frontiers | Frontiers in Virtual Reality

TYPE Original Research
PUBLISHED 15 December 2022
DOI 10.3389/frvir.2022.884189

From my skin to your skin: Virtual image of a hand of different skin color influences movement duration of the real hand in Black and White individuals and influences racial bias

Elisabetta Ambron[1]*, Shayna Goldstein[1], Alexander Miller[1], Roy H. Hamilton[1,2] and H. Branch Coslett[1,2]

[1]Laboratory for Cognition and Neural Stimulation, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA, United States, [2]Department of Neurology, Perelman School of Medicine at the University of Pennsylvania, Philadelphia, PA, United States

OPEN ACCESS

EDITED BY
Frank Steinicke,
University of Hamburg, Germany

REVIEWED BY
Thomas Schubert,
University of Oslo, Norway
Judith Hartfill,
University of Hamburg, Germany

*CORRESPONDENCE
Elisabetta Ambron,
eli.ambron@gmail.com

SPECIALTY SECTION
This article was submitted to Virtual Reality and Human Behaviour, a section of the journal Frontiers in Virtual Reality

RECEIVED 01 March 2022
ACCEPTED 24 November 2022
PUBLISHED 15 December 2022

CITATION
Ambron E, Goldstein S, Miller A, Hamilton RH and Coslett HB (2022), From my skin to your skin: Virtual image of a hand of different skin color influences movement duration of the real hand in Black and White individuals and influences racial bias.
Front. Virtual Real. 3:884189.
doi: 10.3389/frvir.2022.884189

Virtual reality (VR) allows individuals to experience someone else's body, but the possible effects of this embodiment on attitudes and biases are not fully understood. Using a virtual reality (VR) task, we had previously shown that changes in the visual image of the hand influenced action: when the visual image of one's hand was spatially displaced, participants acted as if the virtual hand was theirs. Here we tested whether these effects vary depending on the match between the skin color of the individual and the virtual hand. Black and White participants performed reaching movements with dark or light hands of naturalistic skin tones, or purple hands. As in our previous work, the correspondence between the location of the real and virtual hands was systematically varied. Both Black and White participants showed changes in the temporal and spatial parameters of the movements with the virtual hand of different colors indicating that the hand had been embodied. A larger effect of the illusion was observed in Black as compared to White individuals when performing the action with a dark-skin virtual hand. Ownership of the virtual hand that matched the participants' skin color was associated with their explicit attitude towards their in-group in Black participants and with empathic abilities in White individuals. Importantly, performing the task with a dark-skin hand reduced the implicit racial bias of White individuals. These data show that body representation is malleable and influenced by online perceptual factors as well as attitudes and biases. Our findings raise the possibility that altering the representation of one's body may be used to change participants' perspectives regarding social issues.

KEYWORDS
virtual reality, racial biases, movement, implicit association task, rubber hand illusion

Introduction

The representation of the body is a fundamental aspect in the foundation of the "self" and the distinction with the external world, constituting the lens through which we shape our experience with the world (Damasio, 1994). This representation is not monolithic and static but is dynamic and malleable (Medina and Coslett, 2010, Medina and Coslett, 2016). A classic example of this is the rubber hand illusion (RHI; Botvinick and Cohen, 1998) in which the participant's hand is hidden, while a rubber hand is placed close to the participant's hand at an anatomically plausible position. After an induction period, consisting of synchronous stimulation of the participant's hidden hand and of the RH, participants perceive the RH as part of their own body.

Importantly, changes in the body representation not only influence the limits of what is considered our body, but also participants' ability to perceive and act in the environment. We and others have shown that changes in the size or position of a body part influence the ability to perceive somatosensory stimuli (van der Hoort et al., 2011; Bonakou et al., 2013) or object size (van der Hoort et al., 2011; Bonakou et al., 2013), and to perform aiming movements (Marino et al., 2010; Ambron et al., 2017, 2018, 2020). For instance, it has been shown that objects are perceived to be larger if participants have embodied a big body and smaller if they embodied a large body (van der Hoort et al., 2011; Bonakou et al., 2013). In a previous study (Ambron et al., 2020), we used virtual reality (VR) to recreate the RHI in action. In three experiments, participants played a VR card-matching game using a virtual hand. During the game, the virtual hand corresponded to the location of the real hand or was progressively displaced (7 or 14 cm) above or below the participants' real hand; in the latter condition, there was a mismatch between the visual image of one's hand and proprioceptive information regarding the real hand. Immediately after the card game, participants performed a reaching movement toward (Exp. 1-2) or with (Exp. 3) the drifted hand towards their other hand (which had not been displayed in the VR environment); in both instances, distorted visual feedback regarding the virtual hand influenced action.

Movement execution was longer in the drifted conditions than the no drift condition and the endpoint of the movement was shifted towards the VR hand location. When the reaching movement was performed with the drifted hand and the VR hand drifted above the real hand, the endpoint deviated below the location of the target hand; while the opposite was observed when the visual image of the hand drifted below the real hand and an upward movement deviation was observed (see Figure 1). This evidence suggested that the online representation of the arm and hand that underlies reaching was modulated by vision, at least partially overriding proprioceptive information about hand position.

If changes in body representation induced by VR influence basic sensory and motor abilities do these changes also have implications for attitudes toward ourselves or others? For instance, do changes in perceived body representation influence individuals' beliefs or attitudes toward people different from themselves? There have been numerous studies

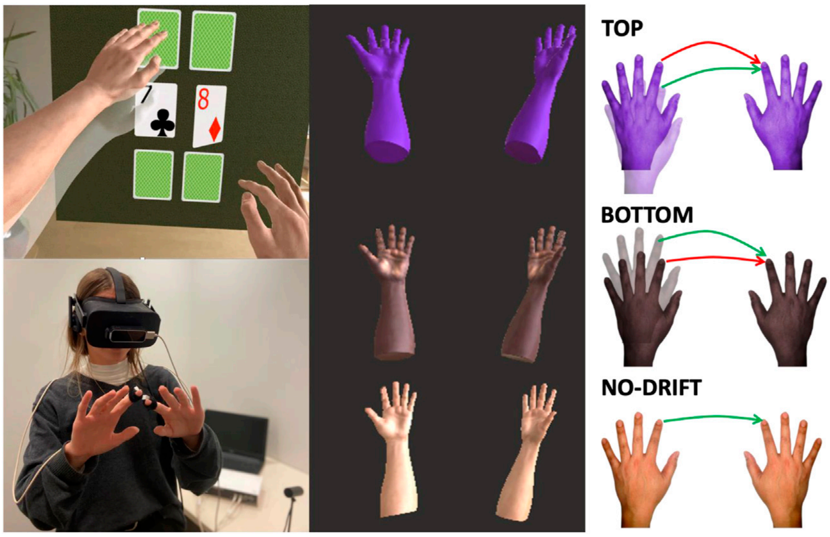

FIGURE 1
From the left-top panel, rendering of the participant's view while playing the card game; left-bottom panel, the participant playing the game using the Oculus headset and vive, and with motion trackers attached to the fingers; central panel, rendering of the avatar hand colors for each experimental condition; right panel, representation of the movement trajectories if participants followed vision and showed the illusion (red lines) or followed proprioception and did not show the effect of the illusion (green lines).

on the effect of immersive VR on implicit attitudes (see Slater & Banakou, 2021 for review). This set of research has shown that after the VR experience, participants' attitudes tend to match the expected attitudes of the experienced body (Proteus effect). For example, individuals show increased self-confidence after experiencing the body of a tall person (Yee et al., 2009), identify with children rather than adults after a VR experience in a child's body (Banakou et al., 2013), or overreact when experiencing a young woman's body in first then third-person perspective in a dangerous situation (Slater and Sanchez-Vives, 2016). Effects of VR experience have also been reported in work exploring implicit attitudes (implicit bias) and stereotypical knowledge toward groups of individuals (e.g., women or elderly individuals). For example, gender bias increased in male participants after a VR experience in a female body during a Tai Chi task, a situation that activated negatively stereotyped knowledge (e.g., 'Women are weak'; Lopez et al., 2019); after embodying an elderly person avatar, individuals showed a reduction of the prejudice and negative attitudes towards elderly people (Yee and Bailenson, 2006; Yee and Bailence, 2007).

In this context, an important topic is whether experiencing another person's skin color can induce changes in racial bias. Indeed, skin color is a visual feature that powerfully activates stereotypical knowledge and prejudice and induces a categorical distinction between in-group and out-group (Groom et al., 2009). If so, experiencing someone else's skin color may represent one of the most immediate vehicles to induce perspective-taking and a powerful tool to change individuals' perspectives and attitudes towards other races. Using the Implicit Association test (IAT) as a measure of implicit racial bias (Greenwald et al., 1998; Nosek, 2005), studies using both RHI and virtual reality show that this is the case. Studies using the RHI showed that light-skinned individuals show the effect of the illusion (e.g., proprioceptive drift or skin conductance response) for both light and dark-skinned rubber hands, and this effect is independent of the initial attitude towards Black individuals (Farmer et all., 2012; Maister et al., 2013; Farmer et al., 2014). Studies of the effect of the RHI illusion on implicit racial bias have been controversial. On one hand, the ownership perceived over both light- and dark-skinned RHs affected the post-illusion IAT (Farmer et al., 2012). On the other hand, between subjects' studies demonstrated that changes in the implicit racial bias depend on the level of perceived ownership over the dark-skinned RH (Maister et al., 2013) and the initial attitude towards dark-skinned individuals; after engaging in a RHI task in which the rubber hand was dark-skinned, a greater effect of the RHI improvement is observed in individuals with a strong racial bias before the RHI (Farmer et al., 2014). Interestingly, Lira et al. (2017) have shown that participants took more time to embody a dark-skinned RHI than a light-skinned RHI and this onset time was positively correlated with IAT (longer time for RHI, higher racial bias).

Studies using immersive VR have also reported controversial results, showing reduction (Banakou et al., 2016; Peck et al., 2013), enhancement (Groom et al., 2009; Slater and Sanchez-Vives., 2016), or no change (Hasler et al, 2017) in the bias of White people towards Black individuals. It has been proposed that the disagreement across studies may be due to the type of VR experience (Slater and Sanchez-Vives, 2016). In studies reporting enhancement (Groom et al., 2009; Slater and Sanchez-Vives, 2016) or no change (Hasler et al., 2017) in racial bias, participants were asked to interact in a social context, with clear connotations and expectations. Therefore, the social context may have played an additional role in the modulation of racial bias. For example, in Groom et al. (2009) study participants were facing a job interview in a dark or light-skinned avatar body, a social context in which racial discrimination is known or expected to be accentuated. The expectation of race discrimination in the interview setting may have enhanced the racial bias when experiencing the interview in a dark-skinned avatar body (Slater and Sanchez-Vives, 2016). No changes in racial bias were reported after a VR experience in which participants embodied light or dark-skinned avatars and interacted with other avatars of different skin colors (light or dark-skinned), but without clear social expectations (Hasler et al., 2017). Importantly, a decrease in racial bias has been noted when participants experience a body with different skin color in a social context that did not involve the interaction of Black and White individuals. For instance, Banakou et al. (2016) showed a reduction of racial bias after participants underwent a virtual tai chi class with an Asian or European teacher. This reduction occurred and persisted over a week from the VR experience when female participants embodied a dark rather than light-skinned avatar. Peck et al. (2013) reported a decrease in racial bias in White women after an immersive VR experience of a few minutes (~12) in a dark-skinned avatar body. This effect was not observed when female participants embodied a purple or light-skinned avatar, or when the avatar body did not move in synchrony with the participant's own body; in this study the VR experience entailed an exploration of a VR environment in which they encountered but did not interact with Black of White avatars. Taken together, this evidence suggests that social context and demand characteristics of the social environment have a strong effect on social biased. A VR experience in a body of dark-skinned color has positive effects on racial bias outside the confounding of pressure and expectations of social context.

Most of these studies explored the racial bias in White individuals (Banakou et al., 2016; Peck et al., 2013) or contrasted the performance of White individuals with non-White individuals of different races (Groom et al., 2009). Therefore, little is known about whether the effects are specific to White individuals or can also be observed in Black individuals. In the present study, we applied our VR paradigm

(Ambron et al., 2020) to test the possible effects of different skin colors on participants' body ownership, action performance, and racial bias in both Black and White individuals. As in our previous study, participants played a card-matching game and in some instances, the visual image of the hand progressively drifted above or below the real hand; after the game, they reached the non-drifted hand with the drifted hand and we measured the movement times and endpoints of the movements (Ambron et al., 2020). In the present study, we manipulated the color of the VR hand, and participants were assessed in three sessions in which the hand color was light or dark-skinned, or purple. Before the VR sessions, questionnaires measuring empathy, and explicit and implicit attitudes towards Black and White individuals were administered to determine if participants' attitudes influenced performance. After each VR session, we assessed the effect of VR on the action and administered the racial.

We made several predictions. First, we expected to replicate the results of our previous study (Ambron et al., 2020) showing the effect of VR on the kinematic parameters of participants' hand movements. Indeed, if participants' action performance followed the visual VR image of the hand rather than proprioception, we expected movement times to be longer and the endpoint deviation of the virtual hand to be larger in the drifted than the no drift condition. Second, if the illusion depends on the participants' body representation (Ambron et al., 2020), a stronger effect of the illusion should be observed in conditions that enhance this representation and that can be more easily incorporated into the body schema. Therefore, we expected the magnitude of the illusion to change depending on the participants' skin color and the color of the avatar's hand. We predicted that the effects of embodiment would be greater when the virtual hand matched the color of their hand. We expected Black participants to show a larger magnitude of the illusion with a dark-skinned avatar and White participants to show larger effects with a light-skinned avatar. We expected these effects to be evident in both kinematic (an increase of movement time and/or endpoint deviation) and body ownership (higher scores on questions 2 and 4, testing the perception of ownership and embodiment on the VR hand). We had no defined predictions regarding the other skin colors.

In addition, to testing for the presence of the illusion in Black and White individuals, we also conducted exploratory analyses to investigate whether the effect of the illusion on kinematic (measured with changes in MT and endpoint deviation) or ownership questionnaire may reflect participants' explicit or implicit attitudes toward ingroup or outgroup individuals. If the illusion captures changes in the body representation and these changes affect participants' attitudes, then we expected a relationship between measures of the illusion and participants' attitudes towards ingroup and outgroup individuals. In both groups of participants, we predicted that ownership and effect of the illusion on action performance would be related to participants' empathic ability (Farmer et al., 2012), and/or explicit or implicit judgment towards Black and White individuals (Farmer et al, 2014). We expected the effect of the illusion to be positively associated with the ability to put oneself in someone else's shoes and empathize with other individuals (Farmer et al., 2012). As empathy towards the ingroup is often higher than the outgroup (Bruneau et al., 2017), we expected a stronger association between our illusion and empathy for the ingroup than the outgroup.

Finally, we also tested whether embodying an avatar of a skin color different from oneself may induce a change in participants' attitudes towards outgroup individuals. In line with previous studies (Banakou et al., 2016; Peck et al., 2013), we expected a reduction of racial bias in White individuals after experiencing the dark-skinned virtual hand. As previous work reported no bias in Black individuals (Nosek et al., 2002), we expected no racial bias in this group and therefore no changes in the IAT because of VR.

Materials and methods

Participants

Twenty-two university students between the ages of 19 and 25 years participated; there were 11 Black (7 females) and 11 White individuals (6 females). Participants filled out a questionnaire regarding their ethnicity and race and all participants self-identified as Non-Hispanic or Latino, and as Black or African American, or White, Caucasian. All participants were paid for their participation and signed informed consent before starting the testing session. This study was approved by the Institutional Review Board of the University of Pennsylvania.

Procedure

Participants underwent two testing sessions of 1 hour each. During the first session, they were presented with a battery of questionnaires, the racial Implicit Association Test (IAT; Greenwald et al., 1998; Greenwald et al., 2003), and a VR task (see below). In the second session, participants underwent two additional blocks of VR tasks. The virtual hand was either purple, dark-, or light-skinned (see Figure 1). Two groups of participants were created based on self-identification as Black/African American or White/ Caucasian. The order was counterbalanced across participants and groups. Seventeen participants performed the VR blocks on the same day, while the remaining five participants performed the blocks on different days. When the VR blocks were presented on the same day, participants were provided with a break of ~10 min between blocks to reduce the likelihood of carryover effects. After each VR block, participants completed the ownership questionnaire and IAT.

Virtual reality task

The virtual reality task and equipment were the same as in Experiment 3 of Ambron et al. (2020). Each trial started with a card-matching game of increasing complexity. Using the avatar hand (see Figure 1), participants turned two cards in a row to find cards of the same value. After participants had matched all of the cards in a display, a new display containing a larger number of cards was presented. During the game, three different conditions could occur: the visual image of one hand could be drifted 14 cm above (top drift) or 14 cm below (bottom drift) the position of the actual hand, or the VR hand could overlap the real hand (no drift). The visual displacement of the hand started immediately after the onset of the card game and continued progressively until the end of the game. We chose a 14 cm visual displacement as our previous work had shown a larger effect of the illusion at this magnitude compared to a smaller drift (7 cm) (Ambron et al., 2020). After 30 s of playing the card game, a tone signaled participants to stop and after 2 s the instructions were presented on the screen, indicating the action to be performed ("Touch the right nail" or "Touch the left nail"). Participants were instructed to perform a reaching movement and touch with the index finger of the hand indicated in the instructions with the index finger of the other hand. Crucially, the drift occurred always on the hand performing the reaching moving (see Figure 1). After 2 s (maximum time provided to perform the movement), a black screen appeared, and participants moved their hands to a neutral position before starting a new trial. Each participant performed 3 blocks of 42 trials each (7 trials for each condition) in which the color of the avatar hand was manipulated (purple, dark, or light-skinned color). The duration of each block was about 25 min.

In all the images, the shadow of the hand represents the real position of the hand, and it is displayed only for descriptive purposes, but was not visible to the participants while playing the games.

Equipment

The VR task was designed using Unity3D Game Engine (Unity Technologies) and presented with the Oculus Rift CV1. We used a Leap Motion sensor attached to the Oculus to track participants' position of the hand in space, while 3D electromagnetic tracking system (trackSTAR, Ascension Technologies Inc., Burlington, Vermont) was used to collect spatial and temporal kinematic parameters of participants' index fingers during the reaching movements.

Data extraction

Data recorded from two sensors placed on participants' index fingers were filtered using a second-order Butterworth filter. The onset and offset of the movements were identified visually by inspecting the movement profiles of each trial; the times at which the velocities increased above or decreased below 5% of the peak velocity, were taken as movement onset and offset times. For each trial, we extracted two dependent variables using customized programs written in R and Labview (National Instruments): movement time (MT) and the y-coordinates of the endpoint of the movement. MT parameters were extracted from the marker placed on the index finger performing the action. The y-coordinates of the endpoint of both markers were used to compute the deviation of the endpoint from the reaching target. This was computed by subtracting the y-coordinate of the marker of the index performing the reaching movement from the y-coordinate of the index finger of the static hand. Positive values of the deviation indicated an upward deviation so that the reaching movement ended above the target index; negative values indicated a downward bias of the endpoint of the movement so that the action ended below the target index. As shown in Figure 1, if participants performed the movements following vision, an upward deviation should be observed when the drift occurred toward the bottom, while downward deviations would occur when the hand drifted towards the top.

Questionnaires

Before starting the VR experiment, participants were presented with a series of questionnaires. We measured the explicit attitude towards Black and White individuals, asking participants to rate on an 11-point Likert scale how warmth (from extremely cold to extremely warm) they felt towards Black or White individuals. We also measured the presence of racism, using the Symbolic Racism scale (Henry, & Sears, 2002). In this scale participants are asked to rate their level of agreement on eight statements, describing different aspects of racism (score range 8–31).

In addition, we measured empathic abilities with the Interpersonal Reactivity Index (IRI; Davis, 1983), in which participants rate their level of agreement on twenty-eight statements using a 5-points Likert scale. The task provides measures of different aspects of empathy, such as Perspective Taking, Personal Distress, Fantasy, and Empathic Concern.

Ownership and agency of the VR hand

After each VR session, participants were presented with a questionnaire on the ownership and agency of the VR hand (Caola et al., 2018; Ambron et al., 2020). Participants were asked to rate their level of agreement for six statements using a scale of 1 (totally disagree) to 7 (totally agree). The statements were as follows:

1) During the experiment, there were moments in which I had the sensation of having more than one right arm (Control)
2) During the experiment, there were moments in which I felt as if the virtual arm was my own arm (Ownership)
3) During the experiment, there were moments in which I felt as if my real arm was becoming virtual (Control/Ownership)
4) During the experiment, there were moments in which the virtual arm started to look like my own arm in some aspects (Control/Ownership)
5) Movement During the experiment, there were moments in which it seemed that my real arm was moving (Movement)
6) During the experiment, there were moments in which I felt that the virtual arm was drifted (Drift)

Racial bias—Implicit Association test

Participants completed the racial Implicit Association test (IAT) (Greenwald et al, 1998; Nosek et al., 2002) online (Inquisit's Racism IAT) on four occasions: before taking part in the VR tasks and after each VR task. Participants were first presented with two blocks, in which they were asked to classify a series of Black and White faces as positive or negative. Next, faces and written adjectives (e.g., joyful, nasty) are presented in random sequences within the same blocks. In one block, participants used the same response keys for Black faces and good adjectives, and for White faces and bad adjectives, whereas in another block the same response key was used for Black faces and bad adjectives, and White faces and good adjectives. D-prime measures identify the strength of association between faces and adjectives and reflect the attitude towards Black or White faces. Positive d-prime scores indicate White-Good and Black-Bad, while negative values indicate the opposite association.

Data analysis

We tested the effects of the illusion on action performance in two analyses. First, we ran a linear mixed model (LMM) analysis with subjects as a random intercept and drift direction (−14 cm, no drift, and +14 cm) as a fixed factor to test whether MT and Deviation changed with the visual displacement of the hand, as found in our previous study (Ambron et al., 2020). If the illusion had an effect, we expected the drift direction to account for both MT and deviation with MT and the magnitude of the error to be longer than the drift condition (−14 and 14 cm drift). Next, we tested if the effect of the illusion varied as a function of participants' race and VR condition. Therefore, we generated an overall index of the illusion for both MT and Deviation. For each subject and condition, we computed the difference between each trial in the drift conditions and the average of the no-drift condition. For the end-point deviation, the difference for the upward drift condition (14 cm drift) was multiplied by −1 to provide an overall magnitude of the illusion, so that positive values indicated a deviation towards the visual image of the hand independent of the drift direction. LMM analysis tested the effect of the fixed factors of VR hand color (dark or light-skinned, or purple) and participants' self-identified racial category (White or Black). In all models, participants were inserted as random intercepts; models were compared with a log-likelihood ratio test using the ANOVA function in R; conditional R^2 describing the effect size of the model was computed with r.squaredGLMM and the effect size of single comparisons estimated with emmeans packages that provide a standardized estimation of effect-size (equivalent to Cohen D). Sensitivity analysis was carried out using the 'confound' package in R to estimate the Robustness of Interference to Replacement (RIP), a score that indicates the amount of change (in percentage) in the data required to overturn the inference (Frank et al., 2013). In a second analysis, we used nonparametric tests (Friedman and Wilcoxon tests) to determine if the perception of ownership changed depending on the color of the hand and whether this differed in the two groups of participants.

Then we conducted two additional exploratory analyses (uncorrected for multiple comparisons). First, we tested the relationship between baseline questionnaires and performance in our VR task. As the normality assumption was violated for most of our variables, we used non-parametric statistics. To test whether the two groups of participants differed in any of the baseline questionnaires we used the Wilcoxon test; Spearman rho correlation analyses were carried out to test for each group of subjects whether baseline questionnaires correlated with the difference between drift and no drift conditions for MT and deviation, and with ownership over the VR hand. Second, we explored changes in the IAT as a consequence of our VR task in three analyses. We ran the first LMM to test the effect of condition (PRE VR, POST-dark-skinned VR, POST -light-skinned VR, and POST -purple VR) and participants' race (Black and White) on the D score of IAT. Then we computed the difference in the D-score for each of the POST -VR conditions from the PRE-VR condition and tested the effect of both hand color (dark and light-skinned, and purple) and race on this difference. Finally, we conducted this last analysis again but including only individuals who showed a racial bias in the PRE VR assessment (−0.15 <D-score< 0.15) (https://www.millisecond.com/download/library/v6/iat/raceiat/raceiat.manual)For correlation and two sample comparisons, sensitivity analysis was carried out using g*power (version3.1).

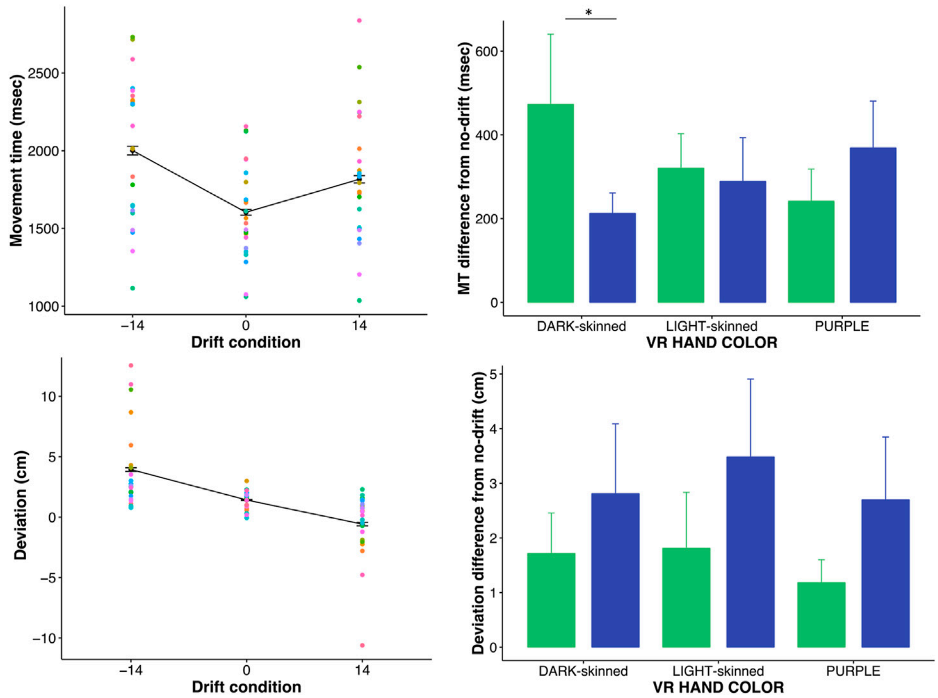

FIGURE 2
Left panels, average MT, and Deviation as a function of the drift condition. The error bars indicate the standard errors of the mean, while each marker represents the average performance for each participant in that condition. Right panels, the average difference of the drift from the no-drift condition for both MT and Deviation of Black (green color) and White (blue color) participants in the VR hand conditions.

Result

The effect of VR task on action performance

Does the illusion work?

MT

Linear Mixed Model (LMM) analysis showed that the drift direction contributed to the model fit (logLik = −19930, χ2 (2) = 197, $p < 0.001$, conditional $R^2 = 0.32$). MT was longer in both drift conditions (top M = 1808, SE = 24, t = 7.8, $p < 0.001$, d = 0.38, RIP = 75%; bottom M = 1993, SE = 28; t = 14.3, $p < 0.001$, d = 0.69, RIP = 86%) than the no-drift condition (M = 1593, SE = 24), suggesting an overall effect of the illusion in MT (see Figure 2 left panel). In addition, MT was also longer in the bottom (−14 cm) than top (14 cm) drift condition (t = 6.5, $p < 0.001$, d = 0.31, RIP = 70%)

Deviation

An effect of the illusion was confirmed also for the deviation of the endpoint of the movement (see Figure 2 left panel). Drift direction accounted for the deviation (logLik = −6839, χ2 (2) = 630, $p < 0.001$, conditional R^2 = 0.24): the no-drift condition (M = 1.42, SE = 0.04) differed from both drift conditions (top t = −11, $p < 0.001$, d = 0.56, RIP = 83.2%; bottom t = 15, $p < 0.001$, d = 0.73; RIP = 87%). There was an upward deviation when the visual image of the hand was shifted towards the bottom (−14 cm) (M = 3.9, SE = 0.15) and a downward deviation when the shift occurred towards the top (14 cm) (M = −0.57, SE = 0.14).

Does the effect of the illusion vary depending on the VR hand color and is this effect modulated by the participants' ethnicity?

MT

LMM analysis showed that the best model to account for MT difference included the interaction of hand color by race (logLik = −26912, χ2 (3) = 51.2, $p < 0.001$, conditional R^2 = 0.13). Black participants showed a larger difference in MT than White participants when the avatar color had dark-skinned (t = −2.47, p = 0.02, d = −0.40, RIP = 16%) (see Figure 2 right panel), while similar performance between the two groups was observed in the other conditions. Furthermore, MTs were also longer with the dark-skin hand than the other color conditions (light-skinned t = −4.4, $p < 0.001$, d = 0.26, RIP = 55.9%; purple t = −6, $p < 0.001$, d = 0.36, RIP = 67.6%); no significant difference was observed between light-skinned and purple conditions. White participants showed similar performance

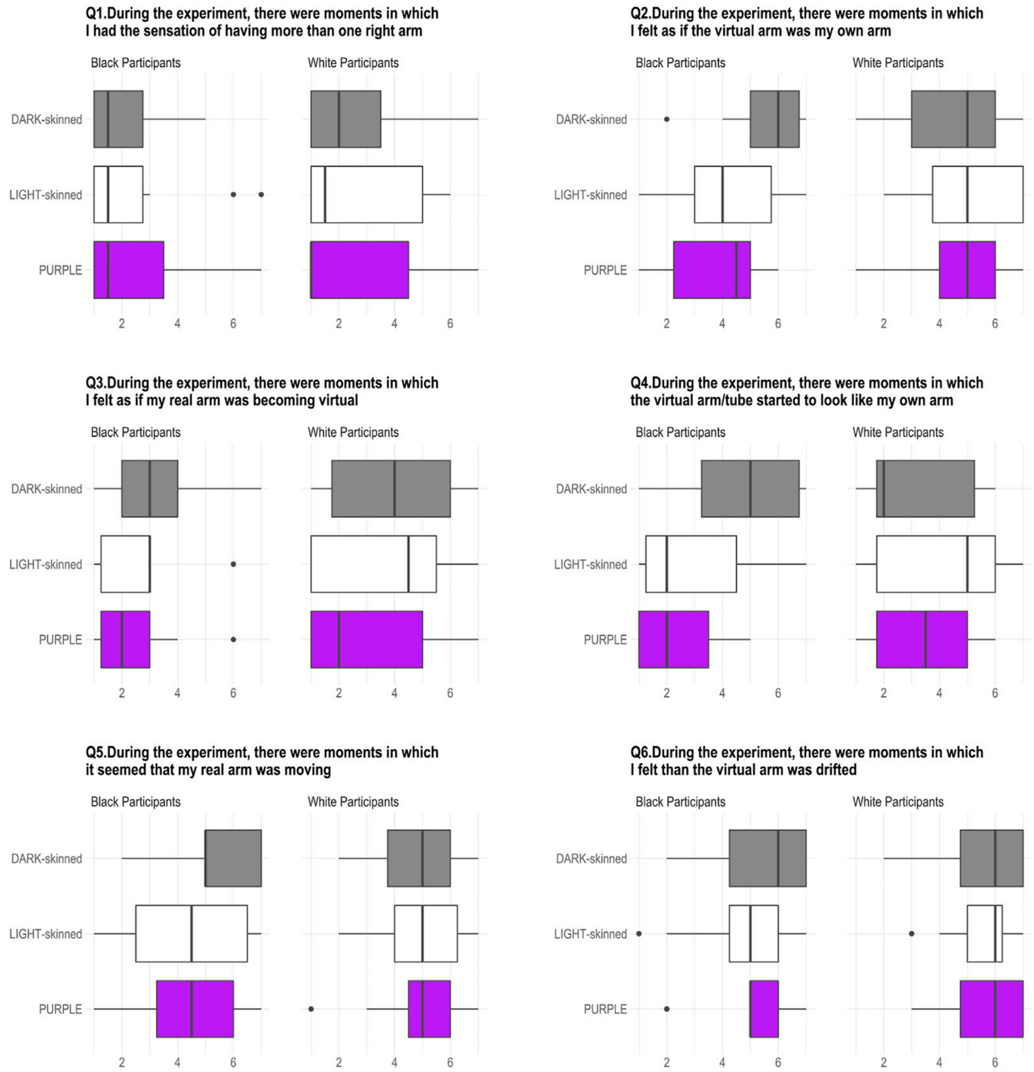

FIGURE 3
Median (dark black line), interquartile range (box) of Black and White participants in the response to ownership questions presented after each VR hand color task.

with the avatar of natural skin colors, but they showed a larger difference in MT in the purple than natural color conditions (dark-skinned $t = -3.9$, $p < 0.001$, $d = 0.23$, RIP = 50%; light-skinned $t = -2.1$, $p = 0.03$, $d = 0.12$, RIP = 10%).

Deviation

The final model included only the main effect of hand color (logLik = −4389, $\chi2$ (2) = 14.8, $p < 0.001$, conditional $R^2 = 0.48$) (see Figure 2 right panel). Overall, the light-skinned hand condition showed a larger difference in the deviation than the dark-skinned ($t = -2.15$, $p = 0.03$, $d = 0.12$, RIP = 85%) or purple hands ($t = -3.85$, $p = 0.03$, $d = 0.22$, RIP = 99%), while the difference between dark-skinned and purple was not significant.

The effect of VR hand color on ownership of the VR hand

Do participants differ in the embodiment of the VR hand across conditions?

Black and White participants showed similar ratings in all the questions (see Figure 3). White and Black participants also showed consistent rating scores across VR hand conditions, except for Question 2 ($\chi2 = 8.06$, $p = 0.02$) and Question 4 ($\chi2 = 6.88$, $p = 0.03$) for Black participants. For this group, the ownership of the VR hand was stronger when the VR hand color was Dark-skin rather than Purple ($p = 0.02$ Question 2 and $p = 0.03$ Question 4), while no significant difference was observed between the other conditions.

Additional exploratory analyses

In addition to these main analyses, we conducted two additional exploratory analyses to test whether participants' attitudes had an impact or changed with our VR task. The results of these analyses show large effect sizes but also low sensitivity (low RIP value), possibly because of the small sample size. Given the low RIP value, the findings should be interpreted with caution.

Relationship between participants' attitudes and performance in our VR task

The two groups of participants did not differ in any of the questionnaires, except for warmth towards Black individuals Table 1. Black participants showed a higher level of warmth than White Americans (W = 100.5, p = 0.007, r = 0.80). Furthermore, Black participants expressed higher warmth towards Black than White Americans (W = 36, p = 0.02, r = 0.74), while no significant difference was reported for White participants (W = 9, p = 0.19). Sensitivity analysis showed that with our sample size we had 80% of the power to detect large effect sizes in the comparison between (d = 1.2) and within (d = 0.96) groups.

We explored the relationship between ownership (Question 2 in the ownership questionnaire), the effect of the illusion on action performance, explicit and implicit attitudes towards Black and White individuals, and empathy using a series of correlation analyses. These analyses were carried out for both Black and White participants to test whether similar mechanisms accounted for the illusion in both groups. Sensitivity analysis showed our design with our sample size of 11 individuals was only able to reliably (power of 0.9) detect correlations >0.74.

There were 2 correlations that met this criterion. First, the correlation between ownership of the light-skinned hand and personal distress (r = 0.75; p = 0.008) subtests of the IRI; second, the effect of the illusion on the endpoint (difference between drift and no drift condition) in the light-skinned condition and the perspective taken (r = −0.75; p = 0.007) subtests of the IRI for Black individuals. In addition, the dark-skinned hand was positively correlated with warmth towards Black individuals (r = 0.65; p = 0.03) and the ownership of the light-skin hand was positively correlated also with the perspective-taking (r = 0.68; p = 0.022) subtests of the IRI, but these correlations were lower than 0.74.

Effect of different skin colors on racial bias

First, we tested whether the performance of Black or White individuals differed across conditions (PRE VR, POST -dark-skin, POST -light-skinned or purple conditions). LMM showed that the best model to account for the D score was the one with participants' race as a factor [logLik = −41.6, χ2 (1) = 6.7, p = 0.009, conditional R^2 = 0.54]. White participants showed a more positive and higher D score than Black participants (t = 2.60, p = 0.01, d = 0.32, RIP = 30%), indicating a stronger association between 'White American-Good' and 'Black American-Bad' (Greenwald et al., 1998, Greenwald et al., 2003). In addition, we tested whether a significant racial bias was present in any of the conditions by determining if the D score was significantly different from zero. While for Black individuals the D score did not differ from zero in any condition, D scores were higher than zero for White participants in the PRE VR (W = 60, p = 0.002), in the POST purple (W = 56, p = 0.04), and marginally in POST light-skinned condition (W = 55, p = 0.053), but did not differ from zero in the POST-dark-skinned condition (W = 49, p = 0.17).

As previous research has shown that changes in the IAT are observed in individuals who show a racial bias PRE VR (Farmer et al., 2014), we carried out an analysis only including subjects that showed a preference for hypothesis-conforming pairings (White-Good and Black-Bad) (n = 12; 3 Black) and a preference for hypothesis-nonconforming pairings (White-Bad and Black-Good) (n = 2; 2 Black) bias in the PRE VR assessment. Within this group of 14 individuals, we tested for the effect of race and VR hand condition. LMM analysis showed that the final model included both race and VR hand condition factor [logLik = −14.5, χ2 (3) = 8.8, p = 0.03, conditional R^2 = 0.33]. As shown in Figure 4, White individuals had a larger difference in the D scores than Black individuals for both natural skin color (dark-skinned: t = 2.31, p = 0.03, d = 0.51, RIP = 12%; light-skinned: t = 2.10, p = 0.04, d = 0.46, RIP = 3%), but not for the purple. There was no significant difference across conditions for either group. Wilcoxon test showed that the only conditions that differed from zero were the light-skinned (W = 0, p = 0.007) and dark-skinned (W = 1, p = 0.015) conditions for White participants.

Discussion

This study had different aims that will be discussed in turn. First, we wanted to replicate and extend our previous VR study (Ambron et al., 2020) showing that a mismatch between the visual image of the hand and proprioceptive information affects action. The present study confirmed that both spatial and temporal parameters of the reaching movements vary as a function of the location of the visual image of the hand. Movement times were longer, and the endpoint of the movement shifted in conditions of spatial mismatch between visual and proprioceptive feedback of the hand. When the visual image of the hand drifted above or below the position of the real hand, participants reached toward the drifted visual image of the hand. The present results expand this evidence by showing that this effect occurs not when the hand is light or dark skinned color but also when the hand is an unnatural color (purple). Indeed, similar effects on MT and deviation were observed when the reaching movements were performed whether the hand was light

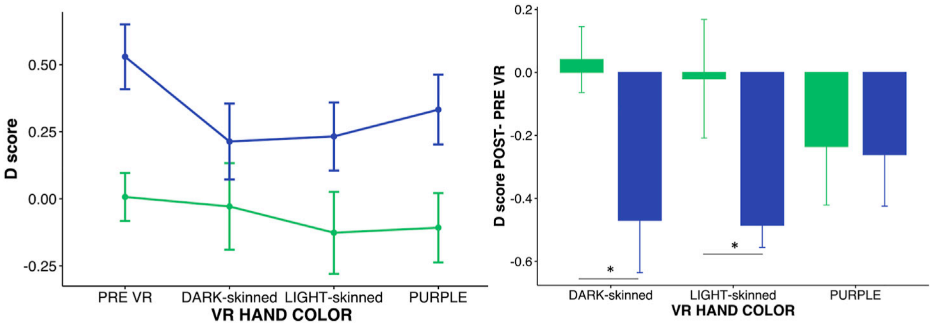

FIGURE 4
IAT D scores (left panel) and difference in the D score of each VR condition from the PRE VR (right panel) for both Black and White participants. In both plots, the performance of Black participants is in green and of White participants in blue. The error bars indicate the standard error of the mean.

TABLE 1 Mean and Standard error of the mean for Black and White participants in our questionnaires.

		Black participants	White participants
Symbolic Racism		10.27 (0.61)	12 (1.01)
Explicit attitudes towards Black Americans (warmth)		9.18 (0.46)* #	7.27 (0.56)*
Explicit attitudes towards White Americans (warmth)		6.18 (0.74)#	6.72 (0.66)
Racial Implicit Association Test (IAT)		0.007 (0.08)	0.52 (0.12)
IRI	*Perspective taken*	6.54 (1.32)	8.45 (2.02)
	Fantasy	11.90 (1.17)	12.09 (1.49)
	Empathic concern	6.09 (1.67)	7.09 (1.46)
	PD	16.90 (1.17)	19.72 (1.66)

*$p < 0.05$ in the comparison between two conditions.
#$p < 0.05$ in the comparison between two conditions.

or dark skinned or purple. Furthermore, participants reported a similar level of ownership for hands of different skin colors. This evidence is in line with RHI studies showing that the effect of the illusion and the ownership over the rubber hand can be elicited with hands of different skin colors (Farmer et al., 2012; Maister et al., 2013; Farmer et al., 2014).

Second, we tested whether the effects of the illusion on action and ownership varied depending on the match between their hand color and that of the virtual hand. We predicted that participants would show more embodiment and larger effects of the illusion for the hand of the same skin color as their real hand. More specifically, we expected White participants to show larger effects of the illusion than Black participants with light-skinned hands, and Black participants to show larger effects of the illusion than White participants with dark-skinned hands. These predictions were only partly met; Black participants showed a larger effect of the illusion on MT than White individuals in the dark-skinned hand condition. In this condition, Black participants also reported a higher degree of ownership over the VR hand than the purple hand. This pattern was not observed for White participants who showed a similar level of ownership (Questions 2 and 4) towards light-skinned hands and purple hands. On one hand, this last piece of evidence is in line with previous VR work showing that light-skinned individuals report a similar level of ownership over the full-body avatar of different skin colors (Banakou et al., 2016; Hasler et al., 2017; Peck et al., 2014). On the other hand, light-skinned individuals experience higher ownership over a rubber hand of their skin color than a dark-skinned rubber hand (Farmer et al., 2012). It has been suggested that full-body ownership illusions are more likely to enhance ownership across avatars of different skin colors than single-body part illusions (Hasler et al., 2017). It is possible to speculate that the single-body part illusion may have reduced the degree of ownership over the avatar of unnatural skin color and enhanced the degree of ownership over the dark-skinned hand in Black participants. While this account could explain the results of Black participants, it does not account for the similarity across scores in White individuals.

Alternatively, the familiarity and frequency of use of computer games may have played a role in the perceived ownership and level of the embodiment with the different color hands of these two groups. It is noticed that many consumer games use unnatural colors or light-skinned hands. White participants may be used to playing games using light-skinned hands and therefore may not perceive a particularly higher sense of ownership with light-skinned hands, whereas reduced experience with VR dark-skinned hands may have enhanced the perception of ownership toward the avatar of their skin color in Black participants. This represents a shortcoming of the study and future research should explore the relationship between familiarity and experience with VR, and ownership and/or movement execution with avatars of different colors.

In addition to the assessment of the illusion, we carried out two additional exploratory analyses to test the relationship between the illusion and the questionnaires testing participants' attitudes. The results of these analyses should be interpreted with caution considering the small sample size of the two groups and the set of data points considered. Indeed, although we observed a significant effect, p-values ranged between 0.01 and 0.05 and observed medium to large effect sizes. In the first exploratory analysis, we tested whether the observed effects of the illusion could be related to differences in empathic abilities or attitudes toward Black and White individuals. The only difference between the two groups was that Black participants reported more warmth than White participants towards Black individuals. Although of a small magnitude, this variable was also positively correlated with ownership ratings in the dark-skinned hand condition for Black individuals. If Black individuals showed a larger effect of the illusion and embodied VR hand that resembled their skin color more than a light-skinned or purple hand; this last piece of evidence suggests that this embodiment may increase when participants related more positively (higher warmth) with their in-group. Different results were observed for White individuals. In this group, the ownership toward the hand of their skin color varied with participants' empathic abilities. This last result is in line with previous research showing that empathic response is stronger in individuals of the same race (Avenanti et al., 2005; Xu et al., 2009; Avenanti et al., 2010) and studies on the RHI that showed an association between the strength of the illusion and empathic concern (Asai et al., 2011) or fantasy (Farmer et al., 2012). For instance, Asai et al. (2011) found a significant correlation between the sensitivity to the RHI and the Empathic concern of the IRI. Farmer et al. (2012) investigated this further and found that the fantasy subtest of the IRI predicted ownership for both dark- and light-skinned RH; in addition, the personal distress of the IRI also predicted the ownership of a dark-skinned RH. Our data suggest an association between ownership and empathy in White individuals: the ownership over the virtual hand may increase with participants' ability to understand and perspective other individuals (Perspective Taking) but also emphasize other people's experience of distress (Personal Distress) (Davis, 1980).

In the second exploratory analysis, we looked at the possible effects of our VR task on participants' racial bias. In line with previous work (Nosek, 2002), Black participants did not show a racial bias in the PRE VR and their IAT scores remained consistent in the POST VR sessions. On the contrary, White participants showed a racial bias in the PRE VR session. This bias was still present after White participants performed the VR task with light-skinned or purple hands, but not as such in the dark-skinned hand condition. Indeed, the d' prime score of the POST VR condition of White participants did not differ from zero after the dark-skinned hand condition but differed from zero in the other two conditions. Although we did not observe a significant reduction of racial bias, these results suggest that the experience of a natural skin color different from the participant's color had a positive effect on the participant's racial bias. This finding is consistent with other VR studies that did not involve social interaction and showed a reduction of racial bias in White individuals after embodying a dark-skinned avatar (Banakou et al., 2016; Peck et al., 2013). One might speculate that the absence of social interaction in our and others (Banakou et al., 2016; Peck et al., 2013) VR tasks may have enhanced the focus on one's body rather than social interactions, thereby increasing the embodiment of the virtual body. Across VR hand conditions, the high ownership and agency ratings support this argument.

Our data also suggested that individuals with greater initial racial bias may benefit the most from VR training with an avatar of different skin color (Farmer et al., 2014). Indeed, White individuals who showed a racial bias before starting the VR had a reduction of d-score after embodying an avatar of natural skin colors, but not as such with a purple hand. This embodiment of the VR hand does not seem to be correlated with participants' racial bias, supporting the idea that body ownership and embodiment might be to a considerable degree automatic rather than mediated by top-down effects (Farmer et al., 2012; Maister et al., 2013; Farmer etal., 2014). This observation might not extend to Black participants, as in this group ownership of the darken-skinned VR was correlated with the explicit attitude towards the in-group. These results should be considered with caution and future studies should investigate whether different mechanisms may account for the embodiment of the VR hand of the in-group color in Black and White individuals.

A possible limitation of the present study is that we used a within-subjects design. A between-subjects design might have been more appropriate as it has the advantage of reducing effects of demand characteristics, social desirability, or carry-over effect across conditions (Maister et al., 2013; Farmer et al., 2014). It is possible that some dissimilarities with previous literature, such as the absence of a significant relationship between ownership and changes in implicit bias (Maister et al., 2013), could be due to the difference in the studies' design; future work should explore this issue.

We used the IAT to measure racial bias. Although widely used, the IAT has been subjected to several criticisms (see Fiedler et al., 2006 for a review on the topic). First, the task measures the strength of the association between adjectives with positive and negative connotations and targets conceptual categories. The implicit assumption is that these measures reflect participants' attitudes toward the target categories, which is not necessarily the case. For instance, as Fiedler et al. (2006) pointed out, the association between negative feelings (e.g., remorse) and an outgroup category could reflect positive (e.g., compassion) rather than negative attitudes towards this outgroup. Second, the IAT effects strongly depend on the specific choice of adjectives and target words, suggesting that the results reflect a contingent representation used to solve the sorting task rather than a more structural attitude towards the target categories. Third, factors such as compliance with the examiner may also play a role, so that participants may switch between response strategies across blocks trying to match the examiner's expectations. Fourth, the effects of IAT are often an overestimation of the bias, which may reflect other factors like cultural differences. This aspect is crucial when comparing the results of IAT between groups of individuals. In addition, the IAT is difficult to manipulate (see Lai et al., 2014). For instance, Lai et al. (2014) tested the efficiency of different forms of intervention in reducing racial bias and found a significant reduction only in eight out of seventeen interventions. Importantly, as the authors pointed out (Lai et al., 2014), it is not clear that the effect of the intervention is long-lasting and induces a behavioral change. Taking into consideration all these factors, our results should be taken with caution, and follow-up work should explore changes in the racial bias in a larger sample, considering possible cultural differences between groups and using a larger variety of tasks to assess racial bias.

In previous studies, we demonstrated that body form representations (e.g., the apparent size of a body part; Ambron et al., 2017; Ambron et al., 2018) or changes in the body schema (e.g., the position of the body in space; Ambron et al., 2020) influence motor abilities. The current study provides additional evidence that changes in body representations influence action performance. Indeed, we confirmed that the embodiment of different skin colors is rapid, can occur only after a few seconds, and influences the motor system. Participants performed the reaching movements as if the VR hand was their hand and as if the hand colors were their skin color; this embodiment influenced participants' attitudes toward other individuals. This evidence has important implications as it suggests that VR and the embodiment of different skin colors can be used as possible interventions to favor inclusion and social integration between different racial groups.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

This study was reviewed and approved by the University of Pennsylvania.

Author contributions

EA designed the study, analyses the data and wrote the manuscript. AM designed and implemented the tasks. SG tested the participants. RH contributed in the design of the study and in the revision of the manuscript. HC designed the study and revised the manuscript.

Acknowledgments

We would like to thank Stephanie Connor for the help in data collection. Samuel Cason and Olufunsho Faseyitan for their help in several aspects of the project.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Ambron, E., Jax, S., Schettino, L. F., and Coslett, H. B. (2018). Magnifying vision improves motor performance in individuals with stroke. *Neuropsychologia* 119, 373–381. doi:10.1016/j.neuropsychologia.2018.08.029

Ambron, E., Miller, A., Connor, S., and Branch Coslett, H. (2020). Virtual image of a hand displaced in space influences action performance of the real hand. *Sci. Rep.* 10 (1), 1–11. doi:10.1038/s41598-020-66348-4

Ambron, E., Schettino, L. F., Coyle, M., Jax, S., and Coslett, H. B. (2017). When perception trips action! the increase in the perceived size of both hand and target matters in reaching and grasping movements. *Acta Psychol.* 180, 160–168. doi:10.1016/j.actpsy.2017.09.011

Asai, T., Mao, Z., Sugimori, E., and Tanno, Y. (2011). Rubber hand illusion, empathy, and schizotypal experiences in terms of self-other representations. *Conscious. cognition* 20 (4), 1744–1750. doi:10.1016/j.concog.2011.02.005

Avenanti, A., Bueti, D., Galati, G., and Aglioti, S. M. (2005). Transcranial magnetic stimulation highlights the sensorimotor side of empathy for pain. *Nat. Neurosci.* 8 (7), 955–960. doi:10.1038/nn1481

Avenanti, A., Sirigu, A., and Aglioti, S. M. (2010). Racial bias reduces empathic sensorimotor resonance with other-race pain. *Curr. Biol.* 20 (11), 1018–1022. doi:10.1016/j.cub.2010.03.071

Banakou, D., Groten, R., and Slater, M. (2013). Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proc. Natl. Acad. Sci. U. S. A.* 110 (31), 12846–12851. doi:10.1073/pnas.1306779110

Banakou, D., Hanumanthu, P. D., and Slater, M. (2016). Virtual embodiment of White people in a black virtual body leads to a sustained reduction in their implicit racial bias. *Front. Hum. Neurosci.* 10, 601. doi:10.3389/fnhum.2016.00601

Botvinick, M., and Cohen, J. (1998). Rubber hands 'feel'touch that eyes see. *Nature* 391 (6669), 756. doi:10.1038/35784

Bruneau, E. G., Cikara, M., and Saxe, R. (2017). Parochial empathy predicts reduced altruism and the endorsement of passive harm. *Soc. Psychol. Personality Sci.* 8 (8), 934–942. doi:10.1177/1948550617693064

Caola, B., Montalti, M., Zanini, A., Leadbetter, A., and Martini, M. (2018). The bodily illusion in adverse conditions: Virtual arm ownership during visuomotor mismatch. *Perception* 47 (5), 477–491. doi:10.1177/0301006618758211

Damasio, A. R. (1994). Descartes' error and the future of human life. *Sci. Am.* 271 (4), 144. doi:10.1038/scientificamerican1094-144

Davis, M. H. (1980). *Interpersonal reactivity index*.

Farmer, H., Maister, L., and Tsakiris, M. (2014). Change my body, change my mind: The effects of illusory ownership of an outgroup hand on implicit attitudes toward that outgroup. *Front. Psychol.* 4, 1016. doi:10.3389/fpsyg.2013.01016

Farmer, H., Tajadura-Jiménez, A., and Tsakiris, M. (2012). Beyond the colour of my skin: How skin colour affects the sense of body-ownership. *Conscious. cognition* 21 (3), 1242–1256. doi:10.1016/j.concog.2012.04.011

Fiedler, K., Messner, C., and Bluemke, M. (2006). Unresolved problems with the "I", the "A", and the "T": A logical and psychometric critique of the implicit association test (IAT). *"A", "T" A Log. psychometric critique Implicit Assoc. Test (IAT). Eur. Rev. Soc. Psychol.* 17 (1), 74–147. doi:10.1080/10463280600681248

Frank, K. A., Maroulis, S. J., Duong, M. Q., and Kelcey, B. M. (2013). What would it take to change an inference? Using rubin's causal model to interpret the robustness of causal inferences. *Educ. Eval. Policy Analysis* 35 (4), 437–460. doi:10.3102/0162373713493129

Greenwald, A. G., McGhee, D. E., and Schwartz, J. K. L. (1998). Measuring individual differences in implicit cognition: The Implicit Association Test. *J. Personality Soc. Psychol.* 74, 1464–1480. doi:10.1037/0022-3514.74.6.1464

Greenwald, A. G., Nosek, B. A., and Banaji, M. R. (2003). Understanding and using the implicit association test: I. An improved scoring algorithm. *J. Personality Soc. Psychol.* 85, 197–216. doi:10.1037/0022-3514.85.2.197

Groom, V., Bailenson, J. N., and Nass, C. (2009). The influence of racial embodiment on racial bias in immersive virtual environments. *Soc. Influ.* 4 (3), 231–248. doi:10.1080/15534510802643750

Hasler, B. S., Spanlang, B., and Slater, M. (2017). Virtual race transformation reverses racial in-group bias. *PloS one* 12 (4), e0174965. doi:10.1371/journal.pone.0174965

Lai, C. K., Marini, M., Lehr, S. A., Cerruti, C., Shin, J. E. L., Joy-Gaba, J. A., et al. (2014). Reducing implicit racial preferences: I. A comparative investigation of 17 interventions. *J. Exp. Psychol. General* 143 (4), 1765–1785. doi:10.1037/a0036260

Lira, M., Egito, J. H., Dall'Agnol, P. A., Amodio, D. M., Gonçalves, Ó. F., and Boggio, P. S. (2017). The influence of skin colour on the experience of ownership in the rubber hand illusion. *Sci. Rep.* 7 (1), 1–13. doi:10.1038/s41598-017-16137-3

Lopez, S., Yang, Y., Beltran, K., Kim, S. J., Cruz Hernandez, J., Simran, C., .and Yuksel, B. F. (2019). "Investigating implicit gender bias and embodiment of White males in virtual reality with full body visuomotor synchrony," in *Proceedings of the 2019 CH*I Conference on human Factors in computing systems, 1–12.

Maister, L., Sebanz, N., Knoblich, G., Tsakiris, M., Medina, J., and Coslett, H. B. (2013). Experiencing ownership over a dark-skinned body reduces implicit racial biasFrom maps to form to space: Touch and the body schema. *CognitionNeuropsychologia* 12848 (23), 170645–178654. doi:10.1016/j.neuropsychologia.2009.08.017

Marino, B. F., Stucchi, N., Nava, E., Haggard, P., and Maravita, A. (2010). Distorting the visual size of the hand affects hand pre-shaping during grasping. *Exp. Brain Res.* 202 (2), 499–505. doi:10.1007/s00221-009-2143-4

Medina, J., and Coslett, H. B. (2016). Understanding body representations. *Cogn. Neuropsychol.* 33 (1-2), 1–4. doi:10.1080/02643294.2016.1197195

Nosek, B. A., Banaji, M. R., and Greenwald, A. G. (2002). Harvesting implicit group attitudes and beliefs from a demonstration web site. *Group Dyn. Theory, Res. Pract.* 6 (1), 101–115. doi:10.1037/1089-2699.6.1.101

Nosek, B. A. (2005). Moderators of the relationship between implicit and explicit evaluation. *J. Exp. Psychol. General* 134 (4), 565–584. doi:10.1037/0096-3445.134.4.565

Peck, T. C., Seinfeld, S., Aglioti, S. M., and Slater, M. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Conscious Cogn* 22 (3), 779–787. doi:10.1016/j.concog.2013.04.016

Slater, M., and Banakou, D. (2021). The golden rule as a paradigm for fostering prosocial behavior with virtual reality. *Curr. Dir. Psychol. Sci.* 30 (6), 503–509. doi:10.1177/09637214211046954

Slater, M., and Sanchez-Vives, M. V. (2016). Enhancing our lives with immersive virtual reality. *Front. Robot. AI* 3, 74. doi:10.3389/frobt.2016.00074

Van Der Hoort, B., Guterstam, A., and Ehrsson, H. H. (2011). Being barbie: The size of one's own body determines the perceived size of the world. *PloS one* 6 (5), e20195. doi:10.1371/journal.pone.0020195

Xu, X., Zuo, X., Wang, X., and Han, S. (2009). Do you feel my pain? Racial group membership modulates empathic neural responses. *J. Neurosci.* 29 (26), 8525–8529. doi:10.1523/jneurosci.2418-09.2009

Yee, N., Bailenson, J. N., and Ducheneaut, N. (2009). The Proteus effect: Implications of transformed digital self-representation on online and offline behavior. *Commun. Res.* 36 (2), 285–312. doi:10.1177/0093650208330254

Yee, N., and Bailenson, J. N. (2006). Walk a mile in digital shoes: The impact of embodied perspective-taking on the reduction of negative stereotyping in immersive virtual environments. *Proc. PRESENCE* 24, 26.

Yee, N., and Bailenson, J. (2007). The Proteus effect: The effect of transformed self-representation on behavior. *Hum. Comm. Res.* 33 (3), 271–290. doi:10.1111/j.1468-2958.2007.00299.x