giummarra et al., 2008). Because of its reliance on multisensory signals, body ownership is not a stable percept, but rather a ductile one: as information coming from sensory modalities is updated, so is the sense of ownership. A variety of studies demonstrated that modulations of body ownership arise when temporally and spatially congruent stimuli are present. At any given time, spatiotemporal congruence of stimuli leads the brain to re-organize the incoming information into a new, coherent percept of the body (Ehrsson, 2020). For instance, when tactile stimulation is delivered over the body of participants but is seen over a rubber limb (Botvinick & Cohen, 1998; Crea et al., 2015; Lenggenhager et al., 2015), another person’s face (Bufalari et al., 2014; Porciello et al., 2018) or a full, virtual body (Lenggenhager et al., 2007; Slater et al., 2009), this brings about the feeling that the observed external object belongs to the individual and is part of his/her body. Crucially, information coming from senses other than touch also appear to induce, or contribute to, body ownership. In fact, motor, auditory and even olfactory signals have been associated to changes in the representation of own limbs (Kilteni et al., 2012;

Tajadura-Jiménez et al., 2015) or of the whole body (Roel Lesur et al., 2020). However, body ownership does not exclusively rely on multisensory integration, but appearance of and perspective over the body were also found to bring significant contributions (Maselli & Slater, 2013; Monti et al., 2020). Indeed, unrealistic bodies and points of observation have been associated to significant reductions in the sense of ownership towards virtual avatars. In two different studies, Tieri and colleagues found that, in the absence of multisensory stimulation, observing a virtual hand that appears detached from a virtual forearm significantly reduced ownership ratings towards the separated, virtual hand in comparison with an intact, connected hand (Tieri et al., 2015a, 2015b). The same reduction of ownership was observed when synchronous visuo-tactile stimulation was present (Perez-Marcos et al., 2012). Similarly, participants reported a lower sense of body ownership when they observed a virtual body from a third vs first person perspective (Slater et al., 2010). Crucially, perspective over the body contributes to the feeling of being located where the body is, or sense of location, and reductions of the latter are associated to diminished sense of body ownership (Serino et al., 2013). While the evidence seems to suggest that modulations of the sense of ownership are possible, it is not yet clear whether conditions of heightened or reduced body ownership may impact higher-level psychological functions, and if so, which of these functions and in what way.

The embodied cognition perspective posits that bodily states play a central role in cognition (Barsalou, 2008). In accordance with this, manipulations of body ownership have been shown to induce changes in a variety of psychological functions. Feeling ownership over a disproportionately big or small body has been associated with congruent changes in how objects and spaces are perceived (Banakou et al., 2013; van der Hoort et al., 2011). Similarly, modulations of ownership also appear to influence the kinematics of the body. For example, slower gait was observed after participants experienced ownership over an elderly body (Reinhard et al., 2020), while the illusion of having an elongated arm affected their reaching movements (Tajadura-Jiménez et al., 2016). Notably, evidence seems to suggest that higher-level cognitive functions may be affected by modulations of body ownership. In support of this, feeling ownership over an ape's face has been shown to predict lower scores in a fluid intelligence task (Ma et al., 2019). Oppositely, embodiment of a virtual avatar bearing a resemblance to Albert Einstein has been associated to improved problem-solving performance (Banakou et al., 2018). Crucially, the body we own also appears to affect social cognition. Indeed, feeling ownership over bodies that differ from the real one can shape our attitudes towards those conspecifics that share similarities with the "new" body (Gonzalez-Liencres et al., 2020; Maister et al., 2015; Peck et al., 2013), as well as our tendency to mimic their actions (Hasler et al., 2017). Also, the distance individuals maintained from others was found to be influenced by the dimensions of a virtual body. Specifically, shorter interpersonal distance was observed following embodiment of a tall body compared to a short one (D'Angelo et al., 2019).

The literature presented so far suggests that indeed the sense of ownership and modulations thereof have an effect over psychological functions and social cognition. However, only a limited number of studies specifically investigated how reductions of the sense of ownership for a virtual body can affect behavior within a virtual environment. Bourdin and colleagues (2017) report that fear of death is reduced following a virtual, out-of-body experience, a condition associated with reduced ownership over the observed body. Understanding whether reduced ownership toward a virtual object/avatar has an effect on moral behavior, is particularly relevant for the contemporary society, where interactions increasingly occur through telepresence and web-based applications. One possibility is that dishonest behaviors may decrease in conditions where people experience lower levels of body ownership, as this may come with less awareness of one's own bodily needs and desires. The first of our studies (presented in Chapter 2) appears to support this hypothesis. Our data showed that individuals engage in less dishonest behaviors if their sense of body ownership is low, but only if this is associated with low sensitivity for rewards. While our results appear to align with other sources of evidence that show an association between awareness of one's bodily signals and egoistic behaviors (Lenggenhager et al., 2013; Mancini et al., 2011), the correlational nature of our previous study does not allow us to draw any definite conclusion regarding how moment-to-moment reductions of body ownership may benefit moral behavior. By experimentally manipulating the sense of ownership associated with a virtual body, we tried to clarify how transient changes of each individual's sense of ownership may affect the moral decision-making process. Also, our previous study allowed participants to engage in dishonesty without their behavior having an impact on others. Here we want to explore whether the relation between the sense of ownership and (im)morality is modulated in social settings, that is, when one's decision affect others.

Thus, with the present study we set out to investigate the link between alterations of body ownership and deceptive behavior in social contexts. In particular, our goal was that of testing whether decreased body ownership could reduce participants' tendency to lie when compared to heightened ownership. To do this, we employed a virtual reality version of the Temptation to Lie Card Game (VR-TLCG), a task where participants interact with other individuals and can freely decide whether to engage in deceptive or honest behavior. To investigate the impact of body ownership over the moral decision-making process, participants were asked to complete the VR-TLCG task within a virtual environment. In the virtual environment, the participants could interact with other individuals by means of i) an intact, virtual body that they could observe as if it was their own, that is, from a congruent point of view (first person perspective); ii) an intact, virtual body that they could observe from its right side (third person perspective); and iii) a virtual body with hands detached from the virtual forearm, which the participants could observe from a congruent point of view (first person perspective). Importantly, to achieve modulations of the sense of ownership while preserving the sense of agency (i.e., the feeling of being able to control and determine the movements of the body) (Haggard, 2017) all conditions entailed full control over the avatar's movements on the part of our participants.

Finally, to test whether reward sensitivity could moderate the relation between body ownership and moral behavior as the first of our studies suggests (Chapter 2), we assigned different reward values (i.e., high vs. low) to each trial of the VR-TLCG.

3.2 Methods

3.2.1 Participants

Sixty individuals, recruited via social media posts or phone calls, agreed to take part to the study from July 2019 to January 2020. 10 participants had to be excluded for the reasons and number of occurrences presented in Supplementary Table 3 (Appendix B, Chapter 9), therefore the final sample included 50 participants (females = 25) whose age ranged from 19 to 30 ($M = 23.1$, $SD = 2.565$). This sample size is consistent with results of an a priori power analysis using R software, with parameters set as follows: $\alpha = 0.05$, effect size = 0.02 (small) and power = 0.8. None of the participants reported ever experiencing motion sickness in VR, having any known neurological and psychiatric condition or being taking any psychiatric drug at the time of testing; all had normal or corrected to normal vision, good understanding of written and spoken Italian and gave their informed consent to participation to the study and to use of their data.

Before recruitment, the Ethic Committee of the IRCCS Fondazione Santa Lucia (Rome) approved the methods and procedures of this study, which are in conformity with the ethical principles of the Declaration of Helsinki. All participants were paid for taking part in the study.

3.2.2 Materials

A virtual version of the Temptation to Lie Card Game (VR-TLCG) (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016; Schepisi et al., 2020) was implemented using Unity software (version 2018.3.3f1) and presented to all participants via the HTC VIVE Head Mounted Display (HMD) (https://www.vive.com/eu/product/vive/). Avatars observed within the virtual environment were created in MakeHuman (version 1.1.1.) and modified with Autodesk 3ds Max 2017 (version 19,0 student). For the duration of the task, participants were also wearing a motion capture (MoCap) system (Xsens MVN Wired Version) which consisted of 17 sensors, each continuously measuring the linear and angular motion of the body part it was attached to. Information regarding movements of each sensor was sent to Unity via MVN Studio software (version 3.5.3.) and used to animate the avatar of participants so that movements temporally and spatially matched those of the person wearing the MoCap system. The participants used a footswitch (PCsensor FS2016-USB2) to rate a series of statements concerning their sense of ownership, agency and location. The final questionnaire was programmed and completed by participants using the online version of PsyToolkit (Stoet, 2017).

3.2.3 Virtual Temptation to Lie Card Game (VR-TLCG)

Participants were persuaded that they would play a card game with other three volunteers, each of whom had taken part in the study in the preceding days and had been randomly assigned to play the “picker”. Participants were told that pickers had been asked to repeatedly select one out of two covered cards, where the ace of harts indicated a monetary win for the person drawing the card while the ace of spades represented a loss (no monetary win). However, pickers had not been given the opportunity to look at the cards they had drawn nor were they given any feedback regarding their picks. Instead, the sequence of selected cards had been recorded and would be shown to participants. This happened within the virtual environment, where an avatar sitting across a virtual table from participants lifted and revealed previously drawn cards. Crucially, and unbeknownst to participants, the sequence of cards was randomly generated by the computer, so that the ace of hearts was presented in 50% of the trials. The task of participants was that of communicating the outcome of each pick to the person they were playing with, while keeping in mind that a win for the picker corresponded to a loss for themselves (*unfavorable situation*). Vice versa, a loss for the picker indicated a win for the participant (*favorable situation*). Participants completed their task within the virtual environment. Here they were represented by an avatar whose movements spatially and temporally matched their own. At all times, the avatars of participants were holding a white paper sheet in one hand and a banknote in the other. In half of the trials, banknotes were held in the right virtual hand of participants' avatars, while they appeared in their left hand in all other trials. The virtual banknote resembled a 5 euros one in 50% of trials, while it looked like a 10 euros banknote in the remaining half. The appearance of the virtual banknote informed participants of which trials were associated with a *low monetary reward* (5 euros resemblance) and which came with a *high monetary reward* (10 euros appearance). However, participants were aware of the fact that they would receive small monetary amounts and that the appearance of the banknote did not reflect the actual payoff associated to that trial. In other words, winning when their avatar was holding a virtual 5 (10) euros banknote did not indicate that our participants would be paid 5 (10) euros for their win, but rather that they would receive a lower (higher) monetary reward in comparison with trials where 10 (5) euros were displayed. We represented rewards as virtual banknotes to facilitate the identification of trials on the part of our participants. In making this choice, we considered the larger dimensions of banknotes (vs coins) as well as their defining colors, which we believed would aid the discrimination of *high* and *low monetary rewards*. To avoid (tacitly) giving the impression that the VR-TLCG entailed large monetary wins, we selected the lowest denominations, which also correspond to the most similar monetary values (that is, 5 and 10 euro denominations have more similar values than any other pair, such as €10-20 or €20-50, etc). Finally, these denominations come with quite distinguishable colors.

To inform the picker that s/he had drawn the winning card, participants were instructed to lift the hand holding the banknote, as if showing it to the picker; to communicate a loss for the other person, participants had to raise the hand corresponding to the white sheet, instead. Technically speaking, this was achieved by using Unity *SphereColliders* placed on the hands of the virtual avatars. Once colliders lost contact with the virtual table, a response was recorded. Participants were aware that all parties involved in the VR-TLCG would receive a fixed amount of money for taking part in the study. In addition to this fixed amount, participants and pickers would receive a small, varying sum dependent on the game itself. Crucially, the additional payment would be calculated based on the reward value associated to each trial and to what was communicated by participants. More specifically, this meant that participants and pickers would not be paid based on which cards were *actually* drawn, but rather, payoffs of all persons involved would be determined by what participants decided to *communicate*. Therefore, participants had the opportunity to confirm or reverse the outcome of each draw. In other words, when shown the ace of hearts (*unfavorable situation*, i.e., the other person has picked the winning card), participants could either lift the banknote to confirm the outcome (*altruistic truth*, i.e., the picker gets the money associated to this trial) or raise the white paper and reverse the outcome (*egoistic lie*, i.e., the participant gets the money and the picker does not receive any money); oppositely, in trials where the ace of spades was drawn (*favorable situation*, i.e., the other person has picked the losing card), participants could show the white paper and confirm the outcome (*egoistic truth*, the participant gets the money), or lift the banknote and thus reverse the outcome (*altruistic lie*, the picker gets the money) (see Figure 6 for a visual representation of the VR-TLCG).

To modulate the sense of ownership associated to the virtual body, participants were asked to complete the VR-TLCG task under three different conditions. In one case, participants observed their virtual body as if it was their real one, that is, from a first person perspective, with wrists showing and connecting the avatar's hands to their virtual arms (*1PP-Wrist*). In a second condition, participants looked at their avatar from a first person perspective, but the virtual wrists were not showing, hence hands appeared detached from virtual forearms (*1PP-No Wrist*). In a yet different condition, participants observed their avatar from its right side (third person perspective) but hands were connected to the rest of the virtual body (*3PP-Wrist*). For each of these conditions (i.e., *1PP-Wrist*, *1PP-No Wrist* and *3PP-Wrist*), participants completed two blocks of 16 VR-TLCG trials before moving to the following condition, resulting in 96 trials in total. The presentation order of the three ownership conditions was counterbalanced across participants. Participants were also informed that in each ownership condition they would be shown the cards drawn by a different picker.

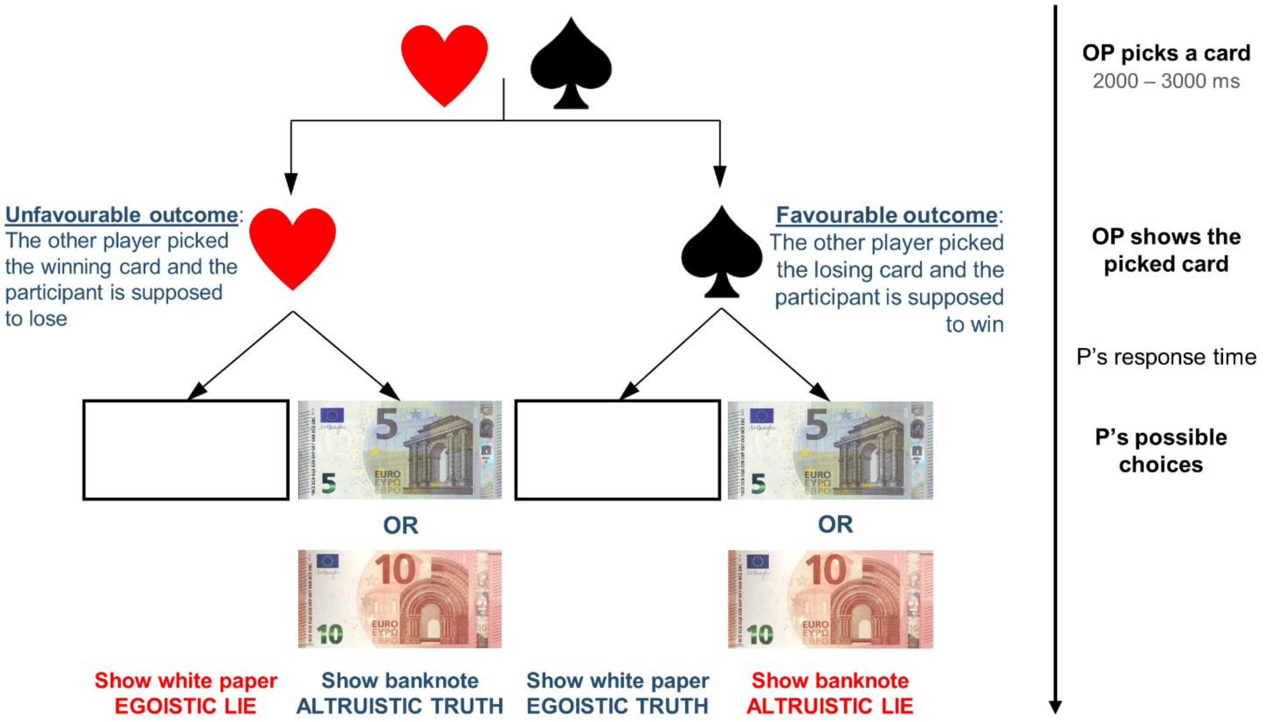


Figure 6. Schematic representation of the virtual reality version of the Temptation to Lie Card Game (VR-TLCG). A timeline of each trial is presented on the rightmost part of the figure. The other player (OP) picks one of two covered cards and the OP's avatar shows the drawn card to the participant (P) within the virtual environment. If the lifted card is the ace of hearts (left side of the figure), this represents an *Unfavorable situation* for the P. If the OP picked the ace of spades (central part of the figure), this indicates a *Favorable situation* for the P. The P can now decide whether to lift a virtual, white piece of paper or a virtual banknote. Both of these appeared on the left (right) hand of P's virtual body on half of the trials. By lifting the white piece of paper, the P are communicating that the OP lost (and they won). To communicate that the OP won (and they lost), the Ps can lift the virtual banknote. In 50% of trials, the virtual banknote resembled a 5€ (10€) banknote, indicating a *Low reward* (*High reward*) trial.

3.2.4 Embodiment ratings in VR

To investigate the feelings of ownership, agency and location associated to their virtual body in different experimental conditions and how these might change over time, we asked participants to rate how much they agreed with 10 of the statements reported in Gonzalez-Franco and Peck (2018). All selected statements were adapted to the characteristics of our virtual environment and are reported in Table 2 (see Supplementary table 4 in Appendix B, Chapter 9, for the Italian version used in the study). These were presented for a total of six times, that is, prior to and then after playing the VR-TLCG in each condition (i.e. *1PP-Wrist*, *1PP-No Wrist*, *3PP-Wrist*). The order of statements was randomized at every presentation. Statements were displayed in white against a dark virtual environment, so that these were the only things visible to participants while responding. Participants rated their agreement along a Visual Analogue Scale (VR-VAS), by positioning a cursor along an horizontal line. The left end of the line indicated total disagreement with the statement and corresponded to a score of 0, the right end of the line signaled total agreement and was associated to a score of 100. When each statement was presented, the cursor appeared in the middle of the line (corresponding to a score of 50) and participants were instructed to use a foot switch to move the cursor towards the desired position. By pressing the left/right pedal, the cursor moved to the left/right. To confirm each rating, participants had to verbally inform the experimenter, who would display the following statement.

To compute combined ownership, agency and location scores, we applied the formulas reported by Gonzalez-Franco and Peck (2018) (see Table 2 for the complete list of statements and their corresponding number).

$$Ownership = (Q1 - Q2) - Q3$$

$$Agency = Q4 + Q5 + Q6 - Q7$$

$$Location = Q8 - Q9 + Q10$$

Following this calculation, the ownership ratings of participants could range from -200 (no ownership over the virtual body) to +100 (full ownership over the virtual body). The possible range of agency ratings went from -100 (no sense of agency for the virtual body) to +300 (full sense of agency for the virtual body). Location ratings could range from -100 (no sense of being located where the avatar was located) to +200 (full sense of being located where the avatar was located).

3.2.5 Procedure

Participants were welcomed by the experimenter, who provided them with written information regarding the study. Once participants had signed the informed consent and had granted permission to use of their data, the experimenter took their body measurements. These were necessary to ensure appropriate calibration of the MoCap system. A list of measurements and their description is provided in Supplementary Table 5 (Appendix B, Chapter 9). Then, participants were asked to wear all parts of the MoCap suit. This consisted of 17 sensors secured to the body by means of Velcro straps and wired to one another. After the MoCap hardware had been set up, and according to the system supplier's guidelines, *N-pose* and *Hand-pose* calibration processes were completed. To avoid possible magnetic distortions, electronics and metal objects were kept at the further possible distance from sensors. For the same reason, participants sat on a wooden chair positioned in front a plastic table for the entire duration of the study. Once seated, participants were asked to wear a Head Mounted Display (HMD), by means of which they could observe the virtual environment.

In the virtual environment, participants were represented by a sex-matched avatar (i.e. female avatar for female participants, male avatar for male participant). The virtual environment consisted of a table and two chairs placed in the center of a dimly lit room The avatar of the participants was sitting on one of the chairs while the other player's

Table 2. Statements assessing the participant's level of embodiment towards the virtual bodies. The statements were presented twice for each experimental condition (i.e., *1pp-Wrist*, *1pp-No Wrist*, *3PP-Wrist*). The statements appeared in randomized order, after each guided observation procedure and after completing two VR-TLCG blocks.

	Measured component	**Statements presented to participants**
Q1	Ownership	I felt as if the virtual body with banknotes in its hands was my body
Q2	Ownership	It felt as if the virtual body with banknotes in its hands was someone else's
Q3	Ownership	It seemed as if I might have more than one body
Q4	Agency	It felt like I could control the virtual body with banknotes in its hands as if it was my own body
Q5	Agency	The movements of the virtual body with banknotes in its hands were caused by my movements
Q6	Agency	I felt as if the movements of the virtual body with banknotes in its hands were influencing my own movements
Q7	Agency	I felt as if the virtual body with banknotes in its hands was moving by itself
Q8	Location	I felt as if my body was located where I saw the virtual body holding banknotes
Q9	Location	I felt out of my body
Q10	Location	I felt as if my real body were drifting toward the virtual body with banknotes in its hands or as if the virtual body with banknotes in its hands were drifting toward my real body

avatar was sitting on the opposite side of the virtual table, facing the participants.
After participants had placed their hands on the plastic table, their point of view and the position of virtual objects were adjusted so that what participants saw in the virtual environment matched their tactile sensations. For example, when participants' real hands were touching the plastic table, their virtual hands were simultaneously touching the virtual table. Adjustments were made under all three conditions to ensure matching from all perspectives (that is, 1PP and 3PP). After being provided with task instructions, participants completed five VR-TLCG practice trials in each experimental condition. At this point, the experimenter reminded participants that they would be allowed to lift only one hand at a time and only to communicate the outcome to the picker. Once the pickers' avatar had lowered the previous card (signaling that participants' choice had been recorded), participants were instructed to place the hand they had just lifted back on the table.
The experimental phase began with a guided observation procedure. During this procedure, the participants observed the virtual body for 30 seconds, following instructions that were verbally provided by the experimenter (see Section 9.1 for a detailed description of instructions). The guided observation procedure was completed before the two VR-TLCG blocks associated with each condition. This was done to ensure that participants were aware of which virtual body they would use during the following two blocks (i.e., whether this was the avatar with wrists showing or not) and from what perspective they would observe it (i.e., from a first or third person perspective). After the 30 seconds observation, participants rated the 10 statements assessing their sense of ownership, agency and location (Table 2). The participants rated the same statements after completing the two blocks of VR-TLCG trials and before the following condition was presented.

At the end of the VR-TLCG, participants were asked to fill a manipulation check questionnaire aimed at assessing how engaging the game was for them (Panasiti et al., 2016). In accordance with previous studies (Panasiti et al., 2016; Schepisi et al., 2020), the target question was the following: “How involved did you feel in the game?”. The participants were asked to rate their involvement on a 5-point Likert scale ranging from “Not at all” (score 1) to “Very much” (score 5). The participants who rated their engagement with values below 3 were excluded from all analysis (see Supplementary table 3 in Appendix B, Chapter 9, for the number of occurrences). Once they had completed the manipulation check questionnaire, the MoCap suit was taken off of participants

At the end of data collection, all participants were debriefed on the real nature of the study and they were informed of the fact that they had actually played against the computer. After this explanation, participants were given the opportunity to confirm or refuse their permission to use of the data collected from them. All participants granted permission following the debriefing.

3.2.6 Data analysis

Data were analysed using R software (version 4.0.2) via RStudio (version 1.3.959). We computed linear mixed effect models by means of the function *lmer*, while we used the *glmer* function for our mixed-effects logistic regression model. Both functions are part of the *lme4* package (version 1.1-23). To select the appropriate random factor structure and avoid over-parametrization of our models, we applied a Principal Component Analysis (PCA). For PCAs, we used function *rePCA* of the *RePsychLing* package (version 0.0.4) over the saturated model. We repeatedly applied the same function over the following, simplified models and until all random effects explained part of the variance. We used function *anova* of the *stats* package to compare the fit of all models that reached convergence. We then used the best-fitting model to test the significance of fixed effects and for post-hoc comparisons. We computed type III Wald Chi-Square test over the fixed effects using function *Anova* of the *car* package (version 3.0-8). Post-hoc comparisons were performed using package *emmeans* (version 1.4.8).

3.3 Results

3.3.1 Embodiment ratings

Ownership ratings. To check whether our experimental manipulations had successfully reduced the participants' sense of ownership towards the virtual bodies in the *1PP-No Wrist* and *3PP-Wrist* conditions, we analyzed their ownership ratings via a linear mixed effect model. The combined ownership score was the dependent variable (see paragraph 3.2.4 for a detailed description of how this was calculated). A model comparison revealed that the model that best fit the present data included ownership condition (i.e. *1PP-Wrist*, *1PP-No Wrist* or *3PP-Wrist*), time of rating (i.e. before or after completing the two VR-TLCG blocks in each condition) and their interaction term as fixed predictors. The ownership condition was also entered as random slope, while participant's identification number (ID) was set as the random intercept. Ownership condition significantly predicted participants' ownership ratings ($\chi 2$ (degrees of freedom or df = 2) = 44.32, $p < .001$). Post-hoc comparisons revealed that the feelings of ownership over the virtual body were lower in the *3PP-Wrist* condition in comparison to the *1PP-Wrist* condition (estimate = 51.89, 95% Confidence Intervals or CI [33.05, 70.7], t.ratio = 6.83, $p < .001$) and the *1PP-No Wrist* condition (estimate = 46.55, 95% CI [27.63, 65.5], t.ratio = 6.10, $p < .001$) (Figure 7). Ownership ratings in the *1PP-Wrist* and *1PP-No Wrist* conditions did not differ (estimate = 5.34, 95% CI [-6.48, 17.20], t.ratio = 1.12, $p = .268$).

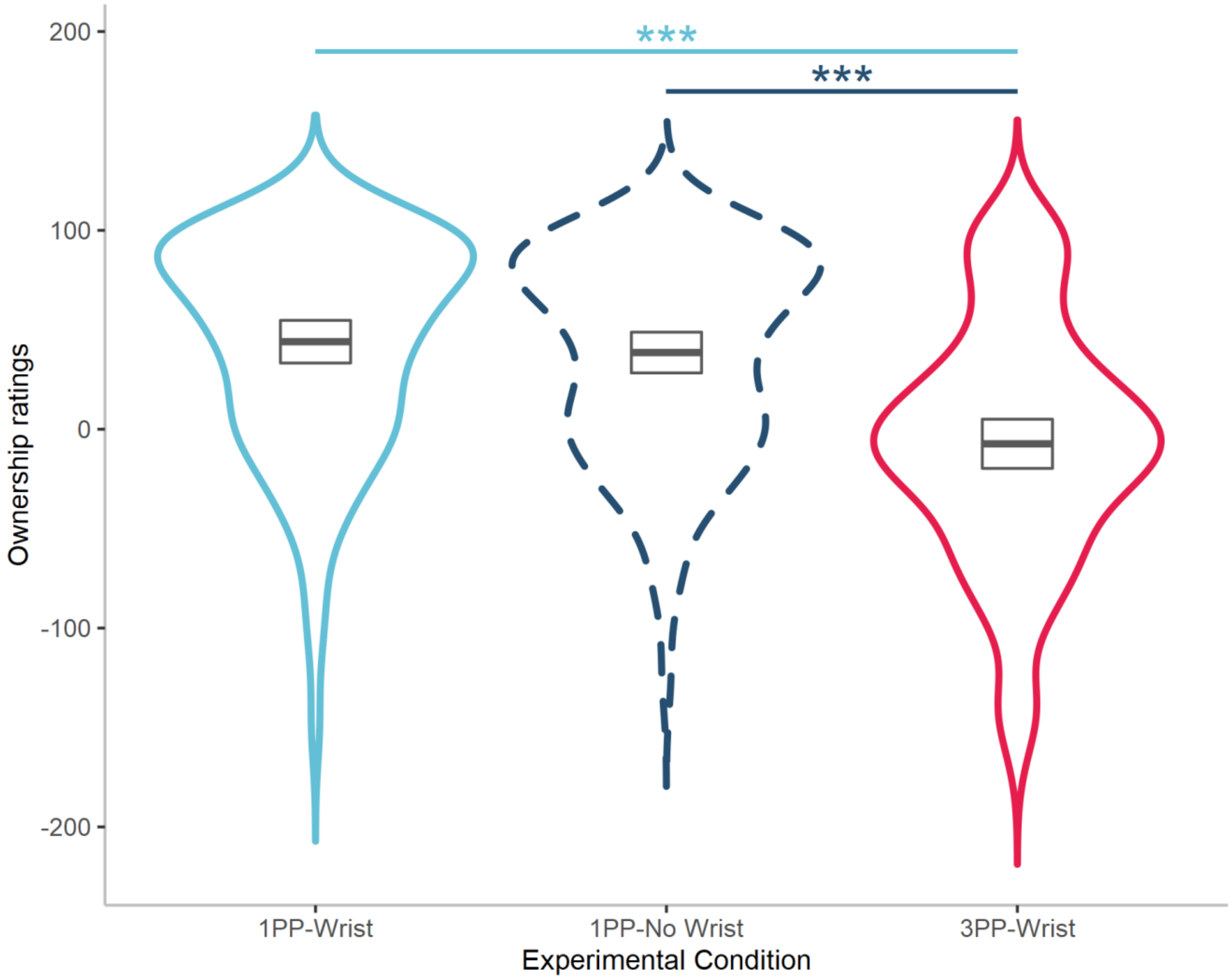


Figure 7. Combined ownership ratings in each experimental condition. Violin plots represent the distribution of ownership ratings for each experimental condition. The thick horizontal lines within the boxes represents the model estimate. The upper horizontal limits represent the upper confidence interval (CI), the lower horizontal limits represent the lower CI. The asterisks indicate significance (***p < .001).

Agency ratings. To ensure that the sense of agency associated to the virtual body remained the same in all ownership condition, we set the combined agency score (see paragraph 3.2.4) as the predicted variable in a linear mixed effect model. Ownership condition (*1PP-Wrist*, *1PP-No Wrist* or *3PP-Wrist*) and time of rating (before or after completing the two VR-TLCG blocks in each condition) were entered as random slope, while participants' ID was included as random intercept factor. Fixed factors were ownership condition, time of rating and their interaction.

This analysis showed a significant main effect of ownership condition ($\chi 2$ (df = 2) = 7.27, p = .026) and a significant interaction between ownership condition and time of rating ($\chi 2$ (df = 2) = 6.15, p = .046). Before completing the VR-TLCG, agency ratings in the *3PP-Wrist* condition were lower than in the *1PP-Wrist* condition (estimate = 11.65, 95% CI [0.26, 23.03], t.ratio = 2.49, *p* = .040) and the *1PP-No Wrist* condition (estimate = 11.76, 95% CI [-0.98, 24.5], t.ratio = 6.10, *p* < .001). Agency ratings did not differ after completing the VR-TLCG trials. In fact, ratings following the *3PP-Wrist* condition were not different from those after the *1PP-Wrist* condition (estimate = -1.56, 95% CI [-12.76, 9.65], t.ratio = -0.34, *p* = .087) or the *1PP-No Wrist* condition (estimate = 0.88, 95% CI [-11.82, 13.58], t.ratio = 0.17, *p* = .087). Independently from the time of rating, agency did not differ between conditions *1PP-Wrist* and *1PP-No Wrist* (before completing the VR-TLCG blocks: estimate = -0.12, 95% CI [-11.37, 11.13], t.ratio = -0.03, *p* = .980; after the VR-TLCG blocks: estimate = -2.44, 95% CI [-13.83, 8.95], t.ratio = -0.34, *p* = .866) (Figure 8).

Location ratings. To investigate whether the sense of location differed between the three ownership conditions, the location score was analyzed by means of a linear mixed effect model. According to our model comparison, the best fit was associated to a model having ownership condition (*1PP-Wrist*, *1PP-No Wrist* or *3PP-Wrist*), time of rating (before or after completing the two VR-TLCG blocks in each condition) and their interaction term as fixed predictors. Ownership condition was included as random slope, while participants' ID was entered as random intercept. A significant main effect of Ownership condition was found ($\chi 2$ (df = 2) = 62.71, p < .001), while no other fixed factor was able to significantly predict location ratings. Post-hoc comparisons revealed that location ratings in the *3PP-Wrist*

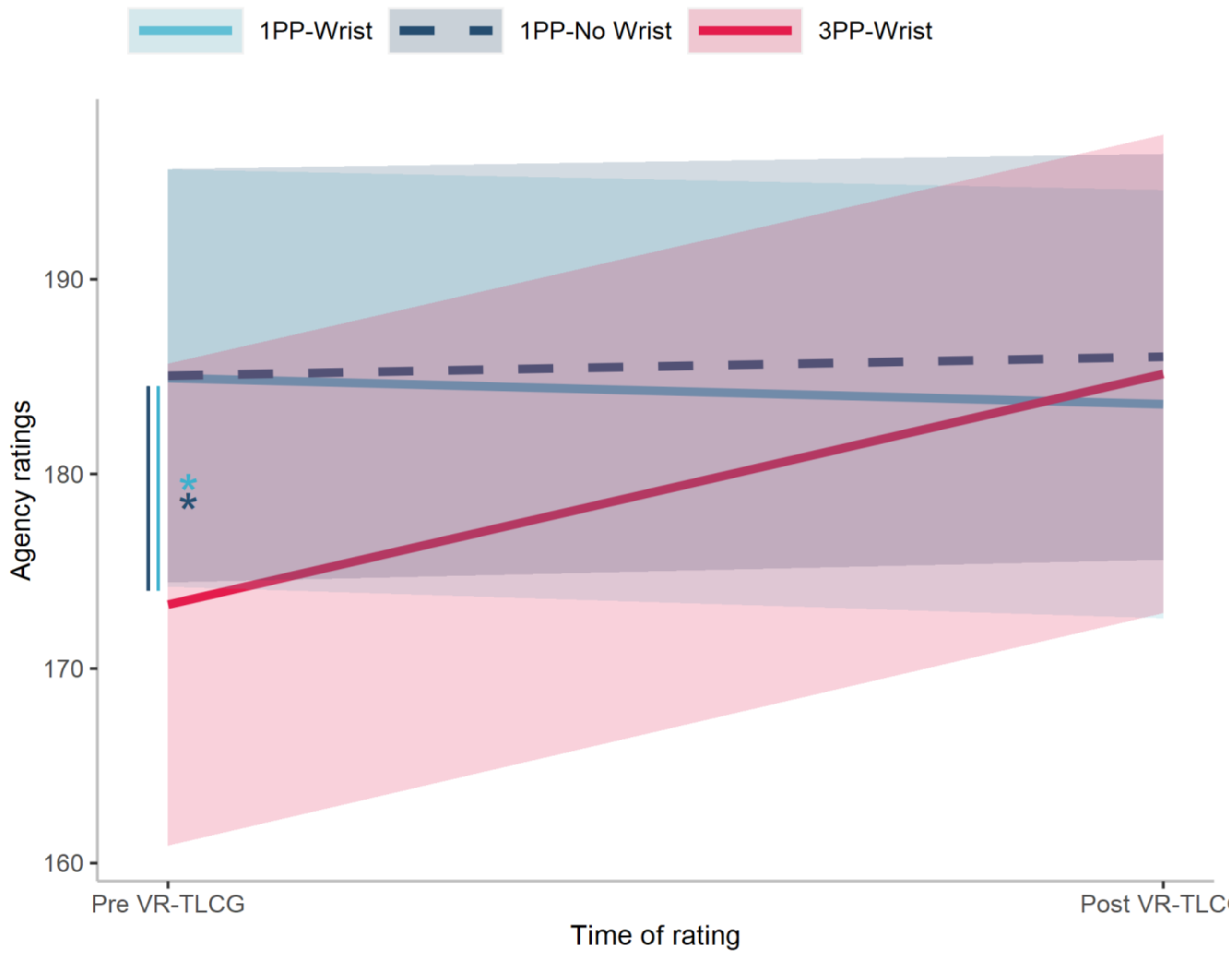


Figure 8. Combined agency ratings in each experimental condition and their change over time. The plot show regression lines for each experimental condition. The shaded bands represent 95% confidence intervals, and the asterisks indicate significance (*p < .05).

condition were significantly lower than in the *1PP-Wrist* condition (estimate = 68.79, 95% CI [49.90, 88.70], t.ratio = 8.57, p < .001) and in the *1PP-No Wrist* condition (estimate = 71.80, 95% CI [49.00, 94.60], t.ratio = 7.82, p < .001). Location ratings associated with the *1PP-Wrist* condition were not different from those provided under the *1PP-No Wrist* condition (estimate = -3.01, 95% CI [-15.90, 9.90], t.ratio = -0.58, p = .566) (Figure 9).

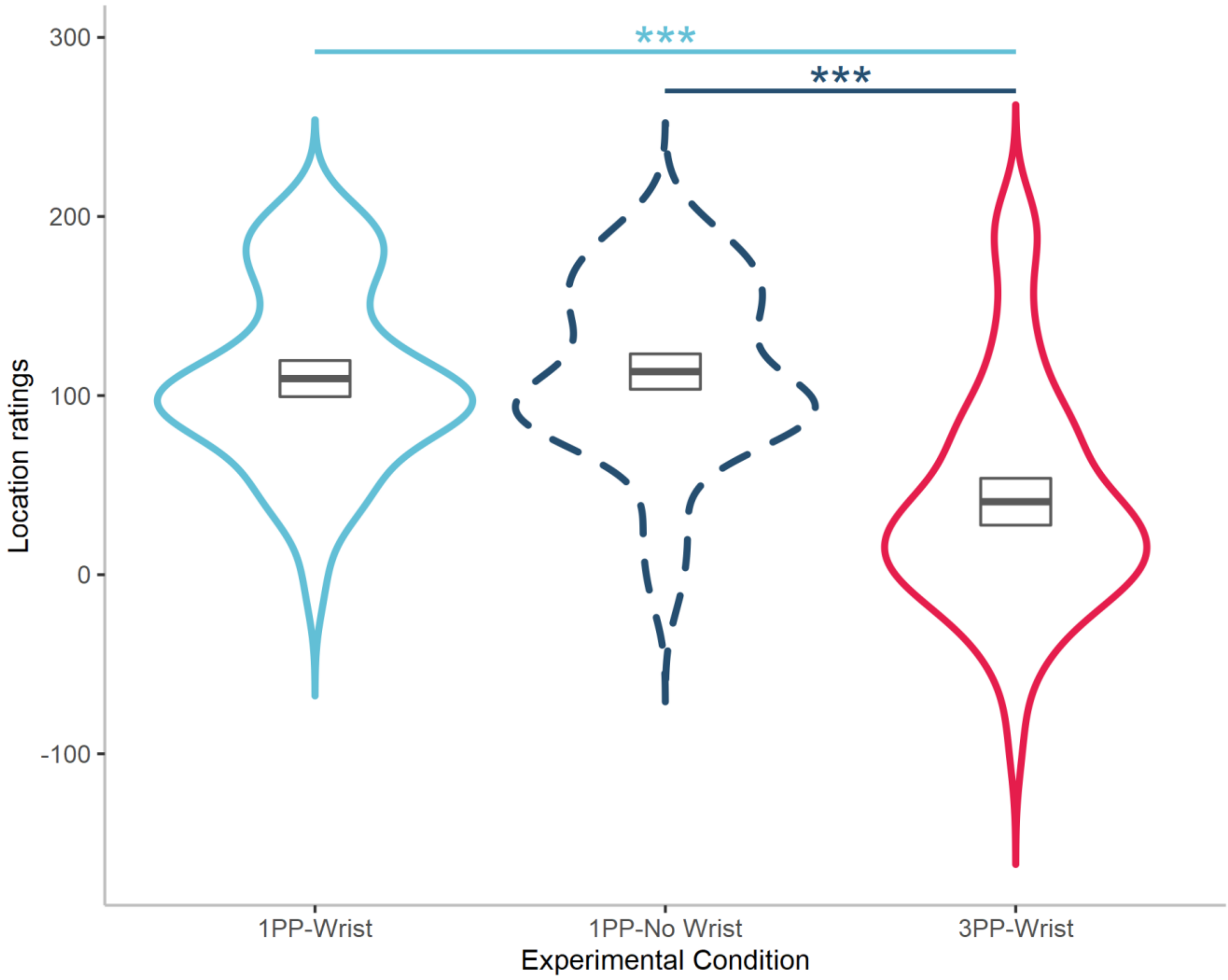


Figure 9. Combined location ratings in each experimental condition. Violin plots represent the distribution of location ratings for each experimental condition. The thick horizontal lines within the boxes represents the model estimate. The upper horizontal limits represent the upper confidence interval (CI), the lower horizontal limits represent the lower CI. The asterisks indicate significance (***p < .001).

3.3.2 Behavior in the VR-TLCG

Participants' decisions during the VR-TLCG were set as a dichotomous dependent variable in a mixed-effects logistic regression model. A decision to communicate the real outcome of the pick was coded as 0, while lies were coded as 1. Situation (*Unfavorable* to the participant coded as 0, *Favorable* to the participant coded as 1), reward value (*low monetary reward* as 0, *high monetary reward* as 1) and ownership condition (*1PP-Wrist*, *1PP-No Wrist* and *3PP-Wrist*) and all interaction terms were set as fixed factors. According to a model comparison, the random effect structure that best fit our data included situation and the interaction between situation and reward value as random slopes factors, while participants' IDs were entered as random intercept factor.

The probability of lying was significantly predicted by the reward value associated to the trial ($\chi 2$ (df = 1) = 13.84, p < .001) and by the ownership condition ($\chi 2$ (df = 2) = 13.15, p = .001). The interaction between situation and reward value was significant ($\chi 2$ (df = 1) = 14.77, p < .001) (Figure 10). When participants are in an *unfavorable situation* (that is, the other person has picked the winning card and lying means that the participant receives the reward associated to that pick), *high rewards* are associated to a higher probability of lying in comparison to *low rewards* (estimate = -1.20, 95% CI [-1.99,-0.42], z.ratio = -4.03, *p* < .001). On the other hand, in the favorable situation (when the picker has drawn the loosing card) lies were more likely to occur in *low reward* trials compared to *high reward* trials (estimate = 0.90, 95% CI [0.18, 1.62], z.ratio = 3.31, *p* = .001). In addition, *high reward* value predicted less lies in the favorable situation than in the unfavorable situation (estimate = 2.39, 95% CI [1.29, 3.49], z.ratio = 5.72, *p* < .001). Lies were also significantly predicted by the interaction between reward value and ownership condition ($\chi 2$ (df = 2) = 12.42, p = .002) (Figure 11). Post-hoc comparisons showed that, when in the *3PP-Wrist* condition, participants lied more when trials were associated to *high rewards* compared to *low rewards* (estimate = -0.43, 95% CI [-0.80, -0.06], z.ratio = -2.27, *p* = .024). Also, when rewards were low, the probability of lying was higher in the *1PP-No Wrist* condition than in the *1PP-Wrist* condition (estimate = -0.35, 95% CI [-0.69, -0.01], z.ratio = -2.48, *p* = .020) or the *3PP-Wrist* condition (estimate = 0.38, 95% CI [0.05, 0.72], z.ratio = 2.71, *p* = .020).

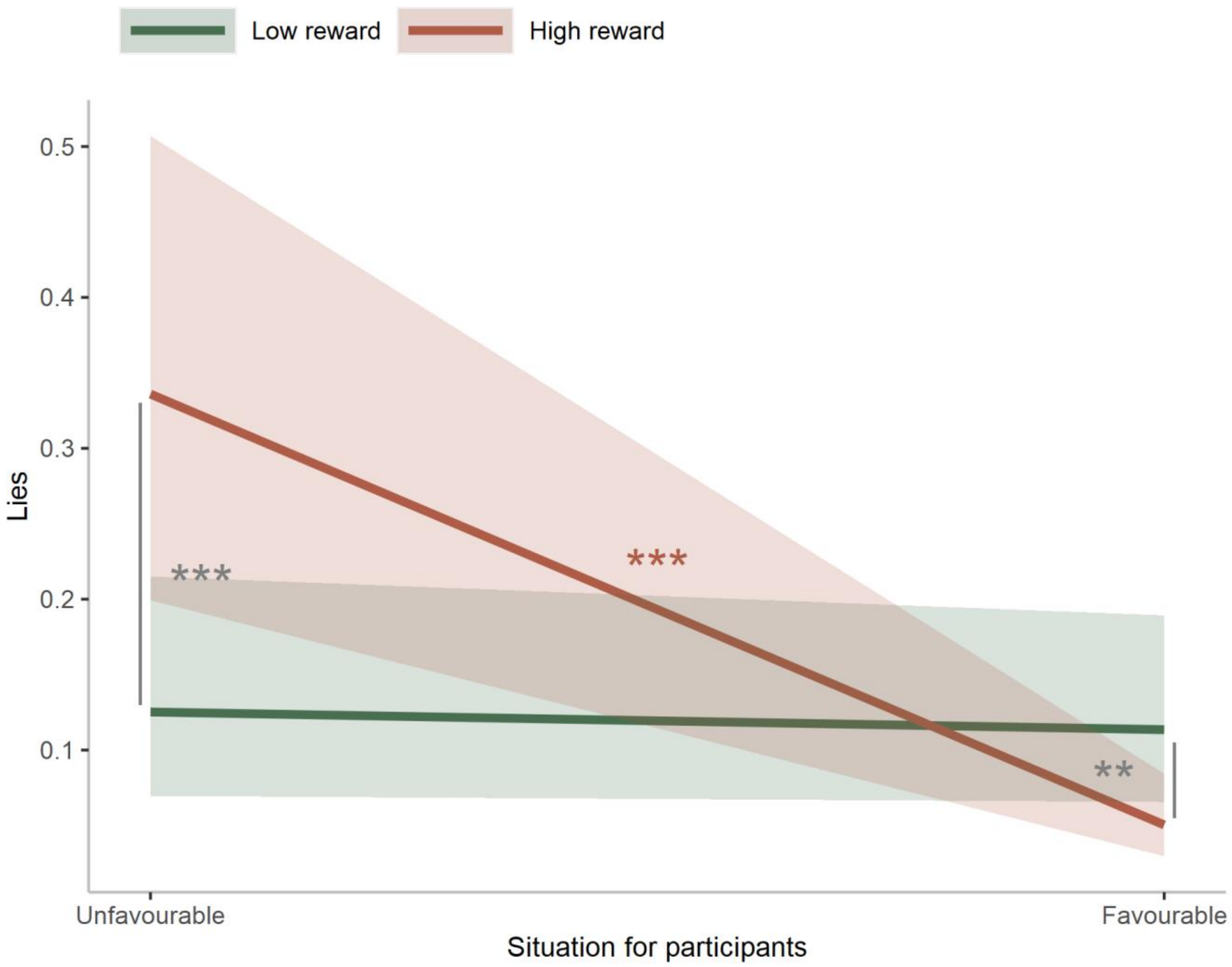


Figure 10. Lies as a function of the situation (*Favourable* or *Unfavourable* to participants) and the reward associated to the trial. The plot represents regression lines for *High reward* and *Low reward* condition. The shaded bands represent 95% confidence intervals, and the asterisks indicate significance (**p < .01, ***p < .001).

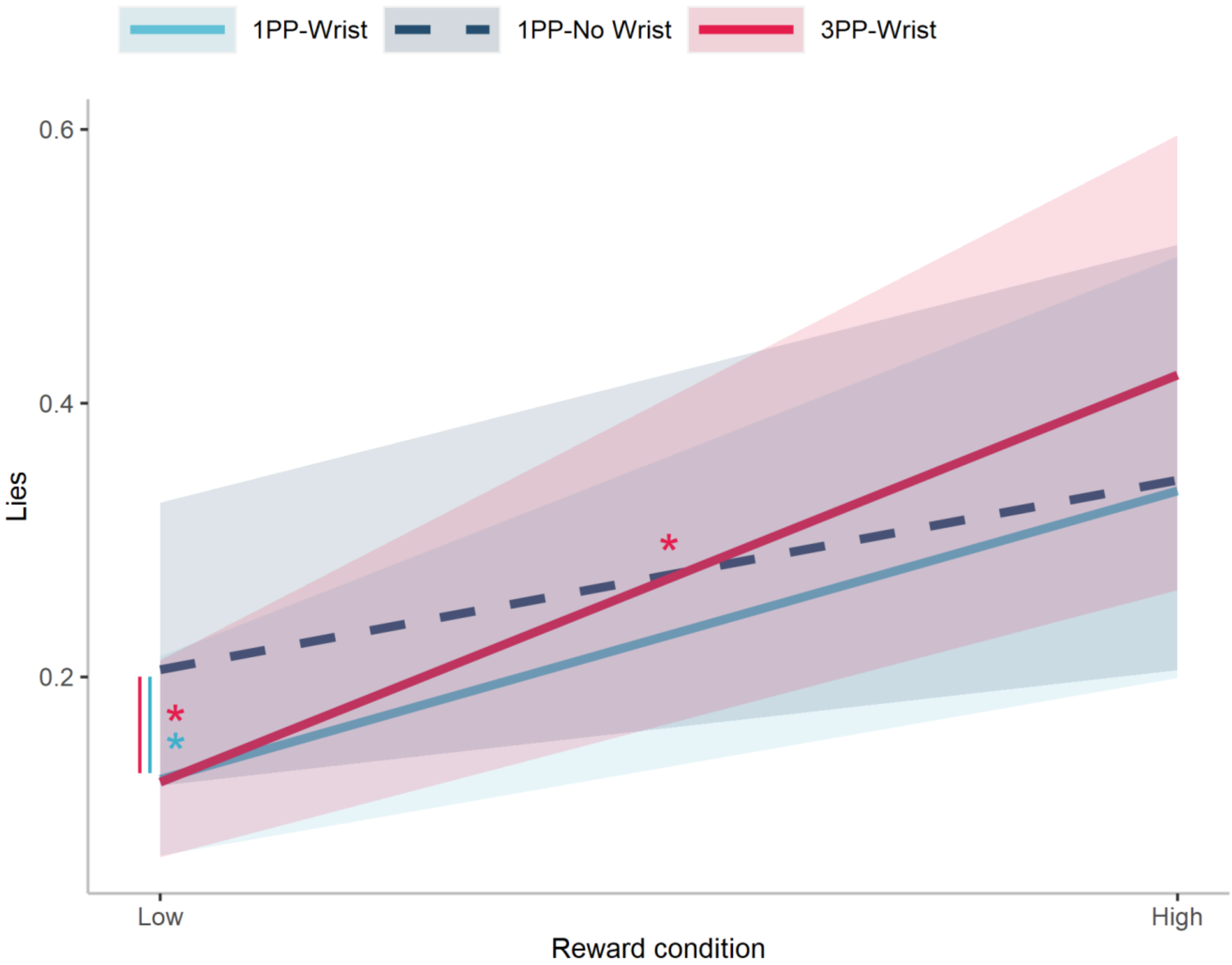


Figure 11. Lies as a function of the experimental condition and the reward associated to the trial (*High reward* or *Low reward*). The plot represents regression lines for each experimental condition (*1PP-Wrist*, *1PP-No Wrist*, *3PP-Wrist*). The shaded bands represent 95% confidence intervals, and the asterisks indicate significance (*p < .05).

3.4 Discussion

With the present study we have investigated whether modulations of body ownership over a virtual avatar can bias the tendency to lie in social situations. We did so by using Virtual Reality to experimentally reduce our participants' sense of ownership towards a virtual body, while they were playing a card game with other individuals. The card game was a virtual version of the TLCG (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016; Schepisi et al., 2020), a task where, by lying or telling the truth, participants not only determine their own gains, but also the other players'. To clarify if different reward values can impact the hypothesized relation between sense of ownership and (dis)honest behavior, we associated each trial of the VR-TLCG with either a high or low monetary reward.

We found that sense of ownership was reduced when the participants observed a virtual body from a third person perspective (*3PP-Wrist*). This result is in line with past research, which showed that visual perspective contributes to the sense of ownership. Specifically, a viewpoint located out of the body has been associated with diminished sense of ownership in comparison with a congruent, first person perspective (Maselli & Slater, 2013; Monti et al., 2020). The same perspective-related reduction of body ownership has been reported also in conditions of preserved visuo-motor synchrony, that is, even when participants could control the movements of a virtual avatar in real time (Gorisse et al., 2017). This is similar to what we observed here. Even though participants could fully control the movements of the virtual body, ownership ratings remained consistently low in the *3PP-Wrist* condition, and independently from the sense of agency. In fact, before the two VR-TLCG blocks, participants' agency ratings in the *3PP-Wrist* condition were lower than in the other two conditions (i.e. *1PP-Wrist* and *1PP-No Wrist*). Instead, while agency ratings no longer differed following the VR-TLCG, ownership ratings remained low when observing the body from an out-of-body perspective. Thus, our experimental manipulation of perspective appears to have successfully reduced body ownership, whereas visual discontinuity of the upper limbs (*1PP-No Wrist*) did not have the same effect. This result stands in contrast with those of previous studies, where observation of hands that are visually detached from a virtual body diminished the feelings of ownership (Perez-Marcos et al., 2012; Tieri et al., 2015a, 2015b). In these studies, however, participants were only passively observing the visually detached hand. On the contrary, the participants who took part to the present experiment had full control over the movements of the avatar, that is, whenever they moved their body, their virtual avatar moved congruently. Crucially, in the *1PP-No Wrist* condition, agency ratings of participants remained consistently high and did not differ from those associated with the control condition (i.e., *1PP-Wrist*). Thus, visuo-motor synchrony may constitute one possible explanation for the difference between past results and those presented here. In support of this hypothesis, a recent study found that passive observation of a static, detached hand (vs. intact hand) was associated with reduced ownership, but this effect disappeared when participants were allowed to move their real arm and its movements reflected on the detached, virtual arm (Brugada-Ramentol et al., 2019).

Taken together, our data seem to suggest that visuo-motor synchrony may be enough to induce ownership over an unrealistic body, but not when participants do not feel like their position coincides with that of the virtual body (i.e. sense of location). Indeed, when observing their virtual body from an incongruent perspective (i.e., in the *3PP-Wrist* condition), our participants not only showed a lower sense of ownership, but also reported lower feelings of location. While evidence appears to support the notion that the sense of body ownership and the sense of location are two separate components of bodily self-consciousness, experimentally induced enhancements or reductions of the latter seem to also produce changes in the reported sense of ownership (Guterstam et al., 2015; Serino et al., 2013). In line with this, a congruent, first person perspective over the virtual body was maintained in the other two experimental conditions (i.e., *1PP-Wrist* and *1PP-No Wrist*), where the sense of location remained intact, as did the sense of ownership.

Our results also seem to support the idea that the sense of body ownership may indeed play a role during moral decision-making and that this relationship may be modulated by the extent of monetary rewards. Specifically, we found that higher rewards are associated with an increase of dishonest behaviors during the VR-TLCG. In general, the results of the present study show that the participants engaged in a higher number of egoistic lies in trials associated with high rewards, that is, when lying meant receiving the highest payoff. On the contrary, lies were significantly reduced when favorable trials came with high rewards. Importantly, lying when the situation was favoring the participants meant allocating the associated monetary reward to the other player. Similarly, some studies have shown that dishonest behaviors increase when individuals find themselves in unfavorable situations (Panasiti et al., 2011, 2014) and when doing so entails high rewards (Gerlach et al., 2019). However, our results stand in contrast with evidence supporting the idea that, as the value of rewards increases, dishonesty is lessened (Cohn et al., 2019; Mazar et al., 2008). Crucially, these results may be more easily understood when considering the role of body ownership. We found that higher rewards were associated with increased dishonesty only when the sense of ownership was reduced, that is, only in the third person perspective condition (*3PP-Wrist).* Although surprising, these results may highlight a possible resemblance between the sense of body ownership and other embodied mechanisms aimed at preserving the moral self-image. As an example, research has shown that when individuals behave immorally or are reminded of past, unethical behaviors, they increase their preference for cleansing products (S. W. S. Lee & Schwarz, 2010; C.-B. Zhong & Liljenquist, 2006). This effect, known as moral cleansing, has been thought of as an attempt to re-establish a threatened concept of self through physical cleanness. Accordingly, allowing participants to use cleansing products appears to reduce their feelings of guilt (West & Zhong, 2015). However, in a recent review, Lee and Schwarz (2021) have proposed a new interpretation of these results, arguing that moral cleansing represents one of the many mechanisms through which people separate the self from stimuli or events, especially negative ones. In this view, it is possible that reductions of the sense of body ownership may serve the same purpose, that is, distancing from negative experiences and therefore reduce their effects over the individual. In support of this hypotheses, reductions of fear (Bourdin et al., 2017; Hofer et al., 2017) and pain sensitivity (Martini et al., 2014) have been observed in association with diminished body ownership. Similarly, motor errors appear to induce lower levels of ownership (Pezzetta et al., 2018). The link we found between diminished body ownership and dishonest behavior may be yet another evidence of this effect. Specifically, one possibility is that the feelings of disembodiment experienced in the *3PP-Wrist* condition may have allowed participants to distance themselves from the virtual body and consequently from the negative attributes associated with it. In other words, because it was not perceived as their own, it may be that behaviors enacted by the virtual body did not feel as a threat to the participants' own moral image, thus favoring dishonest deeds. In line with this, we found that in the *3PP-Wrist* condition, our participants lied more when doing so was associated with the highest reward. Crucially, this behavioral pattern is opposite to that found in the literature, which suggests that individuals act less dishonestly in the presence of high rewards (Cohn et al., 2019; Mazar et al., 2008). In fact, lying for low rewards and refraining from deception when rewards are high, may be interpreted as proof of the moral character of the individual. Indeed, people aim at preserving their image of self, therefore they only indulge in dishonest behaviors when these do not threaten their integrity (Mazar et al., 2008). In light of this, when body ownership is reduced, it becomes easier not to attribute immoral characteristics of the body to the self. This consequently allows for dishonesty, as behaviors that are generally difficult to interpret as proof of moral integrity (i.e., lying in the presence of high rewards) may no longer pose a threat for one's moral image.

On the contrary, the monetary value did not modulate deception during the *1PP-Wrist* and *1PP-No Wrist* conditions, where the number of lies did not differ between low and high rewards. However, we found that the number of deceptive behaviors associated with low rewards was larger in the presence of body discontinuity (*1PP-No Wrist*) than in any other condition. While reduced body ownership may explain our results concerning dishonest behaviors in the *3PP-Wrist* condition, we cannot draw the same conclusion in the case of visual discontinuity between the virtual hands and arms. In fact, this condition was not associated to any reduction (nor increase) of the sense of ownership in comparison to that reported in the control condition (*1PP-Wrist*). However, merely seeing that the virtual hands were detached from the rest of the body may have cued a sense of separation between the virtual effector and the self. In support of this, research shows that physical separation from a written recollection of regrets can reduce negative feelings associated with that regret (Li et al., 2010). Crucially, mental separation may also have similar effects. For example, knowing that state borders divide the self from the location of dangerous events reduces individuals' perception of risk (Mishra & Mishra, 2010). This was observed independently of the actual physical distance from the dangerous event. In light of this, it may be argued that merely seeing that virtual hands are detached from the body suggests a sense of separation from the actions performed with those hands and their attributes (S. W. S. Lee & Schwarz, 2021). Notably, in the *1PP-No Wrist* condition, our participants allowed themselves to perform an higher number violations associated with the smallest monetary reward, again in comparison with the other two experimental conditions. Possibly, this finding is due to the intact feelings of ownership observed in the *1PP-No Wrist* condition. In other words, because the participants felt ownership over the virtual body with disconnected hands, this may have prevented them from engaging in a higher number of more dishonest behaviors (i.e., lying when high rewards were present) than in the other two conditions. However, the visual disconnection may have been sufficient for our participants to distance the self from the negative attributes associated with small violations. Indeed, lying for small rewards poses a lesser threat to a moral view of the self, as these behaviors are more easily framed as manifestations of one's moral character than those involving higher sums of money (Cohn et al., 2019; Mazar et al., 2008).

Crucially we failed to observe an interaction between situation, reward value and experimental condition. Considering this, we cannot draw any definite conclusion regarding the effect of body ownership over egoistic and altruistic lies. However, our findings show that high rewards are associated with i) more lies when participants see their body from a third person perspective, and ii) more self-serving, egoistic lies than altruistic ones. Considering both these results, we speculate that instances of reduced body ownership (as in the case of the *3PP-Wrist* condition) may facilitate lying when higher rewards are involved, and that this may reflect an increase of self-serving behaviors aimed at higher monetary gains. On the other hand, the low reward condition did not predict any difference between egoistic or altruistic lies. In light of this, one possibility is that visual discontinuity between virtual forearms and hands facilitates a general tendency to lie, which may occur regardless of monetary gain or losses. Again, these interpretations are only speculative, as we did not find evidence for the association between the sense of body ownership and either self-serving or other-serving behaviors. Therefore, future research should aim at clarifying this point.

Overall, our study suggests that the sense of ownership over the body can account for modulations of moral behavior. The data presented here support the idea that instances of reduced body ownership may bias towards more dishonest behavior when rewards at stake are high. At the same time, low rewards may favor dishonesty in the presence of mere visual discontinuity. These results indicate that individuals may rely on low feelings of embodiment or on instances of visual separation to distance the self from negative attributes. It follows that because negative attributes are no longer associated to the self, this allows individuals to indulge in dishonesty without having to reconsider their own moral integrity. This evidence is especially significant when considering that an increasing number of human activities occur online, where individuals do not interact through their bodies. Such conditions may facilitate a sense of separation from dishonest behaviors in online contexts. However, this tendency might be lowered if ownership over a virtual, online character is induced. In situations like, for example, multiplayer games, this may be aided by a first-person perspective over the avatars that individuals will use to communicate with others. At the same time, VR interactions may benefit from representing users with *whole* virtual bodies, opposite to the virtual hands employed in most 3D applications.

4 Deceptive behaviors increase the estrangement of unwanted limbs: a study on Body Integrity Dysphoria

4.1 Introduction

The evidence collected in our previous studies suggests that feeling ownership over our specific, unique body may have significant implications for our everyday interactions. However, it is not clear how chronic alterations of the sense of body ownership could impact moral decision-making in social situations.

Such chronic alterations of body ownership are characteristic of one subtype of Body Integrity Dysphoria (BID). The ICD-11 generally defines this condition as an enduring, intense desire to have a physical disability (World Health Organization, 2019a). However, said desire may manifest itself in many forms, like a longing for blindness, deafness, paraplegia or even removal of parts of the male genitalia (First & Fisher, 2012). Here, we will focus on one other possible manifestation of BID, that is, a strong, persistent desire for limb amputation. What makes this specific condition particularly relevant in the context of our studies is the characteristic feeling that one or more limbs do not belong to the individual (First, 2005). Such sense of disownership towards part of the body derives from a sense that the individual's *physical* body "exceeds" the individual's *percept* of the body. The mismatch between the two is what leads to the amputation desire that defines this condition. Crucially, individuals with BID acknowledge that the unwanted limb is part of their body but nonetheless feel that, without its removal, their body is "overcomplete" (First & Fisher, 2012). This fundamental feature hence differentiates BID from psychotic manifestations concerning the body, such as those occurring in somatoparaphrenia, where, following brain damage, patients deny ownership over part of their body (Vallar & Ronchi, 2009). In this sense, BID has more similarities with gender incongruence (World

Health Organization, 2019b) than somatoparaphrenia, as neither BID nor gender incongruence is based on delusional beliefs (First & Fisher, 2012). However, while these conditions share the feeling that the body anatomy does not match subjective experience, feelings respectively regard one’s sexual characteristics or limbs. Finally, BID does not seem to be associated with an altered mental representation of the body, therefore it should not be considered a disorder of the body image. Indeed, individuals with BID symptoms do not show alterations in the visual estimation of their unwanted limb (Stone et al., 2020a). Notably, only a minority of individuals with amputation desires refer comorbid psychopathologies, the most common ones being depressive and anxiety disorders (First, 2005).

Interestingly, BID symptoms have been associated with structural and functional alterations in distinctive areas, which are known for underlying the conscious representation of the affected limb (Hilti et al., 2013; Oddo-Sommerfeld et al., 2018; Saetta et al., 2020). While research efforts have focused on identifying the mechanisms behind BID symptoms, the influence that alterations of the sense of ownership exert over higher-level functions has not yet been clarified. It could be argued that the extent of ownership for the effector limb may differently shape the behavior of individuals with BID. Here we aim at investigating how moral decision-making is modulated when individuals with BID use their wanted or unwanted limb to communicate a truthful or false information.

Information coming from our body is fundamental for the formation of the sense of ownership (Blanke, 2012). Therefore, awareness of bodily signals can make us even more conscious of having a body (Tsakiris et al., 2011). Interestingly, when attention towards bodily signals is experimentally enhanced, individuals’ choices and judgements become more self-interested. This has been investigated, for instance, through Ultimatum Games, where, despite economic losses, receivers tend to refuse offers that they deem unfair

(Nowak et al., 2000). On the contrary, when participants listen to their own heartbeat or experience painful stimulation, they not only offer less to others, but even accept more unfair offers from them (Lenggenhager et al., 2013; Mancini et al., 2011). In addition to this, the intensity of other bodily signals, like hunger, is associated to less severe moral judgements (Vicario et al., 2018). Possibly, relaxed moral standards serve as a way for individuals to justify their own immoral behaviors, which in fact appear to be increased under the same conditions (E. F. Williams et al., 2016). This evidence suggest that an enhanced sense of the body may bias towards more dishonest choices when this is convenient for the self. Crucially, this effect may be mediated by the value attributed to available stimuli, the rewarding value of which is highly dependent on the homeostatic condition of the body (Paulus, 2007a, 2007b). In this sense, increased body ownership may enhance the desirability of available rewards, which consequently boost reward-oriented behaviors, and possibly even deceptive ones. Results of our first study (presented in Chapter 2) seem to only partially support this hypothesis. Our data show that body ownership increases dishonesty when this entails a monetary payoff for the individual. However this was only observed in participants with low sensitivity to rewards.

However, results of our second study (Chapter 3) suggest a different pattern. Specifically, we observed that high rewards increased dishonesty, but only when the sense of body ownership was *reduced*. Considering this, we argue that modulations of body ownership may serve the purpose of distancing the self from negative attributes, such as dishonesty. By achieving physical separation from negatively connotated stimuli or situations (for example, by putting a written recollection of negative events within an envelope), individuals manage to reduce the effects these may have over the concept of self (Li et al., 2010). In light of this, we argue that modulations of the sense of body ownership may serve similar purposes. In other words, enhanced body ownership may facilitate the association between attributes of the physical body and the moral self, while disembodiment could hinder this association (Scattolin et al., 2021). It derives from this that, if a body is not perceived as belonging to the self, its negative attributes (like dishonesty) are less likely to affect one’s moral identity, which is then preserved.

To understand which impact chronic reductions of body ownership may have over morality, we asked participants with BID and participants that have an intact sense of body ownership to complete a modified version of the Temptation to Lie Card Game (TLCG) (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016; Schepisi et al., 2020). During each trial of the TLCG, participants could freely decide whether to lie or communicate the truth to the other participants, knowing that their choices would also impact another person’s payment. Specifically, we asked participants to provide their responses using their legs, by means of a foot-switch. This choice was made in light of the fact that, in the majority of cases, the amputation desire of participants with BID regards the lower limb (First, 2005). Crucially, we only selected individuals whose amputation desire concerned only one of the two legs. Unbeknownst to the participants, in the present study we biased TLCG outcomes towards unfairness. Specifically, in the Unfair TLCG (U-TLCG), participants always won small monetary sums, while the other players always won high monetary rewards. This was motivated by the age of individuals with BID, which we expected to be greater than that of participants tested in past TLCG experiments. Indeed, the mean age reported in studies using the TLCG ranged from 23.1, to 26.7 years (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016; Schepisi et al., 2020), against studies with participants with BID symptoms, whose mean age ranged from 43.1 to 49.6 years (Aoyama et al., 2012; First, 2005; Hilti et al., 2013; Lenggenhager et al., 2015; Oddo-Sommerfeld et al., 2018; Saetta et al., 2020; Stone et al., 2019, 2020a, 2020b). Also, the majority of participants who took part to previous TLCG studies was composed of students, who, being mostly unemployed, may be tempted to lie even in the presence of small monetary rewards. On the contrary, we expected the greater part of participants with BID to be employed and to show reduced sensitivity to rewards in comparison with younger adults (Eppinger et al., 2012, 2013). The present version of the TLCG, that is, the U-TLCG, was therefore aimed at making the task more tempting and engaging for older participants, considering that higher rewards can increase cheating behaviors (Gerlach et al., 2019).

4.2 Methods

4.2.1 Participants

Considering the rarity of BID and the secrecy that often comes with this condition (First, 2005), we set out to recruit 20 volunteers who wished for the amputation of one of their lower limbs. As a consequence, an equal number of individuals without this desire have been included in our control group. A total of 40 participants have taken part in this study. Data collection was carried out from January 2020 to January 2021 at the University of Zurich (CH), in collaboration with the *Body, Self and Plasticity* laboratory, directed by Professor Bigna Lenggenhager. This sample of participants is composed of 20 volunteers with Body Integrity Dysphoria (BID) (females = 5, mean age = 46.55, standard deviation or SD = 12.13), 11 of whom desired amputation of the left leg; for the remaining 9 participants, this desire concerned the right leg. In line with other studies (First, 2005), the desire for amputation first emerged in childhood and early adolescence (between the ages of 6 and 12). None of the participants in this group underwent amputation prior to the study. Amputation desire of participants in the BID group was assessed using an adapted version of the Zurich Xenomelia Scale (ZXS) (Aoyama et al., 2012). In this version, participants' agreement with each of the 12 items of the questionnaire was to be rated along a Visual Analogue Scale (VAS). The VAS scale ranged from "clearly does not apply" (scored as 0) to "clearly applies" (scored as 100). Participants in the BID group showed a mean score of 84.99 (SD = 13.72) out of 100 in the Pure Amputation Desire subscale of the ZXS. None of these participants reported being diagnosed with a neurological disorder. However, two volunteers (10%) in the BID group referred an history of psychiatric disorders and one of them (5% of the BID sample) was taking antidepressant medication at the time of testing. When they took part in this study, seven other participants (35% of the BID group) were using medications for the treatment of non-psychiatric conditions. The control group (CG) is composed of 20 participants (females = 7, mean age = 45.40, SD = 11.07) who had not undergone nor desired lower limb amputation. One male participant in this group did not complete the U-TLCG, therefore his data have not been included in the analysis regarding the task. One of the participants (5%) in the final CG sample reported a diagnosis of psychiatric disorder and being undergoing drug treatment when tested for this study. Six other volunteers were following different types of medical treatment at the time of participation. A more detailed anamnesis of participants in each group can be found in Supplementary Table 6 (Appendix C, Chapter 10).

All participants provided written informed consent to participation in the study and granted permission to use of their data. At the end of the experimental session and after reading a written debriefing form, all participants confirmed authorization to use of the data collected during the study.

4.2.2 Materials

The participants completed all parts of this study while sitting on a chair in front of a table. We used the online version of PsyToolkit (Stoet, 2017) to program and administer all questionnaires included in the study. All parts of the U-TLCG were programmed and presented to the participants by means of E-Prime 2.0 (Psychology Software Tool, PA). The participants completed all questionnaires and the U-TLCG using a 15-inch laptop positioned at a distance of approximately 60 cm from their eyes. During the U-TLCG, the participants provided their responses via two foot-switches, one for each foot (MagiDeal SZADKJ0002).

4.2.3 Unfair Temptation to Lie Card Game (U-TLCG)

The classic Temptation to Lie Card Game (TLCG) (Azevedo et al., 2017; Panasiti et al., 2011, 2014, 2016; Schepisi et al., 2020) was adapted to the purposes of this study. To investigate whether the degree of ownership associated with each leg could predict the tendency to lie or refrain from lying when this entailed using that leg, we asked participants to provide their preferred responses by means of foot pedals. However, and in order to prevent participants in the BID group from guessing our hypothesis, we introduced a simple Reaction Time task (RT task) and a cover story. All participants were told that the aim of the study was that of investigating to what extent social interactions could distract people from other activities. Thus, participants were persuaded that the main task was the RT task. More specifically, participants were informed that the screen in front of them would display cards depicting different amounts of money (that is, one banknote, three banknotes or no banknote) but that, in each trial, only two cards would be shown. In part of the trials (12 out of 44), the two cards on the screen would be identical. Whenever this happened, participants had to be as quick as possible and press the letter *b* on the keyboard, using their dominant index finger. In the remaining trials, cards differed from one another and participants had to follow different instructions. We told participants that trials where cards differed were part of a game that they would complete with another player. The game involved two roles and while the other player had to select one of two covered cards, participants were asked to communicate the outcome of the other player's picks (that is, whether the other person had won or lost). Crucially, and unbeknownst to participants, the other person's choice was generated by a computer. To cover for the other person's absence, participants were told that the other player had been tested in previous days, when s/he had been assigned the role of picker. To fill this role, the other person had been instructed to pick one out of two covered cards: one of the two cards was always empty, while the other always displayed money. Money could be represented as one banknote or as three banknotes. However, we told participants that the picker was not given the possibility of seeing which cards s/he picked, but rather his/her choices had been recorded and were shown to participants themselves. In this version of the TLCG, participants saw one card enlarge on the screen. This was the card that the other player drew. When the selected card showed either one or three banknotes, it indicated that the other player had picked the winning card and thus the participant had lost (*Unfavorable situation* for the participant). Else, if the white card enlarged, it meant that the other player had picked the losing card, and therefore the participant had won (*Favorable situation*). Because the picker is informed of the outcome by participants, they had the opportunity to lie to change the game outcome. In fact, both the participants and the other player would be paid according to the communicated outcome and not on the basis of the actual pick. To communicate the outcome of their choice, participants were instructed to press a foot pedal to select the card they wanted to show to the picker. Pressing the right pedal indicated that participants wanted to show the card displayed on the right-side of the screen, pressing the left pedal indicated that the left-side card should be shown to the other player. The card representing money was presented on the right of the screen on 50% of trials, while it was displayed on the left side on the remaining 50%. Also, participants could choose their response among four possibilities: an *altruistic truth* (the other person won and participants told the truth), an *egoistic truth* (the other person lost and participants told the truth), an *egoistic lie* (the other person won and participants lied), or an *altruistic lie* (the other person lost and participants lied). To make the TLCG task more tempting for older participants, *unfavorable* trials were consistently associated with *high rewards* (*Highly unfavorable* condition) while *favorable* trials always entailed a *low reward* win (*Slightly favorable* condition). This manipulation put participants at a disadvantage: if they were to always tell the truth, their final gains would be lower than those of the other player. Crucially, participants were never made aware of this unfair manipulation.

For a schematic representation of the task, see Figure 12.

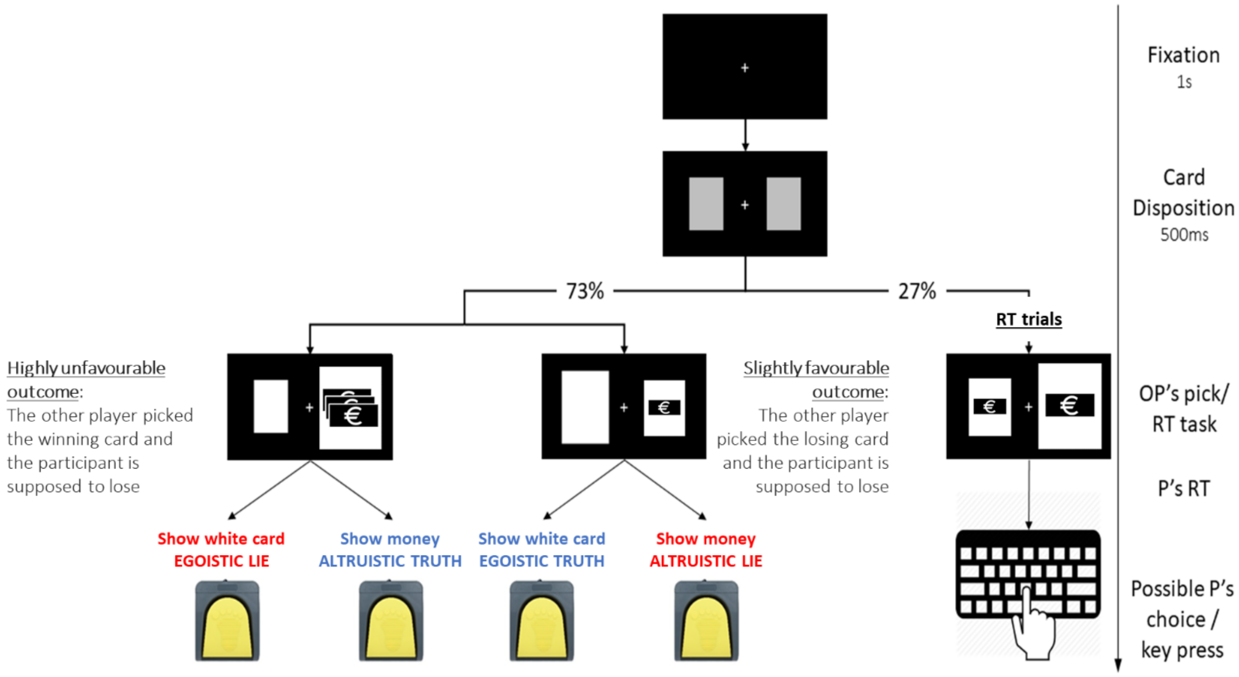


Figure 12. Schematic representation of the unfair version of the Temptation to Lie Card Game (U-TLCG) and the Reaction Time task (RT task). A timeline of each trial is presented on the rightmost part of the figure. On 73% of trials, participants (P) are playing the U-TLCG. This is indicated by the fact that the cards on the screen represent different amounts of money (i.e., one is empty, the other shows one or more banknotes). The other player (OP) had to pick one of the two covered cards. The card that enlarges on the screen represents the OP's pick. When the OP picked the card representing the money, this indicates that OP won and P lost. This was always associated with the three banknotes card and therefore to a higher reward (*Highly unfavorable situation*). When the OP picks the empty card, this indicates that OP lost and P won. These trials were always associated with the one banknotes card and therefore to a lower reward (*Slightly unfavorable situation*). The P can now decide what to communicate to the OP, by either showing a white piece of paper or a virtual banknote. Both of these appeared on the left (right) side of the screen on half of the trials. By showing the white card, the Ps are communicating that the OP lost (and they won). To communicate that the OP won (and they lost), the Ps can show the banknote(s) card. To communicate their decision, Ps were asked to press one of two foot pedals, the one on the same side of the card they wanted to show to the OP.

ON 27% of trials, the cards on the screen showed the same amount of money. When this happened, Ps had to press the letter *b* on the keyboard with their dominant index finger.

4.2.4 Ownership and agency ratings

To ascertain that participants in the two groups experienced different levels of ownership towards their legs, they all rated the feelings of ownership associated with each limb. Specifically, participants were asked to use a Visual Analogue Scale (VAS) to rate all combinations of the following statement: “How strong is the sensation that your left/right arm/leg is part of your body?”. The VAS scale ranged from 0 (labelled as “not part of my body”) to 100 (labelled as “fully part of my body”). To investigate whether behavior to the U-TLCG could influence participants’ sense of ownership over their lower limbs, the same statements were rated after completion of the task.

To control for the possible role of the sense of agency, similar ratings were obtained for feelings of control over each limb. In this case, statements were phrased as follows: “How strong is the sensation that the movements of your left/right arm/leg are controlled by you?”. VAS scales measuring agency ranged from 0 (“not controlled by me”) to 100 (“fully controlled by me”). Agency ratings were collected at the beginning of the study and then after the U-TLCG, together with ownership ratings.

The order of statements assessing ownership and agency was randomized in both presentations.

To understand whether behavior in the U-TLCG could predict changes in the feelings of ownership and agency towards each leg, we calculated how much the ratings changed from one assessment to the following one. Specifically, we subtracted participants’ ownership or agency ratings *before* the U-TLCG from the corresponding ratings *after* the U-TLCG. This was computed separately for each leg. Positive values indicated an increase of the sense of ownership or agency for a specific leg. Negative values indicated that feelings of leg ownership or agency decreased following the U-TLCG.

4.2.5 Procedure

Participants were met at the entrance of the building and accompanied to the room where this and other experiments took place. In fact, the present study is part of a larger project with the overarching goal of investigating different aspects of bodily self-consciousness by comparing data from individuals with and without BID desires. Therefore, participants received written information regarding all experiments that they would take part into. All participants signed the informed consent, confirming their willingness to take part in all studies and providing permission to use their data.

Participants began the testing session by completing a first set of questionnaires. In addition to general, demographic information (i.e. sex, age in years, highest education degree received), participants were asked to report possible neurologic and psychiatric conditions and whether they were under medication treatment at the time of testing. Methods described in Adler et al. (2000) and Ostrove et al. (2000) were adapted to collect a measure of participants' subjective economic status (SES). Specifically, participants were shown an horizontal VAS scale going from 0 (labelled as "People who have the least money") to 100 (labelled as "People who have the most money") and were asked to position themselves along this continuum.

While demographic questions were followed by ownership and agency ratings for the CG, participants in the BID group filled the Zurich Xenomelia Scale (ZXS) (Aoyama et al., 2012) before rating their feelings of ownership and agency for each limb. Following this, all participants were asked to complete the Handedness and Footedness subscales of the Lateral Preference Inventory (LPI) (Büsch et al., 2009; Coren, 1993). The Footedness subscale (e.g. "With which foot would you kick a ball to hit a target?") was included in order to control for the effect of foot preference, especially in control participants. However, the purpose of items assessing handedness (e.g. "With which hand do you draw?") was that of supporting the cover story used in the U-TLCG. In line with this, the experimenter checked participants' handedness subscale scores before the U-TLCG. Scores below 0 indicated a preference for the left hand, while scores above 0 suggested a preference for the right one. Based on this score, participants were instructed to use either the left or right index finger throughout the U-TLCG.

After completing this first set of questionnaires and before the U-TLCG, participants in the BID group completed one of the other studies included in this project. Then, all participants sat in front of a computer. Participants were instructed to place one foot over each pedal and their dominant index finger over the letter *b* of the keyboard. This position was to be maintained for the entire duration of the experiment. Instructions of the U-TLCG were then displayed on the screen and read out by the experimenter. Instructions were followed by 23 practice trials, during which proper understanding of the task instructions was ensured. Upon completion of the U-TLCG, participants filled the Manipulation Check questionnaire (the same employed in our second study, see paragraph 3.2.1) and again rated their feelings of ownership and agency towards each limb.

At the end of the entire testing session, a written debriefing form was provided, which informed participants that they had played the U-TLCG against the computer and revealed the real purposes of this experiment. Permission to use the data collected during the study was confirmed in writing by all participants.

4.3 Results

4.3.1 Embodiment ratings at baseline

Ownership ratings. To ensure that the two groups of participants differed in terms of feelings of ownership associated their lower limbs, baseline ownership ratings were analyzed. Ratings were the predicted variable in a linear mixed effect model, while group

(CG coded as 0, BID coded as 1), leg condition and their interaction term were the fixed predictors. Leg condition was a binary variable and was coded as 0 to indicate the unwanted leg of participants in the BID group or the non-dominant leg for those in the CG. Oppositely, the wanted or dominant leg was coded as 1 for participants in the BID and CG groups, respectively. Participants' identification number (ID) was included in the model as random intercept.

Results show that factors group ($\chi 2$ (degrees of freedom or df = 1) = 126.07, p < .001) and the interaction between group and limb condition ($\chi 2$ (df = 1) = 76.83, p < .001) are significant predictors of the feeling of ownership towards lower limbs (Figure 13). Post-hoc comparison showed that the dominant and non-dominant leg of control participants did not differ in terms of ownership ratings (estimate = -0.42, 95% Confidence Intervals or CI [-13.50, 12.70], SE = 4.73, t.ratio = -0.09, *p* = .929). A significant difference was observed for participants in the BID group, where the unwanted leg had lower ownership ratings compared to the wanted leg (estimate = -58.10, 95% CI [-70.90, -45.30], Standard Error or SE = 4.61, t.ratio = -12.62, *p* < .001). Ownership ratings were significantly lower for the unwanted limb of participants in the BID group compared to those associated with the non-dominant leg of the CG (estimate = 59.27, 95% CI [44.90, 73.60], SE = 5.29, t.ratio = 11.212, *p* < .001). Control participants' ownership ratings concerning their dominant leg did not differ from those associated to the wanted leg of participants in the BID group (estimate = 1.59, 95% CI [-12.2, 15.4], SE = 5.07, t.ratio = 0.31, *p* = .929).

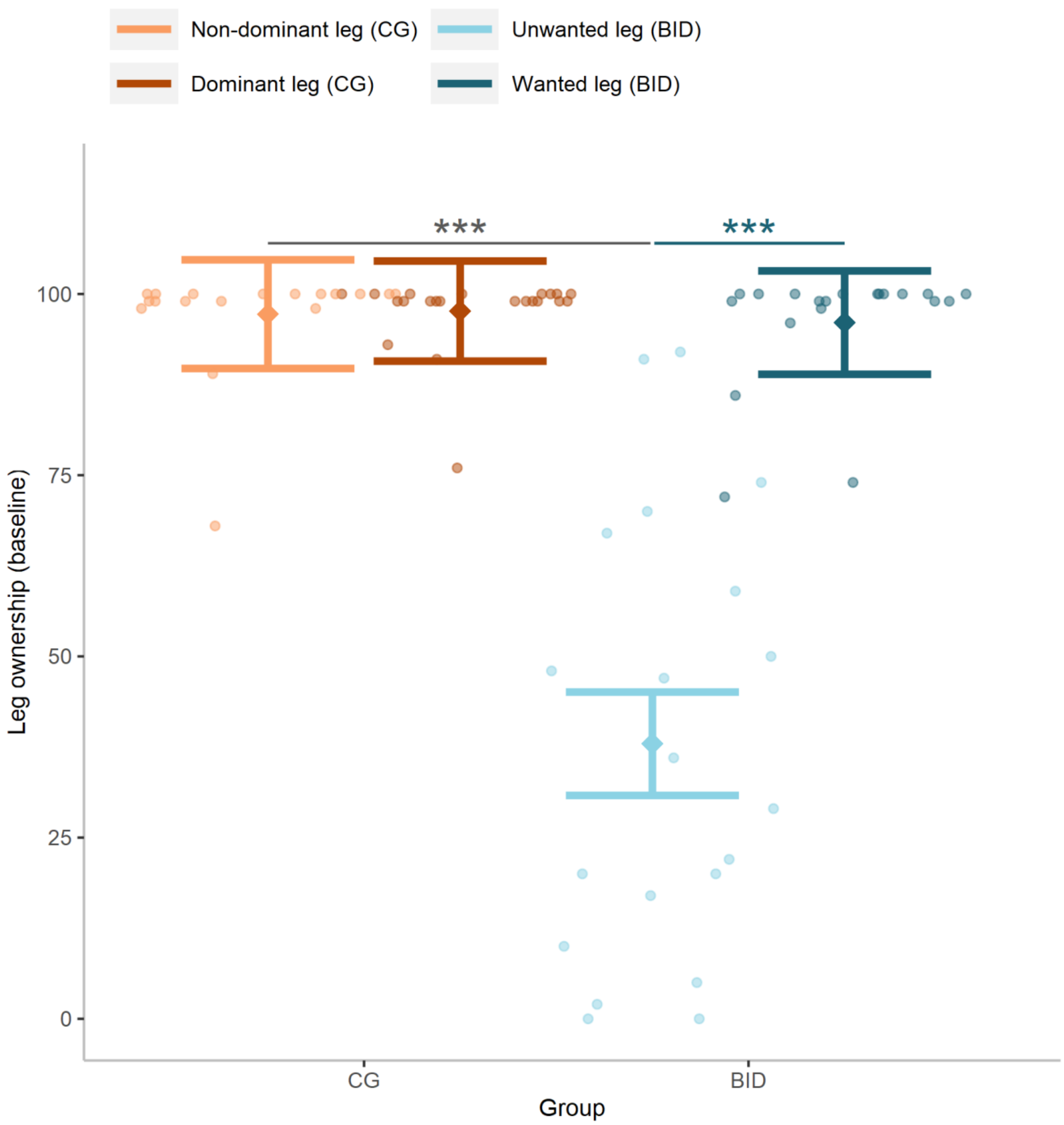


Figure 13. Ownership ratings at baseline as a function of group and leg condition. The upper limits of bar plots represent the upper confidence interval (CI), the lower limit represents the lower CI. Diamonds indicate the model estimate. Points represent each participant's ownership rating. Asterisks indicate significance (****p* <.001)

Agency ratings. Agency ratings were set as the dependent variable in a linear mixed effect model. We computed this with the aim of controlling for possible baseline differences in agency associated to the lower limbs. Participants' IDs were included in the model as random intercept factor, while we entered group (CG as 0, BID group as 1), limb condition (the non-dominant or unwanted leg coded as 0, the dominant or wanted leg coded as 1) and the interaction between group and limb condition as fixed predictors.

Factors group ($\chi 2$ (df = 1) = 13.05, $p < .001$) and the group × limb condition interaction term ($\chi 2$ (df = 1) = 10.39, $p = .001$) were significant predictors of agency ratings. Ratings of participants in the CG did not differ between the non-dominant and the dominant leg (estimate = -0.85, 95% CI [-15.46, 13.77], SE = 5.28, t.ratio = -0.16, $p = .873$; Figure 14). Agency ratings were significantly higher for the wanted compared to the unwanted limb of participants in the BID group (estimate = -24.50, 95% CI [-38.77, -10.23], SE = 5.13, t.ratio = -4.78, $p < .001$; Figure 14).

Agency ratings for the unwanted limb of participants with BID were lower than those associated with the non-dominant leg of control participants (estimate = 22.06, 95% CI [5.47, 38.65], SE = 6.12, t.ratio = 3.61, $p = .001$; Figure 14). Agency ratings for the wanted leg of participants in the BID group were not different from those observed for the dominant leg of control participants (estimate = -1.59, 95% CI [-17.57, 14.39], SE = 5.88, t.ratio = -0.27, $p = .873$; Figure 14).

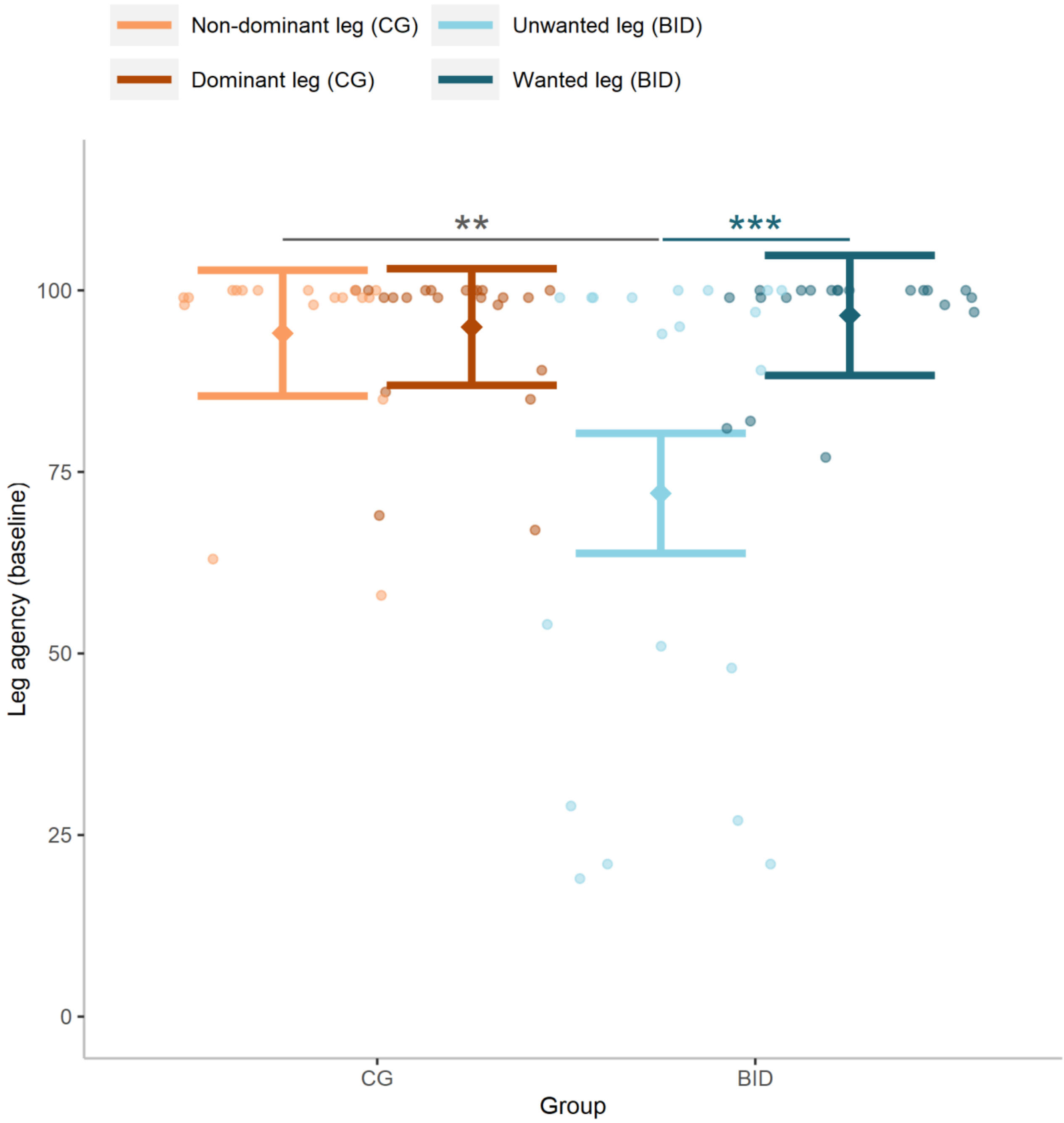


Figure 14. Agency ratings at baseline as a function of group and leg condition. The upper limits of bar plots represent the upper confidence interval (CI), the lower limit represents the lower CI. Diamonds indicate the model estimate. Points represent each participant's agency rating. Asterisks indicate significance (***p <.001)

4.3.2 Behavior in the U-TLCG task

The participants' mean percentage of lies during the U-TLCG was of 34.78% (SD = 20.28%). The percentage of self-gain lies was 58.01% of highly unfavorable trials (SD = 37.55%). Other-gain lies constituted 11.54% of slightly favorable trials (SD = 17.59%).

Participants' (dis)honest behavior during the U-TLCG task was analyzed by means of a generalized linear mixed model. Factor situation (*Highly unfavorable* coded as 0, *Slightly favorable* coded as 1) was included as random slope, while participants' IDs were entered as random intercept factor. To investigate whether the condition of the limb used to communicate the outcome could predict participants' choices, leg condition (0 for non-dominant and unwanted leg, 1 for dominant or wanted leg) was set as fixed factor together with situation (*highly unfavorable* as 0, *slightly favorable* as 1), group (CG coded as 0, BID coded as 1) and all their interactions. To control for differences in the feelings of agency associated with each limb and for how engaging the task felt to participants, baseline ratings of agency and involvement in the U-TLCG were included as covariates.
Situation significantly predicted behavior in the task ($\chi 2$ (df = 1) = 8.74, p = .003) and post-hoc comparisons revealed that participants lied more in highly unfavorable trials compared to slightly favorable ones (estimate = 4.40, 95% CI [2.99, 5.80], SE = 0.72, z.ratio = 6.14, *p* < .001).

4.3.3 Change in ownership – effect of egoistic lies

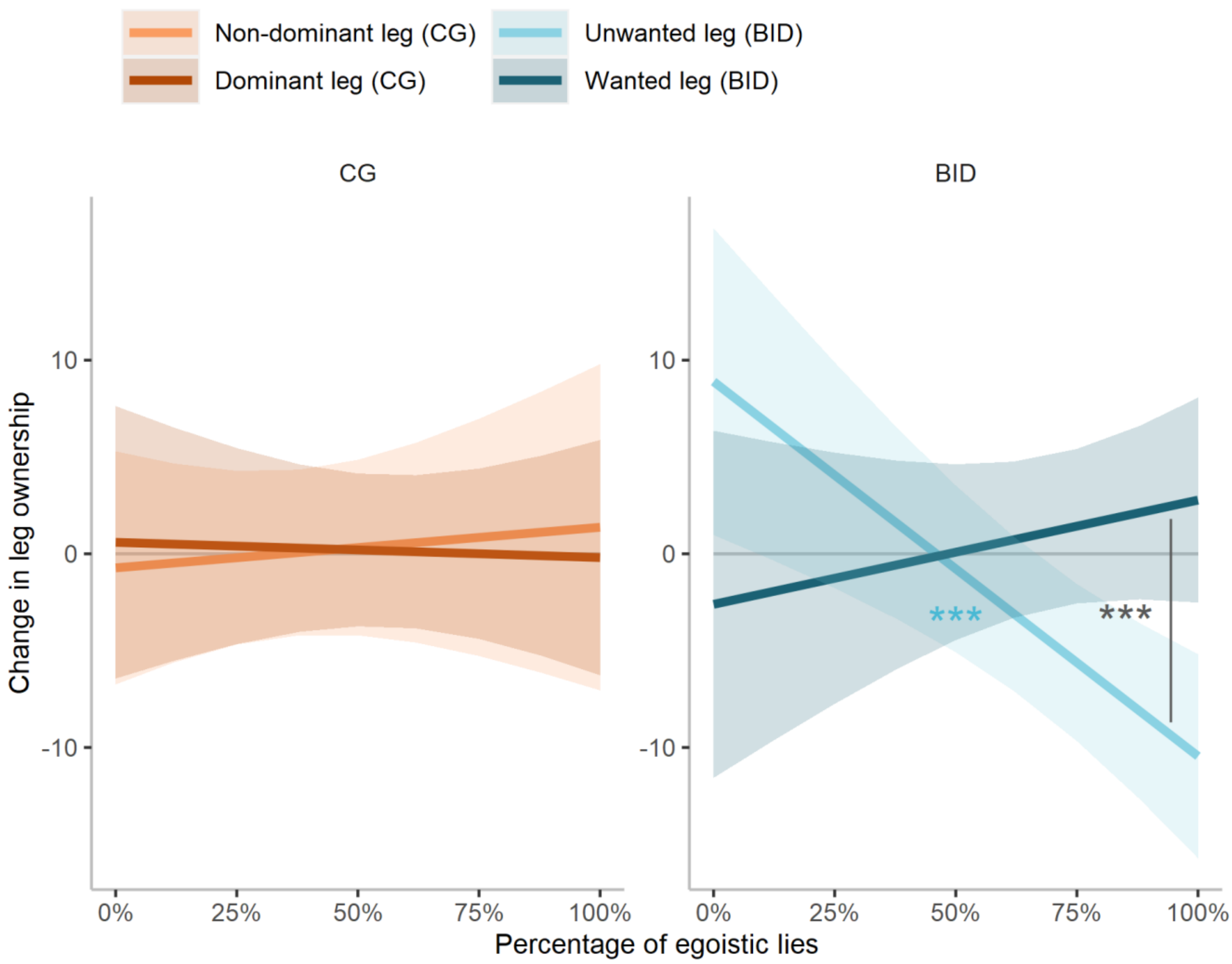
To investigate whether the sense of ownership associated to each leg could change depending on the percentage of egoistic lies communicated with that specific leg, we ran a linear mixed effect regression model. In this model, the difference between ownership ratings before and after the U-TLCG was included as dependent variable, while we set participants' ID as random intercept. We included group (CG as 0 and BID as 1), leg condition (non-dominant leg of the participants in the CG group or unwanted leg of the participants in the BID group were coded as 0, the dominant or wanted leg as 1) and the percentage of egoistic lies communicated by the participants as fixed predictors. We set the change in agency ratings for each leg and the participants' involvement in the task as covariates.

Our participants' involvement during the U-TLCG significantly predicted a change in leg ownership over time ($\chi 2$ (df = 1) = 4.41, p = .036). The interaction between group and leg condition ($\chi 2$ (df = 1) = 7.38, p = .007) and between group, leg condition and percentage of egoistic lies ($\chi 2$ (df = 1) = 6.95, p = .008) were also significant. Post-hoc comparisons on the 3-way interaction revealed that, as the percentage of egoistic lies increased, ownership ratings associated with the unwanted leg of participants in the BID group decreased more after the U-TLCG (estimate = -19.34, 95% CI [-29.68, -9.01], SE = 5.27, t.value = -3.67, p < .001; Figure 15). However, the percentage of egoistic lies was not associated to a significant increase nor decrease of the sense of ownership for their wanted leg, after the U-TLCG (estimate = 5.38, 95% CI [-6.20, 16.96], SE = 5.91, t.value = 0.91, p = .362; Figure 15). At high percentages of egoistic lies, ownership ratings for the unwanted leg of the BID participants decreased more than those associated to their wanted leg (estimate = 12.46, 95% CI [5.85, 19.07], t.value = 3.69, p < .001, Figure 15).

4.3.4 Change in ownership – effect of altruistic lies

To clarify whether the percentage of altruistic lies could predict a change of the sense of ownership, we computed a linear mixed effect regression model including group (0 for participants in the CG and 1 for those in BID group), limb condition (coded as 0 for the non-dominant and unwanted leg of participants in the CG and BID groups, respectively, and as 1 for the dominant and wanted leg) and percentage of altruistic lies as fixed predictors. The change in ownership ratings was the predicted variable, while we included the change in agency over time and rating of involvement in the U-TLCG as fixed covariates. Participants' IDs were the random intercept.

Results of this analysis showed that none of the fixed factors could significantly predict a change in ownership ratings (Figure 16).



ratings for participants in the control group (CG), while ratings of participants in the Body Integrity Dysphoria (BID) group are displayed in the rightmost panel. The plot shows regression lines for each leg. The horizontal line at 0 indicates the absence of difference between the two assessments. Values above the horizontal line indicate that ownership ratings are higher following the Unfair Temptation to Lied Card Game (U-TLCG). Values below the horizontal line indicate that ownership ratings were lower following the U-TLCG. The shaded bands represent 95% confidence intervals. Asterisks indicate significance (*** $p < .001$).

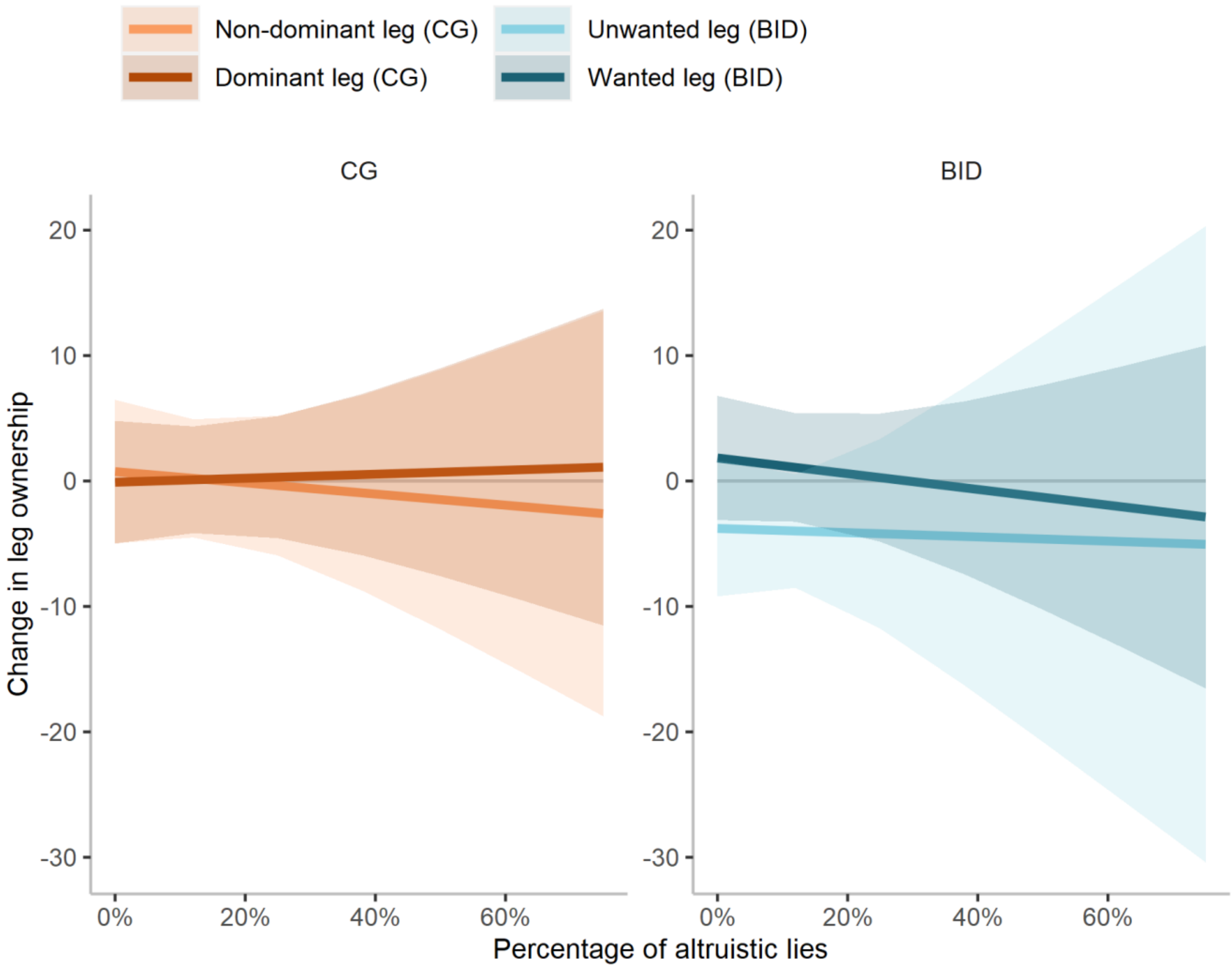


Figure 16. Change in leg ownership as a function of group, leg condition and the percentage of altruistic lies. The leftmost panel represents the change of ownership ratings for participants in the control group (CG), while ratings of participants in the Body Integrity Dysphoria (BID) group are displayed in the rightmost panel. The plot shows regression lines for each leg. The horizontal line at 0 indicates the absence of difference between the two assessments. Values above the horizontal line indicate that ownership ratings are higher following the Unfair Temptation to Lied Card Game (U-TLCG). Values below the horizontal line indicate that ownership ratings were lower following the U-TLCG. The shaded bands represent 95% confidence intervals.

4.3.5 Change in agency – effect of egoistic and altruistic lies

To investigate whether the percentage of egoistic or altruistic lies in the U-TLCG could predict a change in the sense of agency associated with each leg, we computed two separate linear mixed effect models. These included agency ratings as dependent variable, while we set group (0 for participants in the CG and 1 for participants in the BID group), percentage of egoistic or altruistic lies (one in each model) and limb condition (0 for the non-dominant and unwanted leg and 1 for the dominant or wanted leg) as fixed predictors. The model included the change in ownership for each limb and participants' involvement in the task as fixed covariates. Participants' IDs were used as random intercept.

Results suggest that none of the predictors was significantly associated with a change in agency ratings.

4.4 Discussion

With the present study we aimed at investigating whether chronic reductions of the sense of ownership could impact moral decisions. We did so by comparing the behavior of two groups of participants. One group included individuals that report the feeling of disownership of one leg and the intense desire for its amputation (BID group). The second group was composed of participants whose sense of ownership towards both legs was intact and who did not wish to undergo amputation of either one of the lower limbs (CG group). Both groups completed the unfair version of the TLCG (U-TLCG) in which they were tempted to lie for high rewards. To clarify whether limb (dis)ownership can bias individuals’ choices towards more or less self-serving behaviors, we asked participants in both groups to communicate their decisions using their lower limbs.

Our findings show that participants’ dishonest behavior significantly increased when they found themselves in an highly unfavorable situation, that is, when lying meant obtaining the money associated to that trial. These results mirror those found in the original version of the TLCG (Panasiti et al., 2011), as well as results of the study reported in Chapter 3 of this dissertation. Notably, unfavorable conditions were always associated with high rewards, therefore adding to the notion that opportunities for higher payoffs favor dishonesty (Gerlach et al., 2019). However, we did not find evidence supporting either of the two hypotheses concerning limb (dis)ownership and its possible impacts over reward-related decisions. Indeed, lies were not predicted by the limb that the participants used to communicate their decisions. Also, participants’ choices did not differ between the two experimental groups. Contrary to our expectations, these results suggest that long-term reductions of the sense of ownership do not modulate moral behavior. While, to the best of our knowledge, no investigation has been conducted on the relation between BID symptoms and the decision-making process, research focusing on other higher-level functions share similarities with our results. Two studies, one of them assessing mental rotation abilities and the other focusing on visual estimation, found no difference between the performance of individuals with BID and that of controls (Stone et al., 2019, 2020a). In addition, a recent study showed that the peripersonal space surrounding the limbs of individuals who desire an amputation, is not different from that of control participants (Stone et al., 2020b). Crucially, peripersonal space plays a relevant role during the selection of alternative motor actions (Bufacchi & Iannetti, 2018). Therefore, it could be argued that a similarly characterized peripersonal space around owned and disowned limbs may indicate similar action selection processes. In a sense, our results and those of

Stone and colleagues (Stone et al., 2020b) suggest that, even if a limb is disowned, the actions to be performed with it are not selected on the basis of ownership feelings.

Interestingly, while our data suggest that limb ownership does not predict behavior in the U-TLCG, the opposite may be true, that is, behavior during the task may modulate feelings of limb ownership. Notably, after completing the U-TLCG, participants in the BID group show a significant reduction of the sense of ownership for the unwanted limb. This reduction related to the number of egoistic lies the participants had communicated with that limb. Specifically, we found that the higher the percentage of lies for personal gain, the more the sense of ownership towards the unwanted leg decreased. It may be argued that further reductions of the sense of limb ownership represent an effort to separate from a negative event. In fact, individuals aim at maintaining a positive concept of self, even in the face of their own moral violations (Mazar et al., 2008). Therefore, to balance a moral self-concept with their own immoral deeds, individuals can use a variety of mechanisms, such as cleansing behaviors (C.B. Zhong & Liljenquist, 2006). It has been argued that moral cleansing and other embodied procedures may achieve this by eliciting a sense of physical or mental separation between the self and negative attributes (S. W. S. Lee & Schwarz, 2021). In a sense, BID symptoms may be an example of this, considering the negative feelings often reported in association with the disowned limb. It is possible that when the disowned limb is used to communicate an egoistic lie, this negative feature, i.e. dishonesty, is added to the ones already present (e.g., not matching the body image, over-completeness, being in the wrong body because of the leg) (First, 2005) and can sharpen the desire to distance oneself from the leg. These results somewhat resemble those of our previous study (see Chapter 3), which also highlighted an association between dishonesty and reduced body ownership. It may be argued that, if body ownership serves the purpose of disconnecting the self from negative features, it may also be employed to achieve connection with positive attributes. In the case of this study, we could expect that altruistic lies predict an increase of the sense of limb ownership. However, we found that lies benefitting other players did not modulate the sense of ownership for the unwanted leg. We believe that this could be due to the double-faced nature of this type of lies, which, although associated with more positive attributes, like altruism, remain deontologically immoral.

Unlike what we observed for the disowned limb, the sense of ownership towards the wanted leg was not affected by how often participants in the BID group had lied for egoistic purposes. Indeed, the percentage of lies that they communicated with the wanted leg was not associated with a change of ownership for that same leg after our task. This result may be due to a more malleable sense of ownership for the unwanted limb (Lenggenhager et al., 2015). In fact, individuals with BID experience limb ownership illusions more vividly than controls, and this was found to correlate with the strength of their desire for amputation. Therefore, it is possible that a highly malleable sense of limb ownership allows individuals with BID to more easily distance from negative attributes of their body or parts thereof, and thus protect their self-image. In line with this, the participants in our CG group, also did not show significant changes concerning the sense of ownership for each leg, nor were these observed following dishonest behaviors.

This evidence may be relevant for interpreting another result. We observed that, following a high percentage of egoistic lies, the sense of ownership changed differently for the wanted and unwanted leg. Specifically, the decrease of leg ownership was larger for the disowned leg compared to the owned leg, after engaging in a high number of egoistic behaviors. Of course, this result can also be observed from an opposite perspective, that is, the same difference could be interpreted as a lack of ownership decrease for the wanted leg. In other words, using the wanted leg for high numbers of selfish behaviors may prevent the reduction of ownership associated with it. However, considering that i) limb ownership is more malleable for the unwanted (vs wanted) leg (Lenggenhager et al., 2015), and that ii) an increase of egoistic lies during the U-TLCG was associated with enhanced disownership towards the unwanted leg, but not the wanted leg (Figure 15), we argue that the difference observed at higher percentages of selfish behaviors reflect a modulation of ownership for the unwanted leg.

Surprisingly, the participants in our BID group displayed significantly lower levels of agency for the unwanted limb compared to the wanted one. To our knowledge, similar reductions of the sense of agency have not been previously reported. Instead, BID symptoms have so far been considered as purely ownership-related. Considering this, it might be argued that results presented here may reflect changes in the sense of control associated with the unwanted limb. However, agency does not appear to be a significant predictor of behavior to the task. Similarly, the percentage of lies communicated with each limb was not associated to changes of the sense of agency. While our data allow us to (relatively) safely conclude that agency does not seem to be a better predictor of our participant’s behavior, we are aware that this facet of BID symptomatology should be more closely looked into in future studies and be accounted for in future research.

Crucially one limitation of the present study is that, by always associating high and low rewards with the unfavorable and favorable situation, respectively, we cannot make any inference regarding the modulating role of rewards. Our choice was motivated by the age of our sample, however, this aspect requires to be investigated further in future studies. For example, we may hypothesize that participants in the BID group may want to distance themselves more from lies associated with high rather than low payoffs for the self.

Our results provide additional proof for the role of body ownership as a tool for disconnection from negative deeds. More specifically, this evidence shows that reductions of the sense of ownership may occur *after* dishonest behaviors, as an alternative way to separate the self from immorality. Such results offer relevant insights into possible, novel ways of coping with the strong amputation desire of BID. If reductions of limb ownership follow immoral behaviors, enhanced embodiment may be observed after positively connotated actions. We argue that future studies on BID should aim at clarifying this hypothesized association and its temporal duration. If such an association is in fact in place, individuals with BID might benefit from the use of footswitches during online communications, especially when these are perceived as positive. Similarly, collaborative games may have analogous benefits, if these can be played using foot keys. However, we want to stress that these should be regarded as strategies that each individual independently chooses to employ if alleviating the negative feelings associated with a disowned and unwanted leg becomes desirable.

5 General discussion

With the series of studies presented here, we aimed at clarifying whether and how the sense of body ownership can bias the decision-making process towards honesty or dishonesty. We investigated this via a large-scale correlational study (Chapter 2), by using VR technologies to experimentally manipulate the feelings of ownership associated to a virtual body (Chapter 3) and by testing a clinical population who experience long-term reductions of the sense of ownership towards part of their body (Chapter 4). Our results show that feelings of ownership for the body and for parts of it do impact moral decision-making, although in a more complex way than predicted. In fact, we had hypothesized that a stronger sense of body ownership could boost immorality by making rewards more tempting. This prediction was in line with the idea that individuals engage in honest behaviors when they are not attracted by the rewards obtained through dishonesty, or “Grace” hypothesis (Greene & Paxton, 2009). Oppositely, temptations could be boosted by awareness of the body, as this also increases awareness of one’s physiological needs. Support for this hypothesis came from research investigating the role of bodily signals during Ultimatum Games, which had shown an increase of behaviors benefitting the self when information concerning one’s body was made explicitly available or enhanced though stimulation (Lenggenhager et al., 2013; Mancini et al., 2011). If this was indeed the case, we expected to observe higher Moral Identity scores and less dishonesty in participants with low sense of ownership (Study 1, Chapter 2), as well as less lies when body ownership was experimentally reduced (Study 2, Chapter 3) or when using a body part associated with feelings of disownership (Study 3, Chapter 4). However, the data of our three studies suggest that different relationships may be in place. Here we argue that enhancements and reductions of body ownership may constitute a way to achieve association with or dissociation from specific events.

Generally speaking, individuals aim at avoiding inconsistencies between their concept of self and their actions (Blasi, 1980). This is because inconsistencies force individuals to review their idea of self in light of the new information. Accordingly, any form of moral violation creates a potential threat to one's own moral self-image, as this needs to be adjusted to make sense of immorality. Therefore, different mechanisms may be employed to allow oneself some dishonesty while maintaining a moral image of self (Mazar & Ariely, 2006). Among these mechanisms are also embodied procedures, which can create a sense of separation from immorality, and more generally, from negative attributes and events (S. W. S. Lee & Schwarz, 2021).

Results of our studies suggest that modulations of body ownership may elicit similar feelings of separation. Reduced feelings of ownership may create a sense of disconnection from the body and consequently from its negative features and actions. Thus, it is possible that low body ownership facilitates separation from negative behaviors, like dishonest ones. In fact, the results of our second study (Chapter 3) showed that high monetary rewards increased the number of lies only when the sense of body ownership was experimentally reduced, as is the case for the *3PP-Wrist* condition. In this condition, our participants consistently reported low feelings of ownership, both before *and* after completing the VR-TLCG. This indicated that the sense of ownership did not change based on (dis)honest behaviors during the task. Considering all this, we hypothesize that, when body ownership is low, it may allow for more dishonest behaviors, as negative attributes are less easily associated with the self. Interestingly, results of our third study (Chapter 4) may show a different side of the same medal. In this experiment, participants with a low sense of ownership for one leg did not behave differently from controls. However, their sense of ownership for the disowned leg decreased even further following immoral deeds. Specifically, the more they had lied for their own profit, the more their sense of limb ownership was reduced. It is possible that the sense of ownership is reduced in response to past immorality, at least in the presence of a more malleable percept of the body (Lenggenhager et al., 2015). To rephrase this, individuals may separate the self from a body (or from parts of a body) that is associated with negative attributes (like dishonesty), so that these characteristics are not attached to the self.

In summary, both these studies showed an association of reduced body ownership with deception, although in opposite directions. In our VR study, low body ownership was the *antecedent* for future dishonest behaviors, while for participants with BID the further reduction of limb ownership was a *consequence* of dishonesty. While these results may seem contradictory, this pattern has been observed for other embodied mechanisms of separation. For instance, physical cleanness reduces the probability of ethical behavior (it is the *antecedent* of future immorality) and preference for cleansing products is increased following immorality (it is the *consequence* of a negative image of self) (C.-B. Zhong & Liljenquist, 2006). However, the question remains as to why the disownership observed in individuals with BID, despite being present before the U-TLCG, did not influence behavior to the task in ways similar to those observed in study 2. One possible explanation is that BID participants were using their physical body to provide their responses. Although they *feel* that part of their body does not belong to them, they nonetheless *know* it does (First & Fisher, 2012). Also, they use the physical body and the unwanted leg in everyday life. Using the physical body may have prevented an increase in dishonesty. At the same time, it may have triggered alternative strategies to deal with dishonest behaviors, such as distancing from parts of their real body. On the contrary, the participants in our VR study communicated their decisions through a virtual body. Therefore, when observing the virtual body from an out-of-body perspective, they *felt* that it was not theirs and, at the same time, they consciously *knew* it wasn't. This matching between individuals' feelings of ownership and their knowledge of their body may have allowed participants to lie even more in VR.

On the flip side, modulations of body ownership may also induce connection with positive attributes. For example, in enfacement illusions the sense of ownership expands to include the face of conspecifics in the representation of the self (Porciello et al., 2018). Interestingly, this effect is strengthened if the other person is perceived as having positive characteristics (Bufalari et al., 2014; Sforza et al., 2010). We argue that experiencing ownership over a positively connotated body facilitates association of its positive attributes with the self. In line with this, in the first of our studies (Chapter 2), we found that high body ownership is associated with a stronger moral identity. It is possible that, at higher levels of ownership, it becomes easier to associate the body with positive features such as morality.

While modulations of body ownership constitute a useful mechanism to protect the image of self, they might be used only under specific circumstances. It is possible that modulations of body ownership occur only in the presence of serious violations, such as those involving more money. Indeed, it is easier to justify immoral behaviors that involve small rather than high monetary sums (Cohn et al., 2019; Mazar et al., 2008). As such, situations entailing small payoffs may not require individuals to feel disownership for them to indulge in immoral behaviors. Accordingly, when hands appeared detached from the rest of the body (*1PP-No Wrist* condition), participants sense of ownership was intact. Despite this, our participants lied more in this than in the other two conditions (i.e., *1PP-Wrist* and *3PP-Wrist*), but only when lying was associated with small monetary rewards. This suggests that small violations can be justified without the need to separate from the immoral body. This is also in line with results of study 1 (Chapter 2) which showed that when high ownership was associated with low reward sensitivity, people allow themselves to deceive more. On the contrary, more serious violations may require additional mechanisms, like reductions of the sense of ownership. Accordingly, our studies show that, when modulations of body ownership were present, deception was associated with the highest available reward. This was observed in VR (study presented in Chapter 3), where the highest reward increased dishonesty only in the *3PP-Wrist* condition, that is, when the sense of ownership was consistently low. Because we did not manipulate the value of rewards associated with favorable and unfavorable situations, we cannot draw any conclusion concerning the modulating role of rewards in the reduction of ownership after moral violations observed in our third study (Chapter 4). However, future research should clarify whether lying for larger amounts of money may elicit a stronger estrangement from the unwanted leg when compared with lies associated with smaller amounts of money.

In conclusion, the results of our three studies appear to support a role of body ownership as a way to prevent reconsideration of one's own image of self. Specifically, reductions of body ownership may distance the individual from immorality and reduce its negative consequences for the self. It is worth noting that reductions may facilitate future immorality or they may occur following past dishonesty. Oppositely, higher body ownership can increase association with positive characteristics. These results also suggest that such relations are modulated by the rewards associated with lies. Individuals may indulge in violations that entail high payoffs only if their sense of ownership is reduced, so that negative consequences are more easily separated from the self. On the contrary, smaller rewards may not be perceived as threatening to the moral self-concept, therefore they appear to be carried out even when feelings of ownership are preserved.

We believe that these results are particularly relevant for present-day societies, where more and more interactions are moved from the real world to a space where individuals are no longer represented by their bodies. In such conditions, the ability to direct attention towards the physical body may help prevent dishonesty in the cyberspace. Considering all this, training programs aimed at enhancing corporeal awareness, and specifically the sense of body ownership, may be helpful for the prevention of dishonesty, benefitting society at large. Additionally, cues that favor reflection over the sense of ownership may be provided at specific points in time, and these might help achieve reductions of dishonesty. For example, asking individuals to rate their feelings of ownership may be helpful for preventing the occurrence of negative deeds or for avoiding false statements in online forms.

While the results presented here aid our understanding of the association between enhancements and reductions of body ownership and (dis)honest behaviors, the neural mechanisms underlying this relationship remain to be studied. Considering this, we argue that future investigations should aim at clarifying this point. For example, different degrees of body ownership may relate to specific changes concerning the brain electrical and/or metabolic activity. Such elements may be particularly helpful for evaluating the effectiveness of trainings aimed at improving the sense of ownership or the adequacy of bodily cues that online platforms may implement in the future.

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8 Appendix A: Supplementary information concerning the study presented in Chapter 2

Supplementary table 1. Reasons for exclusion from the dataset of some of the participants of our main study. 'No. excluded' indicates the corresponding number of occurrences; '% excluded' indicates the percentage of occurrences for each reason. 'STDT' indicates the Spot The Difference Task.

Reason for exclusion	**No. excluded**	**% excluded**
No answer provided	4	0.57
Participated twice		
Completed the study the first time (second excluded)	1	0.14
Completed the study the second time (first excluded because STDT was not presented)	1	0.14
Did not complete the STDT the first time (excluded)	6	0.85
Completed STDT twice (second excluded)	11	1.56
Did not complete the study	17	2.41
Failed all attention checks	7	0.99
Total	**47**	**6.67**

8.1 Validation study

This pilot was designed to select two pairs of images for our main study based on the following criteria: a) the two pairs of images display the same number of differences; b) the two pairs of images are similar in terms of the number of differences identified by the participants; c) at least 90% of participants identify *every* difference in each of the two pairs; and d) participants take similar amounts of time to find every difference within the two pairs of images.

8.1.1 Participants

We recruited our participants over a two-week period in May 2018 via personal communications and word-of-mouth. A total of 87 volunteers participated in the study, 38 of whom did not complete the task and were thus excluded from the dataset. 49 participants (females = 26) were included in the final sample, aged between 21–40 (M = 30.22, SD = 4.96). All gave their informed consent prior to participation and took part in the study voluntarily.

8.1.2 Materials

All image pairs shown to participants during this validation study were obtained via web search and selected among those presenting up to nine differences. We instructed our participants to compare pairs of images and click on any differences between the two. Clicks were allowed on either image forming a pair. Participants were informed that the number of differences could range from 0 to 9 and that a 90-second inspection time was allowed. Each pair of images was shown at the center of the screen, while a countdown was displayed on the top center. We asked the participants to perform the task for 11 pairs of images, which were presented in a randomized order. Nine pairs of images contained five differences, while the remaining two contained seven and nine, respectively. The number of differences within each pair was set as the maximum number of clicks allowed to the participants. Once all allowed clicks had been performed, or the countdown hit zero (whichever came first), participants were shown the following pair. For each click, we recorded i) the position of the mouse along the x- and y-axis of the screen; and ii) the time elapsed since the presentation of the images.

We analyzed the Accuracy variable to identify two pairs of images where participants found a similar number of differences (criterion b) and where at least 90% of participants could find every difference (criterion c). Accuracy was coded as 1 if the participants had clicked on all differences within a pair and as 0 if they had not. To identify which pairs of images required similar amounts of time to identify every difference (criterion d), we analyzed the time it took for participants to click on all differences within each pair. To do so, we measured the time elapsed from the moment images were displayed on the screen to the last click. Data regarding the last click were not included in our time analysis if the number of clicks was lower than the number of differences between the two images. In fact, this indicated that not all differences had been identified for that pair of images. In these cases, the timing of the last click was not informative of the amount of time needed to find *every* difference.

8.1.3 Procedure

The study could be completed using any computer connected to the internet.

We first provided our participants with some information regarding the study and informed them that they could only participate after giving consent. We then asked about their sex, age, and nationality. Completion of all parts of the study required approximately 10 minutes. We used the web-based version of PsyToolkit (Stoet, 2017) to develop and present all parts of this study.

8.1.4 Results

We analyzed the data using RStudio, version 1.2.5033 (RStudio Team, 2019). The logistic linear regression and generalized linear mixed effect model regression analyses were performed using package *lme4*, version 1.1-21 (Bates et al., 2015). Specifically, we used the Anova function of the *car* package (version 3.0-6) (Fox & Weisberg, 2019) to test significance, and the *emmeans* package (version 1.4.5) (Lenth, 2020) to perform the pairwise comparison of estimated marginal means with Turkey correction.

To ensure that the participants had followed our instructions, we first plotted the position of clicks over all the images. A visual inspection revealed that the participants identified a sixth difference between the images belonging to Pair1. As this pilot aimed to select two pairs of images for our following study, it was necessary for selected pairs to differ for the same number of details – which in this case was five (see criterion a). Considering this, we excluded Pair1 (six differences), Pair8 (seven differences), and Pair10 (nine differences) from further analysis.

Accuracy was analyzed via a logistic linear regression model with logit link. Finding fewer than five differences was coded as 0 and finding all five differences was coded as 1. We entered the participant's IDs as random intercepts, and Pair of Images was the fixed, categorical factor. The variable Pair of Images significantly predicted accuracy (χ^2 (7, 49) = 18.83, p = .009). However, pairwise post hoc analysis revealed (somewhat surprisingly) that there was no difference in accuracy between any of the image pairs.

We set the time needed to find *all* differences as the dependent variable of a linear mixed effect model. Pair of Images served as the fixed predictor, while Participant ID was set as a random intercept. The variable Pair of Images was a significant predictor of the time needed to find all differences between two images (χ^2 (7, 49) = 86.31, p = < .001). Post hoc pairwise comparison revealed that less time was required to find all differences in Pair3 (M = 14872, 95% CI = [10804, 18939]) than in any other pair (Pair2: M = 30144, 95% CI = [25997, 34290], $t(297) = -5.78$, $p < .001$; Pair4: M = 30374, 95% CI = [26000, 34748], $t(299) = -5.67$, $p < .001$; Pair5: M = 32772, 95% CI = [28706, 36839], $t(296) = -6.86$, $p < .001$; Pair6: M = 37441, 95% CI = [32986, 41836], $t(298) = -8.19$, $p < .001$; Pair7: M = 24841, 95% CI = [20607, 29074], $t(297) = -3.73$, $p = .006$; Pair9: M = 28552, 95% CI = [24523, 32581], $t(296) = -5.27$, $p < .001$; Pair11: M = 25131, 95% CI = [21102, 29160], $t(296) = -3.95$, $p = .002$). Pair6 required significantly more time than both Pair7 ($t(299) = 4.46$, $p < .001$) Pair9 ($t(299) = 3.23$, $p = .030$) and Pair11 ($t(299) = 4.48$, $p < .001$). Considering that the participants appeared to find similar numbers of differences for all image pairs – thereby satisfying criterion b – we based stimuli selection on criteria c and d. As such, we opted for using Pair5 and Pair11. Over 90% of the participants identified all of the differences within both pairs of images (criterion b; Pair5 = 93.88%; Pair11 = 95.92%). The two pairs were similar in terms of the time taken to identify all differences (criterion d; Pair5: M = 32772, 95% CI = [28706, 36839]; Pair11: M = 25131, 95% CI = [21102, 29160], $t(295) = 2.95$, $p = .067$).

8.2 Main Study

8.2.1 Morality Measures

Moral identity

We used the Moral Identity Measure (Aquino & Reed, 2002) to assess the participants' moral identity. This questionnaire is composed of items loading on two factors, namely symbolization (e.g., 'I often buy products that communicate the fact that I have these characteristics'; $\alpha = .73$) and internalization (e.g., 'Being someone who has these characteristics is an important part of who I am'; $\alpha = .79$). Due to our aim being that of investigating individuals' moral self-concept (as measured by factor internalization), and not the way in which these notions of self are conveyed to others (factor symbolization), we focused exclusively on the Internalized subscale of the questionnaire.

Supplementary table 2. Description of all the existing differences between the two images in each pair. 'Left-side image' and 'Right-side image' refer to the position of the described image on the screen. 'Pair 5' and 'Pair 11' indicate the two pairs of images selected through the validation study and presented to the participants in the main study.

Left-side image	Right-side image
Pair 5	
Two birds flying	One bird flying
Dress with polka-dotted pattern	Dress without polka-dotted pattern
Hat with flower	Hat without flower
One balloon	No balloon
One squirrel on tree	No squirrel on tree
Pair 11	
Four flower on the ground	5 flowers on the ground
One hot-air balloon	Two hot-air balloons
One worm tunnel	No worm tunnel
Still rabbit	Running rabbit
Two clouds	One cloud

8.2.2 Body self-consciousness measures

Sense of Ownership

Participants' sense of ownership was measured using the BCQ (Miller et al., 1981) and the ESSS (Asai et al., 2016).

The BCQ has a three-factor structure, namely private body consciousness (e.g., 'I am sensitive to internal bodily tensions'), public body consciousness (e.g., 'When with others, I want my hands to be clean and look nice'), and body competence (e.g., 'I'm capable of moving quickly'). Due to our specific research interest in the interoceptive component of ownership, we only included the 5 items of the private body subscale (α = .65) in the survey.

Items within the ESSS have the following three factors: ownership (e.g., 'Sometimes the clothes I am wearing feel heavy'), agency (e.g., 'I sometimes bump into things or people when I am out walking'), and narrative (e.g., 'Sometimes I feel that I no longer know my own personality'). It should be noted that we asked the participants to only complete the 9-item ownership subscale (α = .73).

Sense of Agency

Sense of agency was assessed using Tapal and colleagues' scale (Tapal et al., 2017). Both factors of this scale, namely sense of positive agency (e.g., 'I am in full control of what I do') and negative agency (e.g., 'My actions just happen without my intention'), were found to be reliable (α > .7). As our hypotheses concerned the feeling of control over one's own actions, we included only positive agency in the analysis.

8.2.3 Results

We computed robust regression analyses using RStudio (version 1.3.959) (RStudio Team, 2020). Specifically, robust linear regressions were performed using package *MASS* (version 7.3–51.6) (Venables & Ripley, 2002), while we employed package *robustlmm* (version 2.3) (Koller, 2016) for performing robust linear mixed effect models. Moreover, package *car* (version 3.0-8) (Fox & Weisberg, 2019) was used to test significance.

Robust analysis on the effect of sense of ownership on (im)moral behavior

In order to predict Moral Behavior, we computed a robust model with sense of ownership, experimental condition (no reward coded as 0, reward coded as 1), sensitivity to rewards, and all interactions (sense of ownership × experimental condition × sensitivity to rewards) as fixed factors. Experimental condition (no reward/ reward; $\beta = 0.001$, 95% CI = [0.00, 0.01], $t(652.40) = 7.99$, $p < .001$), reward sensitivity ($\beta = 0.001$, 95% CI = [0.00, 0.01], $t(1268.34) = 2.13$, $p < .001$), and age ($\beta = 0.001$, 95% CI = [0.00, 0.01], $t(650.65) = 3.52$, $p < .001$) significantly predicted an increased number of lies. Additionally, the interaction between sense of ownership, experimental condition, and reward sensitivity ($\beta = -0.001$, 95% CI = [-0.01, -0.00], $t(651.21) = -4.23$, $p < .001$) was a significant predictor of behavior in the task.

9 Appendix B: Supplementary information concerning the study presented in Chapter 3

Supplementary table 3. Reasons for exclusion of some participants who took part to the study presented in Chapter 3. 'No. excluded' indicates the corresponding number of occurrences; '% excluded' indicates the percentage of occurrences for each reason.

Reason for exclusion	No. excluded	% excluded
Did not complete the study	1	1.67
Knew the task (and cover story) beforehand	1	1.67
Did not believe the other players were real	1	1.67
Not engaged in the task	7	11.67
Total	**10**	**16.67**

Supplementary table 4. Italian version of the statements assessing the participant's level of embodiment towards the virtual bodies. The statements were presented twice for each experimental condition (i.e., *1pp-Wrist*, *1pp-No Wrist*, *3PP-Wrist*). The statements appeared in randomized order, after each guided observation procedure and after completing two VR-TLCG blocks.

	Measured component	Statements presented to participants (Italian version)
Q1	Ownership	Ho avuto l'impressione che il corpo virtuale con le banconote in mano fosse il mio
Q2	Ownership	Ho avuto l'impressione che il corpo virtuale con le banconote in mano fosse di qualcun altro
Q3	Ownership	Ho avuto l'impressione di avere più di un corpo
Q4	Agency	Ho avuto l'impressione di poter controllare il corpo virtuale con le banconote in mano come se fosse il mio corpo
Q5	Agency	I movimenti del corpo virtuale con le banconote in mano erano determinati dai miei movimenti
Q6	Agency	Ho avuto l'impressione che i movimenti del corpo virtuale con le banconote in mano influenzassero i miei movimenti
Q7	Agency	Ho avuto l'impressione che il corpo virtuale con le banconote in mano si muovesse da solo
Q8	Location	Ho avuto l'impressione che il mio corpo si trovasse dove vedevo il corpo virtuale con le banconote in mano
Q9	Location	Ho avuto l'impressione di essere fuori dal mio corpo
Q10	Location	Ho avuto l'impressione che il mio corpo reale si avvicinasse a quello con le banconote in mano o che il corpo con le banconote in mano si avvicinasse al mio corpo reale

Supplementary table 5. Description of all body measurements taken during the study. These were entered in MVN Studio software to ensure appropriate calibration of the Motion Capture system.

Measured component	Description
Body Height	From floor to top of the participants' head
Foot Size	Full shoe length (from back of the heel to front of the toe)
Arm Span	From one middle finger tip to the other, with arms spread out
Ankle Height	From floor to center of the ankle
Hip Height	From floor to medium trochanter
Hip Width	Distance between the two anterior superior iliac spines
Knee Height	From floor to lateral epicondile
Shoulder Width	Distance between left and right acromions
Shoe Sole Height	Shoe sole thickness
Eyes Height	From floor to eyes while seated on the wooden chair (needed for the point of view in the third person perspective condition – *3PP-Wrist*)

9.1 Guided observation procedure

During the guided observation procedure, the experimenter instructed participants by reading the instructions presented in Supplementary Table 5. These instructions were presented to the experimenter, who read them out loud to the participants as soon as they appeared on the screen. The order of statements remained the same, with the only exception being that half of our participants observed the left arm first while the other half observed the right virtual arm first.

The first statement appeared at the beginning of the 30 seconds observation, all other statements were presented at an interval of 6 seconds from the previous one.

Supplementary table 6. Statements read by the experimenter during the guided observation procedure

English version	Italian version
Look at the still left/right arm	Osserva il braccio sinistro/destro da fermo
Lift the left/right arm and observe it	Alza il braccio sinistro/destro e osservalo
Lower the left/right arm and observe the still right/left arm	Abbassa il braccio sinistro/destro e osserva il braccio destro/sinistro da fermo
Lift the right/left arm and observe it	Alza il braccio destro/sinistro
Lower the right/left arm	Abbassa il braccio destro/sinistro

10 Appendix C: Supplementary information concerning…

Supplementary table 6. Anamnestic information of participants in the Control Group (CG) and Body Integrity Dysphoria (BID) group, respectively. 'No.' indicates the number of occurrences for each entry; '%' indicates the corresponding percentage of occurrences within each group.

Anamnestic information	**No. CG group**	**% CG group**	**No. BID group**	**% BID group**
Psychiatric conditions	**1**	**5**	**2**	**10**
Depression	1	5	1	5
Burnout	0	0	1	5
Psychiatric Medications				
Antidepressants	1	5	1	5
Other Medications	**6**	**30**	**7**	**35**
Hormone Replacement Therapy	0	0	1	5
Heart medication	1	5	0	0
Hypertension treatment	3	15	3	15
Diabetes treatment	1	5	0	0
Muscular pain medication	1	5	0	0
Hormonal therapy for hypo- and hyper-thyroidism	0	0	2	10
Menopausal symptoms treatment	0	0	1	5

11 Appendix D: Overview of publication status of the Chapters in this thesis

Chapter number and title	**Original text (not published before)**	**Submitted: no feedback received**	**Submitted: revision requested or revision submitted**	**Accepted/published (specify journal or book)**
1. General introduction	X			
2. Morality in the flesh: on the link between bodily self-consciousness, morality and (dis)honest behaviour[1]		X		
3. Reduced body ownership increases dishonesty: evidence from an immersive virtual reality study	X			
4. Deceptive behavior increases estrangement of unwanted limbs: a study on individuals with Body Integrity Disorder	X			
5. General discussion	X			

[1] The study presented in this chapter is available as a preprint associated with the following DOI: https://doi.org/10.31234/osf.io/tcu23

11.1 Other papers

- **Scattolin, M.**, Panasiti, M.S., & Aglioti, S.M. (2021). Body Ownership as a Proxy for Individual and Social Separation and Connection. *Behavioral and Brain Sciences* 44:E21. https://doi.org/10.1017/S0140525X20000473.
- Ponsi, G., **Scattolin, M.**, Villa, R., & Aglioti, S. M. (2021). Human moral decision-making through the lens of Parkinson's disease. *npj Parkinson's Disease*, *7*(1), 18. https://doi.org/10.1038/s41531-021-00167-w
- **Scattolin, M.**, Panasiti, M. S., & Aglioti, S. M. (2021, January 6). Morality in the flesh: on the link between bodily self-consciousness, morality and (dis)honest behaviour. https://doi.org/10.31234/osf.io/tcu23
- Lisi, M. P., **Scattolin, M.**, Fusaro, M., & Aglioti, S. M. (2020, December 23). A Bayesian approach to reveal the key role of mask wearing in modulating interpersonal distance during the COVID-19 outbreak. https://doi.org/10.31234/osf.io/pf6rm