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Exploring Virtual Embodiment and Implicit Racial Bias in Adolescents and Adults

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Abstract

Racial bias emerges early in life: explicit bias is often observable in childhood but tends to decline with age, whereas implicit bias typically persists through adolescence, shaped by stereotypes, peer dynamics, and identity development. Given adolescents' heightened sensitivity to peer exclusion and discrimination, interventions targeting implicit bias during this stage may have important implications. Prior studies suggest that embodying avatars of different races in virtual reality (VR) can influence implicit attitudes, with effects depending on surrounding social context: positive interactions may reduce bias, whereas negative experiences may exacerbate it. This study extends this work, examining whether implicit racial bias changes from pre- to post-exposure following embodiment in a Black virtual body presented in either a positive or negative social context among White adolescents and adults. Participants experienced a strong sense of embodiment, with adolescents reporting greater perceived agency, while adults exhibited stronger emotional reactions to social cues. Nevertheless, no statistically detectable changes in racial bias were found from pre- to post-exposure, and these changes did not differ significantly by social context condition or age group. Overall, in this brief, single-session, and primarily non-interactive embodiment scenario with non-reciprocal crowd exposure, we found no statistically significant short-term changes in racial bias. However, the intervention elicited strong embodiment and selective, age-dependent differences in socio-affective experience, suggesting that more intensive, socially interactive, and tailored VR designs may be required for attitude change.

Keywords: virtual reality; virtual embodiment; implicit racial bias; adolescents; social context; co-presence

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1. Introduction

1.1. The Development of Racial Bias

Racial bias is the tendency to respond negatively to individuals of a particular racial group due to one's own group affiliation. This bias manifests in negative beliefs, prejudiced attitudes, and discriminatory behaviors toward members of that group [1], which can have significant and widespread harmful effects on individuals, communities, and society as a whole [2]. Research on the development of racial bias has largely focused on explicit racial bias, which involves conscious stereotyping and discriminatory behavior, and emerges quite early in development. Indeed, studies indicate that young children exhibit racial bias when asked to assign positive or negative attributes to individuals of different racial groups, for example when associating more favorable traits (e.g., "nice," "friendly") with their own race and more negative traits (e.g., "bad," "naughty") with other races [3,4].

Importantly, the emergence of this bias appears to be supported by an even earlier tendency to prefer own-race faces compared to other-race faces [5]. Indeed, by 3 months of age, infants tend to show a visual preference for faces that match the race of their primary caregivers and those in their immediate environment [6,7]. The preference for own-race faces in infancy should not necessarily be interpreted as an early form of racial bias [8]. Instead, it likely reflects infants' greater familiarity with the faces they see most often. As children grow, this perceptual bias likely supports the emergence of explicit forms of racial bias, which, however, appear to decline by age 7 and disappear around age 12 [4]. This decline has been attributed to a series of cognitive, social and moral factors, such as the development of a greater sense of fairness [9], as well as greater control over explicit expressions of racial bias [10].

However, there is also another, more subtle, form of racial bias known as implicit racial bias, which refers to automatically activated and often unintentional racial associations. Interest in implicit bias grew partly from evidence that racial inequalities persisted despite declines in openly expressed prejudice [11]. In children, using child-friendly IAT variants, racial bias has been documented in very young children [12,13]. Interestingly, it appears that reducing such bias is possible through exposure to positive outgroup exemplars. For example, Gonzalez and colleagues [14] exposed White and Asian children to Black individuals who were depicted as 'good' individuals. Racial bias, as assessed using the IAT, revealed that those children exposed to positive Black exemplars showed a reduction in implicit racial bias compared to children in the control condition. However, this only occurred in older children (10 years), but not in the younger ones (6 years), suggesting that younger children are more resistant to changes.

How can this developmental trend be explained? It could be, in line with the explicit racial bias studies, that older children acquire more control over their responses. This, in turn, could also modulate more automatic and implicit responses. If this is true, one would expect even older children and adolescents to exhibit less bias. However, data are not so consistent. Indeed, racial bias, both implicit and explicit, has been reported to undergo important changes during adolescence: explicit racial biases tend to decrease as adolescents become more aware of social norms and egalitarian values; on the contrary, implicit biases often persist and may even strengthen due to exposure to societal stereotypes and group identity formation [15]. Several cognitive and social factors might influence the development and expression of racial bias during adolescence, one of these being the need to belong to specific ingroups. Adolescents are particularly susceptible to ingroup favoritism, as they seek social belonging and self-identity, which can inadvertently reinforce biases unless actively challenged. Peers play a crucial role in shaping attitudes and behaviors during adolescence, so that friendships that include peers with diverse ethnic backgrounds reduce racial bias, whereas exposure to racially homogenous peer groups can reinforce stereotypes and prejudices [3].

Adolescence represents a period of heightened susceptibility to environmental exposure, and this is particularly true when it comes to mental health. In other words, a heightened susceptibility to mental disorder is commonly triggered in adolescence by stressors, one of these being discrimination and social exclusion. For example, Benner and Wang [16] conducted a meta-analysis on 214 studies involving over 91,000 adolescents, and showed that perceived racial/ethnic discrimination is significantly associated with increased socioemotional distress, decreased academic motivation and achievement, and higher engagement in risky behaviors.

Taken together, this developmental literature suggests adolescence is both a theoretically important and practically relevant period for examining bias and its malleability.

Against this background, the core question of the present study is whether embodying White participants in a Black virtual body in VR can modify implicit racial bias and whether any such effect depends on the social context of the experience. We focus particularly on White adolescents, for whom peer-based inclusion and exclusion may be especially salient, and we compare their responses with those of White adults exposed to the same VR scenario. Importantly, our hypotheses are derived from prior VR embodiment research showing that bias outcomes depend on the valence of the surrounding social context [17].

1.2. Virtual Embodiment

Over the past decade, immersive VR has been applied to understand and address implicit racial bias in different scenarios. This is accomplished by altering how individuals' bodies are represented in the virtual realm, a process known as virtual embodiment. It involves substituting a person's actual body with a life-sized virtual body, spatially and visually aligning the virtual body with the real body, allowing the individual to perceive events from the viewpoint (first-person perspective) of this virtual representation. When participants wearing a wide-field-of-view, head-tracked, stereo head-mounted display engage with their virtual representation, they see a life-sized virtual body in place of their own. This virtual body imitates their movements synchronously with their real body via real-time motion capture data. Furthermore, it can be configured that when the virtual body is perceived to be affected by an object, a corresponding tactile sensation can be felt on the person's real body.

Virtual embodiment can create a subjective sensation of owning the virtual body addressed in the literature as a body ownership illusion (BOI) [18]. Body ownership involves the perception that a foreign body part belongs to one's own body or that an entirely different body is, in fact, one's own [19–21]. The illusion of body ownership hinges on specific factors including the merging of proprioceptive and vestibular signals pinpointing body part (or whole-body positioning), the visual perception of one's body configuration, and prolonged multisensory stimulation confirming these bodily aspects [22,23]. In VR BOIs have been replicated with respect to different body parts and whole virtual bodies [21,24,25] even when these differ substantially from participants' real bodies with respect to age [26–29], gender [30–33], or other visual characteristics [27,34–36]. More interestingly, however, research has shown that virtual embodiment can lead to changes in individuals' behaviors and attitudes based on the perceived expectations linked to that particular body [37], a phenomenon known as the Proteus effect [38]. For instance, the attractiveness of the virtual body influenced how closely participants approached others, and embodying a taller virtual body boosted confidence during negotiations, an effect that carried over to real-world interactions as originally shown by Yee and Bailenson [39]. Adults placed in a child's virtual body perceived objects in the virtual world as larger compared to those in an adult-shaped body of the same height [40]. Changes occurred not only in perceptions but also in actions as shown in [41], where participants change their gameplay while embodied in an alien-like avatar compared to being embodied in a humanoid avatar. Similarly, embodying a body resembling an older Albert Einstein enhanced young adults' cognitive performance in comparison to being in a virtual body of their actual age [27]; and embodying Leonardo da Vinci led to significantly higher divergent thinking abilities compared to embodying self-avatars [35].

Together, these findings suggest that altering self-representation via immersive embodiment can shape cognition, affect, and social behavior, thus making VR embodiment a promising method for experimentally probing whether (and under what conditions) perspective-taking can influence intergroup attitudes such as racial bias.

1.3. Virtual Embodiment and Racial Bias

With respect to race, multiple research studies have indicated that when White individuals embody a dark-skinned virtual body, it results in a decrease in their implicit racial bias. Maister et al. [42] demonstrated this using the rubber hand illusion, where participants felt ownership over a black rubber hand, and their bias was measured using the racial implicit association test (IAT) [43]. The IAT measures associations between categories (in this case, racial categories) and stimuli with positive or negative values. Faster responses and fewer errors when Black faces are linked with negative words and White faces with positive words indicate implicit bias against Blacks.

Peck et al. [36] conducted a study with White participants embodying different virtual bodies and found a reduction in bias against Blacks only among those in the black-skinned virtual body. This effect, replicated in [44,45], showed sustained results for at least a week after the VR experience. Hasler et al. [45] discovered that participants mimicked a virtual partner more when that partner shared the same virtual skin color. Bedder et al. [46] proposed a neural network model that reproduces these virtual embodiment results. According to this model, embodying a different race provides significant new information, creating a disruption in prior associations, leading participants to more readily associate a Black face in the IAT with themselves and their positive attributes, disrupting existing associations. A systematic review of IVR for reducing racial bias [47] highlights both the potential of these approaches and the variability of their effects, suggesting that outcomes depend critically on the specific design of the embodiment experience and the surrounding social context.

Recently, the authors of [44] sought to investigate how the social context and negatively charged embodiment experience impacted the results. It was observed that while implicit racial bias decreased for participants in affective positive or neutral scenarios, it increased for those in a negative context, aligning with the findings reported by Groom et al. [48]. It was argued that this shift in associations between group representations and emotional valence involves implicit learning. Past research indicates that negative emotions can impede the formation of new associations [49], likely explaining why a reduction in implicit bias does not occur in negatively charged settings.

However, it remains unclear how reliably these effects generalize to younger populations, and how contextual social cues (acceptance vs. subtle rejection) shape the embodiment–bias link. Studies directly manipulating social context valence in adolescent samples remain scarce. This motivates the present study's focus on social context as a potential moderator of bias change following racial embodiment.

1.4. Aim and Hypotheses of Present Study

In summary, prior VR studies demonstrate that embodying an outgroup body can sometimes reduce implicit bias, but outcomes appear sensitive to social context, and adolescent evidence remains scarce. In this study, our objective is to explore the influence of virtual embodiment on implicit racial bias in White adolescents, building upon the previously introduced findings, and examine whether the same pattern generalizes to a comparison sample of White adults tested in the identical VR scenario. Currently, research examining VR embodiment and racial bias in adolescents remains scarce. Indeed, experiencing racism and racial/ethnic discrimination during adolescence is associated with poorer well-being and increased socioemotional distress among racially minoritized youth [16,50]. Because adolescents' peer environments strongly shape exclusion and inclusion dynamics, understanding whether White adolescents' racial attitudes are malleable and under what social context conditions has implications for efforts to reduce discriminatory peer behaviors and improve school social climate.

We designed an experimental study based on the protocol introduced by [44] where White adolescents were placed in a virtual street outside a high school while embodied as Black individuals, amidst crowds of virtual students (Exp. 1). Some passer-by students displayed negative behavior like frowning and turning away, and some passer-by offered friendly acknowledgments like waving at them with a pleasant expression. Building on prior research, showing that negative affect can hinder the formation of new associations underlying embodiment-related bias change [44,48], we hypothesized that when within a Black avatar embodiment scenario, pre-to-post changes in implicit racial bias would differ depending on the valence of the surrounding social context. We compared the results with those obtained from a group of White adults embodied in the same virtual setting (Exp. 2). In addition, self-esteem and sensory processing sensitivity were included as exploratory individual difference variables, given possible age-related differences between adolescents and adults. Self-esteem was included because previous virtual embodiment research suggests that responses to adopting a virtual identity may vary according to participants' self-esteem [17,27]. Sensory processing sensitivity (SPS), measured using the Highly Sensitive Person Scale, is a continuous temperament-related trait reflecting individual differences in the perception and processing of sensory, emotional, and social information. Higher SPS has been associated with greater responsiveness to environmental influences and increased neural processing of subtle visual changes [51,52]. SPS may therefore be relevant to VR because virtual embodiment requires the integration of visuomotor, bodily, and environmental information, while participants may differ in how strongly they attend and respond to social cues within the virtual environment. Previous research has shown that stronger virtual embodiment can intensify emotional responses to events presented in VR [53]. Self-esteem and SPS were exploratory variables and were not part of the primary hypotheses.

2. Materials and Methods

2.1. Experimental Design

Exp. 1 and Exp. 2 followed between-group design with the variable Crowd split in two levels: negative where some passers-by acted negatively towards the participant such as standing and looking at them while frowning and then turning away (Figure 1A) and positive, where some passers-by greeted the participant by acknowledging them in some way, such as waving at them with a pleasant facial expression (Figure 1B). Social context was conveyed only through brief, non-verbal behaviors from passers-by (facial expression/gesture/body orientation), without dialog or reciprocal task interaction and participants were passive observers during the crowd sequence. Thus, the manipulation targeted the behavioral valence of the crowd toward the participant, rather than stable character roles such as 'likable' or 'villainous' agents. Participants in both Exp. 1 and Exp. 2 were embodied in a Black adolescent virtual body and were exposed to the same set of virtual crowd agents, with Crowd valence as the experimental manipulation.

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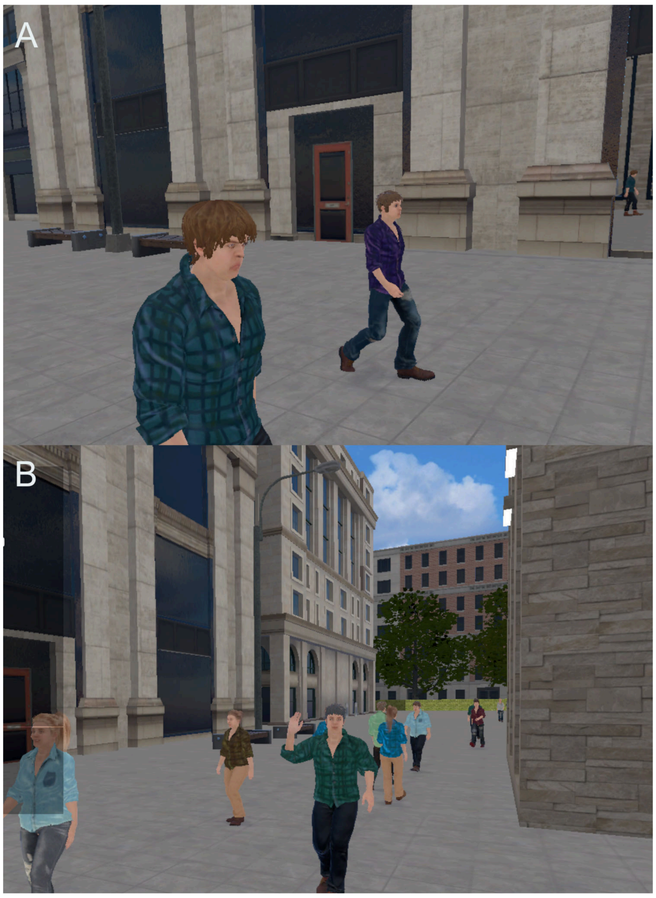

Figure 1. The VR experience. (**A**) The negative condition showing some passers-by acting negatively towards the participant such as frowning, and (**B**) the positive condition where a passer-by greets the participant.

2.2. Participants

In Exp. 1, 32 White adolescents (male n = 18, female n = 14, mean age = 15.28, SD = 1.14) were recruited by word of mouth. In Exp. 2, 39 (male n =14, female n = 25, mean age = 23.15, SD = 2.50, all White) adult participants were recruited through the SONA system of the University of Milan and tested during the same period as the adolescents. Participants reported their sex in the demographic questionnaire and were allowed to provide additional demographic information. One adult female additionally self-described as non-binary. Because gender identity was not assessed using a separate structured measure, this information is reported descriptively and is not treated as a category of the recorded sex variable in further analysis. The study took place at the MiBTec Lab of the University of Milan-Bicocca.

Five additional participants (two adults and three adolescents) were excluded because of technical VR setup failures or incomplete data collection. Some exclusions were determined after completion of the session when the VR data were found to be technically unusable. Crowd condition assignments for the excluded cases were not retained in the final de-identified analytical dataset because excluded operational records were maintained separately from the cleaned analysis files. The final AgeGroup × Crowd cell sizes are shown in Table 1. All participants voluntarily participated in the experiment and signed informed consent before starting the experiment. For adolescents, at least one parent signed informed consent too. Participants had no prior knowledge of the experiment. The sample size was determined pragmatically on the basis of recruitment feasibility for a two-visit lab-based VR study, particularly in adolescents, and was broadly comparable to prior embodiment studies; a formal a priori power analysis was not conducted. Accordingly, the AgeGroup × Crowd analyses should be interpreted as exploratory, particularly for interaction effects.

Table 1. Baseline mean and SD values for self-esteem and sensitivity.

AgeGroup	Crowd	N	Mean ± SD Self-Esteem	Mean ± SD Sensitivity
Adolescents	Negative	15	35.60 ± 3.62	4.74 ± 0.36
Adolescents	Positive	17	37.53 ± 3.45	4.65 ± 0.506
Adults	Negative	20	37.50 ± 3.17	4.33 ± 0.51
Adults	Positive	19	36.63 ± 3.48	4.38 ± 0.368

The experiment was approved by the ethical committee of the University of Milan-Bicocca and performed according to the guidelines of the Declaration of Helsinki for research involving human participants. Ethical considerations were considered, including written informed consent, the right to withdraw from the experiment at any time, and confidentiality. Participants were excluded if they had epilepsy, were taking medication, had mental health difficulties requiring medication, or were not White. After the final phase of the experiment, participants were debriefed about the purpose of the study. For adolescent participants, the debriefing was conducted in age-appropriate language, and a parent or guardian was available for further discussion if concerns arose.

2.3. Technical Setup—VR Application

Participants were fitted with a VIVE Pro (https://vive.com/eu/product/vive-pro) (accessed 8 November 2025) head-mounted display (HMD) with a field of view of 110°, resolution of 2880 × 1600 pixels (1440 × 1600 per eye), and refresh rate of 90 Hz. Five additional VIVE Trackers (https://vive.com/eu/accessory/tracker3) (accessed 8 November 2025) were fitted to the participants to achieve full-body tracking. Specifically, two trackers were used on the arms, two on the legs and one on the participant's waist (Figure 2A).

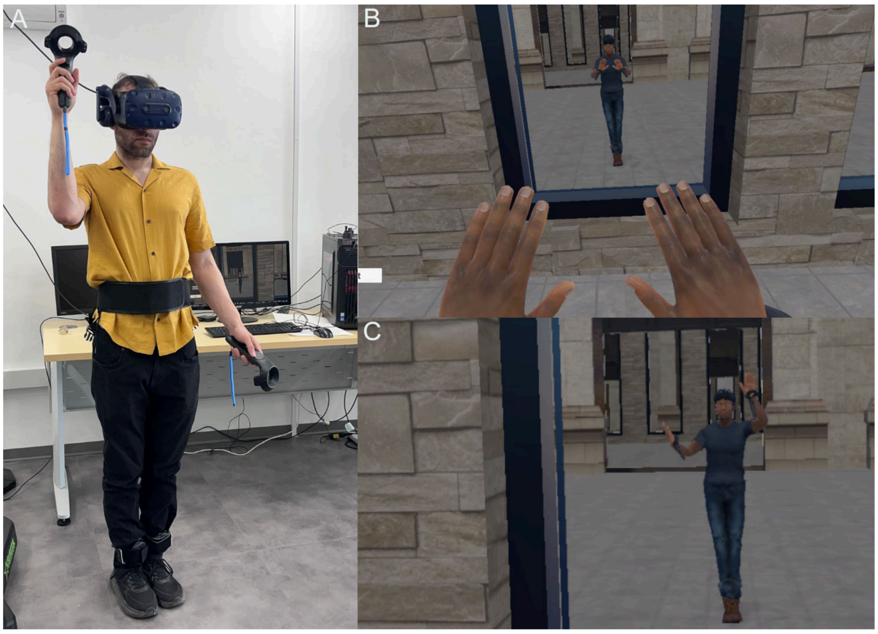

Figure 2. The experimental setup. (**A**) A participant with the VR equipment, (**B**,**C**) the participant embodied in a Black virtual body seen from 1PP and reflected in a window surface during the embodiment process.

The VR application used for this study was developed using Unity (https://unity.com) (accessed 8 November 2025). The virtual agents used were created using the Reallusion Character Creator (https://reallusion.com/character-creator) (accessed 8 November 2025). Also, the various walking animations used for the virtual agents were obtained from Mixamo (https://mixamo.com) (accessed 8 November 2025). For the lip synchronization, gaze animation, and facial expressions, the SALSA (https://crazyminnowstudio.com/unity-3d/lip-sync-salsa) (accessed 8 November 2025) plug-in for Unity was used. The participants' motion tracking data recorded by the HMD and five additional trackers were used to animate the virtual body in real time, using inverse kinematics. This was done using Final IK (http://www.root-motion.com/final-ik.html) (accessed 8 November 2025).

2.4. Procedure

Participants attended two laboratory sessions separated by 30–60 days. Baseline measures were completed during the first session, and the VR exposure and post-exposure assessments were completed during the second session. Participants attended the experiment at scheduled times.

Upon their first visit, participants were seated in front of a desktop computer to complete a demographics questionnaire. Additionally, they underwent assessment using the Rosenberg self-esteem scale [54], the racial IAT [43], and the Pettigrew questionnaire for subtle and blatant prejudice [55].

During their second session, participants were equipped with the head-mounted display (HMD) and body tracking devices (Figure 2A). Upon entering the virtual environment, they found themselves standing near a school entrance surrounded by buildings. Their physical body was replaced by a Black virtual body, observed from a first-person perspective (1PP). Real-time mapping of head and upper body movements onto the virtual body was enabled. Participants viewed their virtual body by looking down and through a reflective window surface (Figure 2B,C). They received a series of instructions through pre-recorded audio. Initially, they were prompted to look around and describe their surroundings, followed by exercises exploring the capabilities and real-time motions of the virtual body, involving movements of their upper body. Following this 3 min embodiment/orientation phase, the scene transitioned to the social context phase, in which virtual characters walked through the same environment and displayed behaviors corresponding to the assigned positive or negative crowd condition. During this phase, participants continued to experience the virtual body from a 1PP but they were not required to directly converse or interact with the virtual characters (Figure 1). Then the virtual scene faded out, concluding the VR exposure. The HMD and trackers were then taken off, and participants were instructed to retake the racial IAT, as well as to complete the Pettigrew questionnaire.

Throughout the VR session, participants were reminded that they could pause or discontinue the procedure at any time without penalty. The entire process took about 40 min, overseen by two experimental operators (two females) present throughout the experiment, who monitored participants for signs of discomfort, distress, or cybersickness. Following completion of the post-VR measures, participants received an age-appropriate debriefing explaining the aims of the study and clarifying that the positive and negative behaviors of the virtual crowd were scripted components of the experimental manipulation rather than genuine evaluations of the participant. Participants were given an opportunity to ask questions and discuss any discomfort arising from the experience.

2.5. Response Variables

Primary outcomes are (i) IAT dscore and (ii) subtle/blatant prejudice (pre/post). Secondary outcomes were post-VR embodiment and social experience measures (ownership, agency, presence, and crowd evaluation) included as manipulation checks and to aid interpretation of bias outcomes. More specifically:

1. **Self-Esteem.** Before the VR exposure, self-esteem was assessed using the Rosenberg self-esteem scale [54]. Its inclusion stemmed from the theory presented in [46], which proposes that individuals embodying a Black virtual identity are inclined to display decreased racial bias in proportion to their level of self-esteem. Participants responded to each statement on a 6-point Likert scale ranging from 1 (strongly disagree) to 6 (strongly agree). Five negatively worded items were reverse-coded prior to the analysis so that higher values represented greater global self-esteem. Total scores were computed by summing all 10 items, resulting in a possible range of 10 to 60, where higher scores indicate higher levels of self-esteem. The typical range is from 38 to 48 equivalent to the standard 15–25 range on the traditional 0–3 scale. In the study by [46], self-esteem was excluded from the analysis as it showed no contribution to the outcomes due to limited variation in self-esteem levels.
2. **Sensitivity.** Sensitivity was measured at baseline using the Highly Sensitive Person (HSP) Scale [56], designed to identify individuals with sensory processing sensitivity (SPS). The HSP Scale consists of 27 items, each rated on a 7-point Likert scale ranging from 1 (not at all) to 7 (extremely). The questionnaire evaluates various aspects of sensitivity, including sensory sensitivity, emotional reactivity, and depth of cognitive processing. Example items include: "Are you easily overwhelmed by strong sensory input?", "Do you seem to be aware of subtleties in your environment?", "Do other people's moods affect you?", etc. Higher overall scores suggest a higher level of sensory processing sensitivity. Item responses were averaged to produce a mean sensitivity score ranging from 1 to 7.
3. **Implicit Association Test (IAT).** Implicit racial bias was assessed at baseline and again after the VR session using an adapted race IAT based on [43] and IAT best research practices [57]. The task comprised four blocks. In Block 1 (race categorization practice), participants categorized photographs of Black and White faces (6 exemplars per category). In Block 2 (valence categorization practice), participants categorized positive and negative adjectives (6 per category) presented auditorily through headphones. Blocks 3 and 4 were the critical combined blocks used to assess associative strength. During each trial, participants responded either to a face shown on the screen or to an auditory adjective. The category mappings were displayed continuously on the left and right sides of the screen: the race categories were represented by Black/White face labels, and the valence categories by happy/sad emoticons, which served as on-screen indicators of positive versus negative valence. In the congruent block, White faces and positive adjectives shared one response key, whereas Black faces and negative adjectives shared the other. In the incongruent block, these pairings were reversed. Participants responded using the q and p keys, which served simply as the left- and right-hand response keys. These keys were selected because they are positioned at opposite ends of the keyboard, providing a clear and spatially distinct two-choice mapping; the specific letters themselves had no theoretical significance. The IAT scoring and exclusion procedures followed the recommendations described in Greenwald et al. [43]. Scores were computed from the two critical combined blocks after applying the recommended latency, error handling, and exclusion procedures. The order of the congruent and incongruent critical blocks was counterbalanced across the pre- and post-VR assessments. Participants who completed the congruent-first sequence at the pre-VR assessment completed the incongruent-first sequence at the post-VR assessment, whereas participants who completed the incongruent-first sequence at pre-VR completed the congruent-first sequence at post-VR. Implicit bias was indexed by a

standardized congruency score (dscore), computed as the mean reaction time in the incongruent combined block minus the mean reaction time in the congruent combined block, divided by the standard deviation across the two combined blocks. Higher values indicate relatively faster responding in the White + positive/Black + negative mapping than in the White + negative/Black + positive mapping, reflecting stronger implicit pro-White/anti-Black associations. The IAT was implemented in E-Prime software (https://pstnet.com/products/e-prime/) (accessed 8 November 2025).

4. **Subtle and Blatant Prejudice Scale.** The scale was developed by Pettigrew and Meertens [55] as a psychological instrument to measure two distinct forms of prejudice: blatant and subtle. Blatant prejudice refers to overt and direct negative attitudes toward outgroups, characterized by open rejection and discrimination (e.g., "I would not mind if a Black family moved next door"). Subtle prejudice involves more covert and indirect negative attitudes, often manifesting as the defense of traditional values, exaggeration of cultural differences, and denial of positive emotions toward outgroups (e.g., "Black people are just as intelligent as people from my group"). The scale comprises 20 items, evenly divided between the two types of prejudice. Participants indicated their level of agreement with each statement on a Likert scale, ranging from 1 (strongly disagree) to 5 (strongly agree). Higher scores on the blatant prejudice items indicate more overt prejudicial attitudes, while higher scores on the subtle prejudice items reflect more covert biases. The scale was administered at baseline and after the VR experience.
5. **Post-VR Questionnaire.** Participants completed a post-VR questionnaire assessing body ownership, agency, and presence as distinct aspects of the embodied experience (Table 2). Body ownership was indexed by the core ownership items (e.g., ownership of the virtual body and its mirror reflection; variables body and mirror), while additional items (e.g., feeling as if one had two bodies, that the virtual body did not feel like oneself, or that the avatar's features felt unfamiliar; variables twobodies, notme, and features) served as control items assessing the specificity of the ownership. Agency over the virtual body's movements (variable agency) and presence in the virtual environment (the feeling that one is really there) were assessed separately, and additional items (Table 2) were used to gauge how participants evaluated the virtual crowd and served as additional manipulation checks. The post-VR questionnaire was adapted from established embodiment/presence measures used in prior VR studies (e.g., [44]).

Table 2. Post-VR questionnaire on embodiment, presence, and evaluation of the virtual crowd. The scores ranged from −3 (strongly disagree) to +3 (strongly agree).

Variable	Statement
body	"I felt that the virtual body I saw when looking down at myself was my own body"
mirror	"I felt that the virtual body I saw when looking at myself in the mirror was my own body"
twobodies	"I felt as if I had two bodies"
notme	"I felt as if the virtual avatar was not me"
features	"I felt that my virtual body resembled my own (real) body in terms of shape, skin tone, or other visual features"
agency	"I felt that the movements of the virtual body were caused by my own movements"
presence	"I felt I was in the middle of a crossroad with people walking by"
ingroup	"I identified myself with the people of the crowd and I felt I was one more of them"
gazenegative	"I felt that people of the crowd were looking at me and that situation made me feel nervous and/or uncomfortable"
gazepositive	"I felt that people of the crowd were looking at me and that situation made me feel untroubled and/or comfortable"

Table 2. *Cont.*

Variable	Statement
distancenegative	"I felt that people of the crowd were keeping a distance from me and that situation made me feel nervous and/or uncomfortable"
distancepositive	"I felt that people of the crowd were keeping a distance from me and that situation made me feel untroubled and/or comfortable"
avoidance	"I felt that people of the crowd were avoiding me"
judgement	"I felt I was being judged by the people of the crowd"
rejection	"I felt I was being rejected by the people of the crowd"
friendliness	"The people in the crowd looked friendly"

2.6. Statistical Analysis

Statistical analyses were conducted according to outcome type. Baseline self-esteem and sensitivity were analyzed using two-way ANOVAs with AgeGroup, Crowd, and AgeGroup × Crowd as predictors. Because sensitivity differed between adolescents and adults at baseline, it was included as a covariate in subsequent analyses where AgeGroup comparisons of post-VR social experience or racial bias outcomes were central.

Post-VR questionnaire items were treated as ordinal outcomes and analyzed using ordered logistic regression. Body ownership and control items were modeled as:

$$outcome \sim AgeGroup \times Crowd$$

Agency, presence, and crowd response items were modeled as:

$$outcome \sim AgeGroup \times Crowd + Sensitivity$$

Ordered logistic models are reported using likelihood ratio χ^2 tests, odds ratios, 95% confidence intervals, and nominal p values. AgeGroup contrasts are presented as adults relative to adolescents, and Crowd contrasts as positive relative to negative. Because multiple secondary ordinal questionnaire outcomes were tested, Benjamini–Hochberg FDR correction was applied within conceptually defined outcome families to the AgeGroup, Crowd, and AgeGroup × Crowd tests (body ownership—5 outcomes × 3 experimental effects = 15 tests); agency/presence—2 outcomes × 3 effects = 6 tests; and crowd appraisal—9 outcomes × 3 effects = 27 tests). The proportional odds assumption was assessed using Brant tests. Where predictor-specific non-proportionality was indicated, targeted partial proportional odds sensitivity models were fitted. Sensitivity was treated as a covariate and was not included in the correction families. FDR-adjusted q values are reported in Supplementary Table S1.

Subtle and blatant prejudices were analyzed as change scores, calculated as post-VR minus pre-VR scores. Separate ANCOVA models were fitted for each outcome:

$$score \sim AgeGroup \times Crowd + Sensitivity$$

The IAT was first analyzed using a change score regression:

$$diat \sim AgeGroup \times Crowd$$

Because baseline IAT scores differed between age groups, the primary IAT analysis used ANCOVA predicting post-IAT while controlling for pre-IAT:

$$postiat \sim preiat + AgeGroup \times Crowd$$

For continuous outcomes, the results are reported with F statistics, *p* values, effect sizes, unstandardized estimates, and 95% confidence intervals in Supplementary Tables S3 and S4. Model assumptions were checked using residual diagnostics, and the ANCOVA homogeneity-of-regression-slope assumption was assessed by testing pre-IAT interactions with AgeGroup and Crowd.

3. Results

We first report baseline comparisons to assess group equivalence and identify relevant covariates, followed by manipulation checks to verify the effectiveness of the VR embodiment and social context manipulation, and finally the primary outcome analyses on implicit and explicit racial bias. Full model estimates, effect sizes, and 95% confidence intervals are reported in either in-text or in Supplementary Tables S1–S4.

3.1. Baseline Self-Esteem and Sensitivity

Self-esteem was normally distributed. A two-way ANOVA to test for baseline differences showed no significant main effect for self-esteem across AgeGroup (adolescents vs. adults), $F(1, 67) = 0.38$, $p = 0.542$, $\eta p^2 = 0.006$ or Crowd (positive vs. negative), $F(1, 67) = 0.42$, $p = 0.518$, $\eta p^2 = 0.006$, and no significant AgeGroup × Crowd interaction, $F(1, 67) = 2.94$, $p = 0.091$, $\eta p^2 = 0.042$. Although adolescents showed lower self-esteem overall (M = 36.63, SD = 3.61) than adults (M = 37.08, SD = 3.31), this difference was not significant. The estimated adult–adolescent mean difference was 0.50, 95% CI [−1.13, 2.13]. Mean and SD values for self-esteem are shown in Table 1.

Sensitivity (SPS) was normally distributed. A two-way ANOVA to test for baseline differences in sensitivity across AgeGroup (adolescents vs. adults) and Crowd (positive vs. negative) showed a significant main effect of AgeGroup, $F(1, 67) = 10.31$, $p = 0.002$, $\eta p^2 = 0.133$, with adolescents overall (M = 4.69, SD = 0.44) showing higher sensitivity than adults overall (M = 4.35, SD = 0.44). The estimated adolescent–adult mean difference was 0.34, 95% CI [0.13, 0.56]. Neither the main effect of Crowd, $F(1, 67) = 0.01$, $p = 0.909$, $\eta p^2 < 0.001$ nor the AgeGroup × Crowd interaction, $F(1, 67) = 0.41$, $p = 0.525$, $\eta p^2 = 0.006$ was significant. Because of such group difference, sensitivity was used as a covariate in the subsequent analyses between adolescent and adult groups. Mean and SD values for sensitivity are shown in Table 1.

Baseline sensitivity was also examined as a function of self-reported sex. Females (M = 4.57, SD = 0.48) showed slightly higher sensitivity than males (M = 4.43, SD = 0.45), but this effect did not reach significance $F(1, 63) = 3.91$, $p = 0.055$, $\eta p^2 = 0.058$. No interactions involving sex were significant (all $p > 0.77$). The SDs overlap, indicating high variability in sensitivity scores within both groups. Baseline self-esteem did not differ by sex, $F(1, 63) = 0.31$, $p = 0.579$, $\eta p^2 = 0.005$, with males and females showing similar self-esteem scores.

3.2. Post-VR Experience

3.2.1. Body Ownership

Figure 3 shows the questionnaire scores for body ownership (body and mirror) and the control variables (twobodies, notme, features; Table 2). Body and mirror ratings were generally higher than the control items which remained low or negative across conditions, as expected. Adults showed slightly higher embodiment scores than adolescents in the negative crowd, with a median of 2 [0.75, 2] in adults versus 1 [−1, 2] in adolescents, whereas adolescents showed greater variability. For twobodies, scores were low in all conditions; in the negative crowd, both adolescents and adults had a median of −2, although the spread was wide in both groups (adolescents: [−3, −0.5]; adults: [−3, 0.25]).

For notme scores are again low across AgeGroup and Crowd with median around −1 (adolescents–negative: −1 [−2, 2]; adolescents–positive: −1 [−3, 2]; adults–negative: −1.5 [−2.25, −1]; adults–positive: −1 [−1.5, 0.5]). For features, distributions are similar. Variability is greater in adolescents compared to adults (adolescents–negative: −2 [−3, −1]; adolescents–positive: −3 [−3, −2]; adults–negative: −1 [−2, 0]; adults–positive: −2 [−2.5, −1]). Because these questionnaire outcomes were ordinal, they were analyzed using ordered logistic regression. No significant main or interaction effects were observed for any variable, either before or after FDR correction (all ps $\geq$ 0.086; all FDR-adjusted qs $\geq$ 0.607; full odds ratios and 95% CIs are reported in Supplementary Table S1).

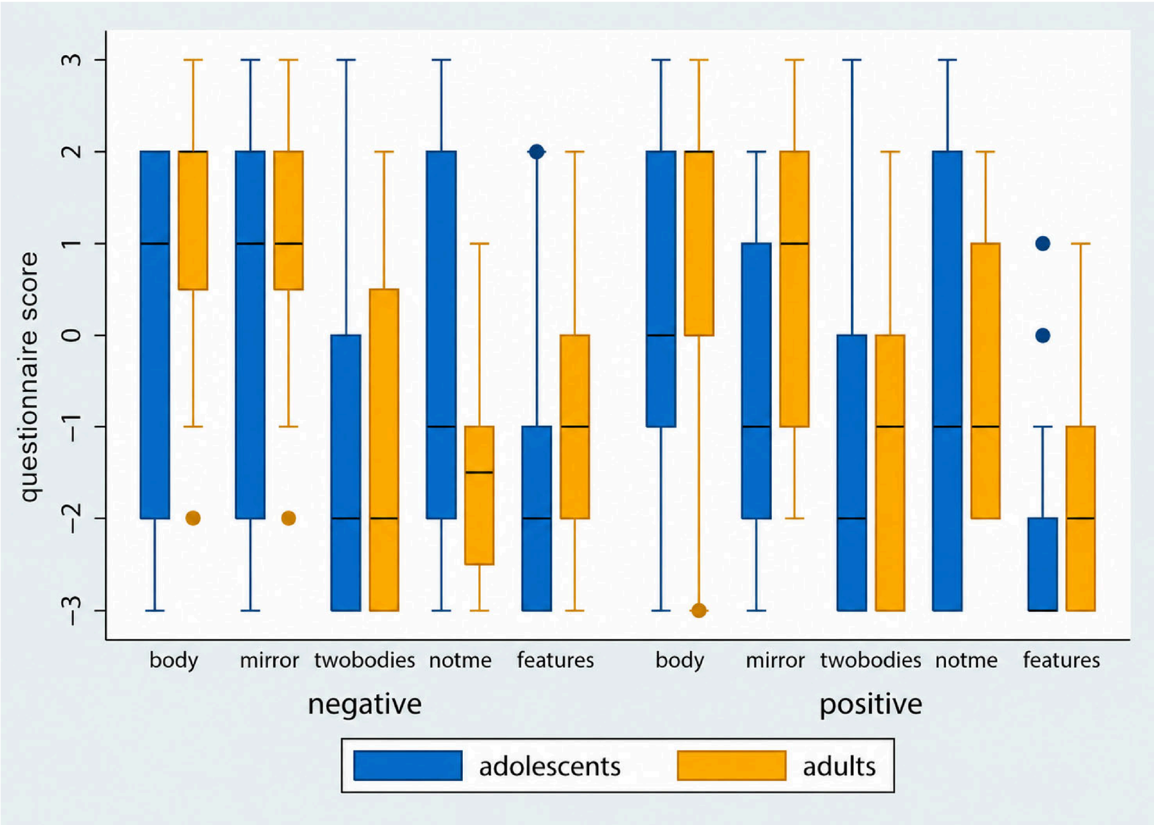

Figure 3. Post-VR ratings for body ownership items (body and mirror) and control items (twobodies, notme, and feature similarity) by AgeGroup and Crowd condition. The thick black horizontal lines are the medians, the boxes are the interquartile ranges, and the whiskers extend to ±1.5 × IQR. Individual points are outliers.

3.2.2. Agency and Presence

Figure 4 shows the questionnaire scores for agency and presence. Agency was high across all conditions, indicating that participants generally felt able to control the virtual body, consistent with stable overall body tracking during the VR experience. However, adolescents reported higher agency than adults (median [Q1, Q3] agency scores were 3 [3, 3] for adolescents in the negative crowd condition and 3 [2, 3] in the positive crowd condition, compared with 2 [2, 3] for adults in both crowd conditions). An ordered logistic regression revealed a nominal effect for AgeGroup with adults reporting lower agency than adolescents ($\chi^2(1) = 6.55$, $p = 0.010$, q = 0.060). However, this effect did not survive FDR correction across the agency/presence outcome family. There were no other significant main or interaction effects. There are no significant differences for presence (AgeGroup, $\chi^2(1) = 0.14$, $p = 0.710$, Crowd, $\chi^2(1) = 0.09$, $p = 0.765$, or their interaction, $\chi^2(1) = 0.59$, $p = 0.443$). Full odds ratios and 95% CIs are reported in Supplementary Table S1.

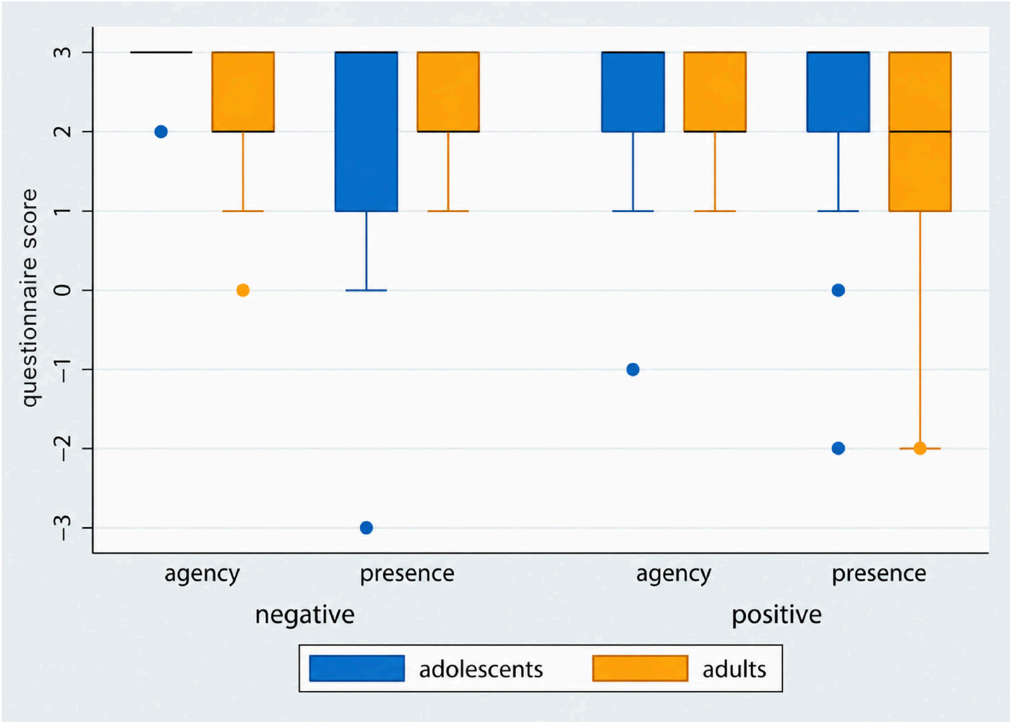

Figure 4. Post-VR agency and presence ratings by AgeGroup and Crowd condition. The thick black horizontal lines are the medians, the boxes are the interquartile ranges, and the whiskers extend to $\pm 1.5 \times$ IQR. Individual points are outliers.

3.2.3. Response to the Crowd

The questionnaire for assessing the impact of the crowd on affect is shown in Table 2. Figure 5 shows the distribution of crowd appraisal ratings across the four AgeGroup × Crowd cells, with cell-level medians and interquartile ranges provided in Supplementary Table S2. Ordered logistic regression models were fitted for each crowd response variable, including AgeGroup, Crowd, AgeGroup × Crowd, and baseline sensitivity as predictors. Because multiple secondary crowd response outcomes were tested, FDR correction was applied across the AgeGroup, Crowd, and AgeGroup × Crowd effects. Nominal *p* values are reported below, and FDR-adjusted q values are reported in Supplementary Table S1:

For gazepositive, there was a nominal main effect of AgeGroup with adults reporting significantly lower scores than adolescents ($\chi^2(1) = 4.87$, $p = 0.027$, q = 0.073). There was no main effect of Crowd. There was an interaction effect where adults in the positive crowd condition report significantly higher scores ($\chi^2(1) = 4.42$, $p = 0.036$, q = 0.079). Neither effect survived FDR correction.

For gazenegative, even though the scores are lower in the positive Crowd, there were no significant main or interaction effects (all $p \geq 0.079$).

For distancepositive there was a nominal effect for AgeGroup, where adults report significantly lower scores than adolescents ($\chi^2(1) = 4.31$, $p = 0.038$, q = 0.079), but this did not survive FDR correction. There is no main effect of Crowd, but there is an interaction effect where adults in the positive crowd condition report significantly higher scores ($\chi^2(1) = 7.92$, $p = 0.006$, q = 0.027), which remained significant after correction. Sensitivity is a significant predictor ($\chi^2(1) = 5.70$, $p = 0.019$), with higher sensitivity associated with lower distancepositive scores.

For distancenegative, there were no main effects for AgeGroup and Crowd, but there was an interaction effect where adults in the positive crowd condition report significantly lower scores ($\chi^2(1) = 5.69$, $p = 0.017$, q = 0.057). However, this did not survive FDR correction. Sensitivity was not a significant predictor here.

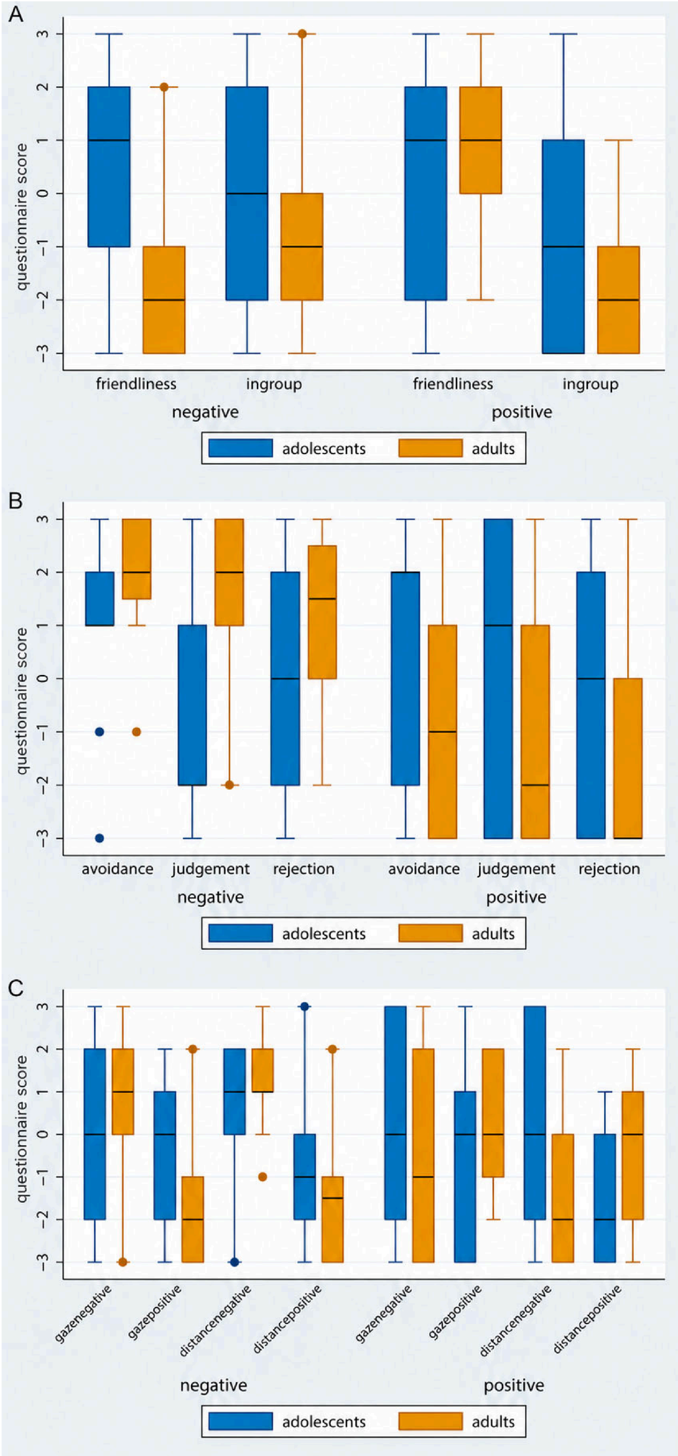

Figure 5. Post-VR crowd appraisal ratings by AgeGroup and Crowd condition. (**A**) Positive appraisal items (perceived friendliness and identification with the crowd as an ingroup), (**B**) negative appraisal items (perceived avoidance, judgment, and rejection), and (**C**) comfort and discomfort associated with the crowd's gaze and interpersonal distance. The thick black horizontal lines are the medians, the boxes are the interquartile ranges, and the whiskers extend to $\pm 1.5 \times$ IQR. Individual points are outliers.

For avoidance, there was a marginal effect of AgeGroup where adults had a tendency for higher scores, but this was not significant ($\chi^2(1) = 3.86$, $p = 0.052$, q = 0.100) and did not survive FDR correction. There was no main effect of Crowd. There was an interaction effect where adults in the positive crowd condition reported significantly lower scores ($\chi^2(1) = 9.03$, $p = 0.003$, q = 0.014), which remained significant after correction.

For judgment, there was a main effect of AgeGroup with adults reporting significantly higher judgment scores than adolescents ($\chi^2(1) = 11.17$, $p = 0.001$, q = 0.014). This was significant after correction. There was no main effect of Crowd. There was an interaction effect even after FDR correction with adults in the positive crowd condition reporting significantly lower judgment scores ($\chi^2(1) = 9.77$, $p = 0.002$, q = 0.014). Sensitivity was not a significant predictor.

For rejection, there is a nominal effect of AgeGroup where adults report higher rejection scores than adolescents ($\chi^2(1) = 4.58$, $p = 0.032$, q = 0.079), but this did not survive correction. There was no main effect of Crowd, but there was an interaction effect where adults in the positive crowd condition reported significantly lower rejection scores ($\chi^2(1) = 7.45$, $p = 0.007$, q = 0.027) even after correction. Sensitivity is a significant predictor ($\chi^2(1) = 4.14$, $p = 0.047$), meaning individuals with higher sensitivity also report higher rejection scores.

For friendliness, there was a main effect of AgeGroup, which remained significant after correction, where adults reported lower friendliness scores than adolescents ($\chi^2(1) = 15.25$, $p < 0.001$, q = 0.014). There was no main effect of Crowd, but there was an interaction effect with adults in the positive crowd condition reporting significantly higher friendliness scores ($\chi^2(1) = 9.99$, $p = 0.002$, q = 0.014), even after correction. Sensitivity is not a significant predictor.

For ingroup, there was a significant main effect of AgeGroup ($\chi^2(1) = 6.50$, $p = 0.011$, q = 0.037) after correction, with adults reporting lower scores than adolescents, but no significant effects of Crowd or interaction effects. Sensitivity is not a predictor.

Predictor-specific diagnostics indicated possible non-proportionality for the Crowd effect in the avoidance and judgment models. Partial proportional odds sensitivity analyses did not alter the substantive AgeGroup or AgeGroup × Crowd conclusions.

3.3. Subtle and Blatant Prejudice

Figure 6A shows the difference in subtle prejudice from pre- to post-VR exposure, calculated as dsubtle = postsubtle–presubtle for the AgeGroup and the Crowd conditions. Thus, positive values indicate an increase from baseline, whereas negative values indicate a decrease from baseline. Descriptively there seems to be a decrease in subtle prejudice for adolescents post-VR intervention for positive (-0.16 ± 0.15) and negative (-0.06 ± 0.28) crowds compared to adults who showed little change overall (positive: 0.03 ± 0.07; negative: 0.04 ± 0.11). However, ANCOVA including baseline sensitivity as a covariate revealed no statistically detectable effects for AgeGroup, $F(1, 66) = 0.09$, $p = 0.766$, $\eta p^2 = 0.001$, Crowd, $F(1, 66) = 0.19$, $p = 0.662$, $\eta p^2 = 0.003$ or their interaction, $F(1, 66) = 0.09$, $p = 0.763$, $\eta p^2 = 0.001$ under the present sample and paradigm. Sensitivity was also not a significant predictor, $F(1, 66) = 0.18$, $p = 0.675$, $\eta p^2 = 0.003$.

Similarly, Figure 6B shows change in blatant prejudice, calculated as dblatant = postblatant − preblatant. Again, descriptively, the scores seem to be reduced for the adolescents group for the negative crowd (-0.14 ± 0.10) compared to the positive (0.05 ± 0.08), whereas adults showed little change (negative: 0.03 ± 0.07; positive: -0.01 ± 0.09). ANCOVA including baseline sensitivity as a covariate revealed no significant effects of AgeGroup, $F(1, 66) = 0.94$, $p = 0.336$, $\eta p^2 = 0.014$, Crowd, $F(1, 66) = 1.93$, $p = 0.169$, $\eta p^2 = 0.028$, or their interaction, $F(1, 66) = 1.45$, $p = 0.233$, $\eta p^2 = 0.021$. Sensitivity was not a significant predictor, $F(1, 66) = 1.21$, $p = 0.275$, $\eta p^2 = 0.018$. Full model estimates and 95% confidence intervals are reported in Supplementary Table S3.

https://doi.org/10.3390/virtualworlds5030040

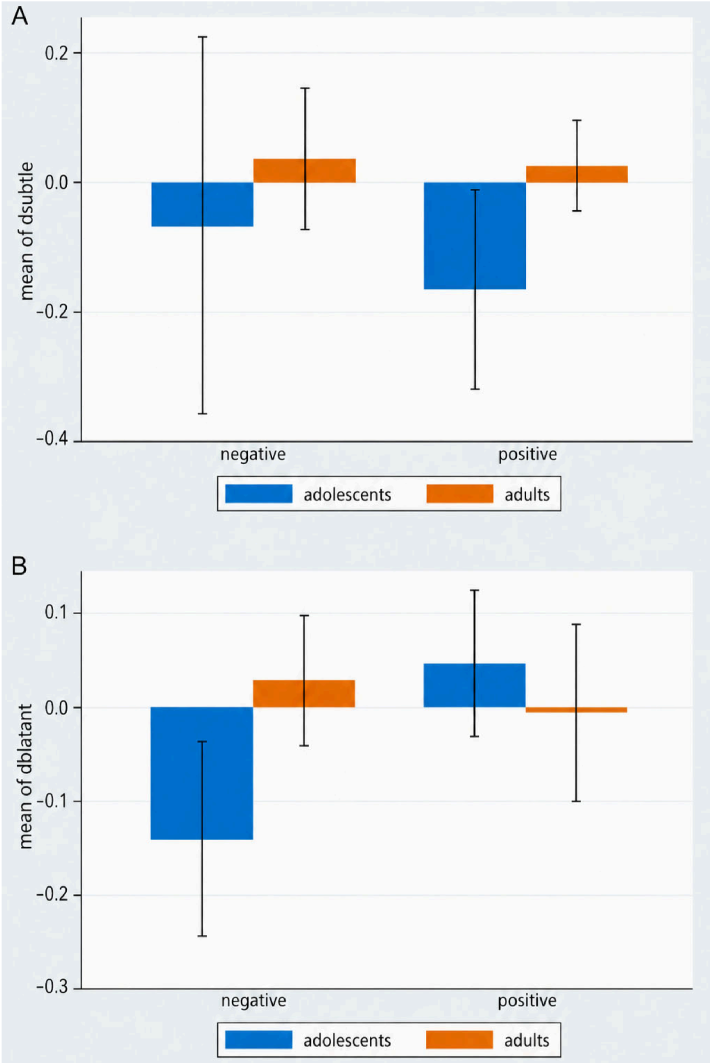

Figure 6. Mean pre-to-post change in (**A**) subtle prejudice (dsubtle) and (**B**) blatant prejudice (dblatant) by AgeGroup and Crowd condition. Change scores were calculated as post-VR minus pre-VR scores. Positive values indicate an increase in prejudice and negative values indicate a decrease. Error bars represent standard errors.

3.4. Implicit Association Test

All participants in the analytical sample contributed valid baseline and post-VR IAT scores. No participants were excluded on the basis of IAT-specific latency, error rate, or performance criteria. An initial change score regression analysis on diat = postiat–preiat shows that being an adult (relative to adolescents) is associated with an increase in diat of 0.0385 units. However, the overall model was not significant $F(4, 66) = 1.70$, $p = 0.160$, $R^2 = 0.094$ and none of the predictors significantly predicted diat: AgeGroup ($\beta = 0.103$, 95% CI [−0.099, 0.305], $p = 0.313$), Crowd ($\beta = 0.081$, 95% CI [−0.119, 0.281], $p = 0.422$), or their interaction ($\beta = 0.023$, 95% CI [−0.247, 0.292], $p = 0.867$). Baseline sensitivity was positively associated with IAT change scores ($\beta = 0.157$, 95% CI [0.003, 0.311], $p = 0.046$.

However, as adolescents exhibited a higher baseline score (preiat) (0.507 ± 0.046) compared to adults (0.268 ± 0.035), an ANCOVA was also conducted to evaluate the effect of the Crowd (positive vs. negative) and AgeGroup (adults vs. adolescents) on post-intervention IAT scores, controlling for baseline scores (preiat). The homogeneity-of-regression-slope assumption was met, as the interactions between baseline IAT and both AgeGroup and Crowd were non-significant (both $p > 0.65$). The overall model was significant, $F(5, 65) = 5.94$, $p = <0.001$ and explained 31.4% of the variance in post-intervention scores ($R^2 = 0.314$).

Nevertheless, the adjusted effects of AgeGroup (F(1, 65) = 0.04, $p = 0.835$, $\eta p^2 = 0.001$), Crowd (F(1, 65) = 0.37, $p = 0.544$, $\eta p^2 = 0.006$), or their interaction (F(1, 65) = 0.16, $p = 0.686$, $\eta p^2 = 0.003$) were not statistically significant. The baseline score (preiat) was a significant predictor of post-intervention scores (F(1, 65) = 20.94, $p < 0.001$, $\eta p^2 = 0.244$). Baseline sensitivity was not a statistically significant predictor of post-IAT scores (F(1, 65), $p = 0.163$, $\eta p^2 = 0.030$). These results indicate that, after controlling for pre-intervention performance, there were no significant differences in post-intervention scores attributable to Crowd or AgeGroup within the present sample and paradigm. Full model estimates and 95% confidence intervals are reported in Supplementary Table S4.

3.5. Findings Summary

Participants reported a strong sense of ownership over the virtual body, along with high levels of agency and presence consistent with previous virtual embodiment studies. In addition, crowd evaluation measures provided partial support for the social context manipulation. Item-level analyses did not reveal a consistent overall crowd effect. Instead, partial evidence for the manipulation emerged through several AgeGroup × Crowd interactions, with clearer differentiation between the positive and negative crowd condition among adults and more variable responses among adolescents. Thus, the manipulation appeared to be perceived more clearly by adults, whereas adolescents showed more variable differentiation between the positive and negative crowd context. Finally, neither explicit prejudice change scores nor post-intervention IAT scores showed significant effects of AgeGroup or Crowd after accounting for baseline performance, although these null findings should be interpreted in light of the modest cell sizes and limited power to detect small-to-medium effects.

4. Discussion

We investigated pre-to-post changes in racial bias following a brief Black avatar embodiment scenario presented in positive or negative social contexts in two age groups (White adolescents and adults). Our key finding was that neither a brief embodiment in a Black avatar nor the social behavior of a virtual crowd produced a statistically significant pre-to-post change in implicit or explicit racial bias under the present sample size and single-session paradigm. In other words, participants' IAT scores and explicit prejudice questionnaire scores did not differ after the VR experience, regardless of whether the surrounding virtual crowd was welcoming or hostile. This outcome contrasts with prior studies that reported reductions in bias following similar VR interventions [17,36,44,45], and we elaborate on these discrepancies below.

Despite the lack of effect on bias measures, the VR manipulation did influence participants' subjective experiences and self-related measures. First, participants in all conditions reported a strong sense of embodiment in their virtual body, indicating that our VR setup successfully induced the illusion. This held true for both adolescents and adults, consistent with previous research showing that immersive embodiment yields a powerful body ownership illusion irrespective of the avatar's appearance. We did find an age-related difference in one component of embodiment: agency (the sense of controlling the virtual body's movements) was significantly lower in adults than in adolescents, although this effect did not survive FDR correction. Both groups reported similar presence (feeling of "being there" in the virtual environment), but adolescents felt slightly more in control of their avatar's actions. Second, we observed selective and age-dependent differences in participants' crowd appraisals rather than a consistent overall effect of social context condition. Several corrected AgeGroup × Crowd interactions indicated clearer differentiation among adults, whereas adolescents' responses were more variable. Specifically, a positive crowd (friendly peers) led to a markedly more positive experience than a negative crowd (peers who ignored or subtly rejected the participant), particularly for adult participants. Adults generally reported more negative feelings, such as feeling judged, rejected, or not belonging than adolescents did, but these negative feelings were significantly mitigated in the positive crowd condition. In fact, with a friendly crowd, adults' sense of being accepted approached the levels reported by adolescents, who overall tended to feel less scrutinized by the virtual crowd. We also found that individual differences in trait sensitivity played a role: participants (across ages) who had higher baseline sensitivity scores were more susceptible to feeling rejected or uncomfortable in the VR social scenario.

4.1. Implicit Racial Bias

A central aim of our study was to test whether embodying White participants in a Black virtual body would reduce their implicit racial bias, as measured by the IAT. We found no significant pre-to-post changes in IAT scores for either adolescents or adults, in any experimental condition. This absence of a statistically detectable effect within the present sample stands in contrast to earlier studies [36,37,44,45] that reported immediate implicit bias reductions after White participants experienced embodiment in a dark-skinned avatar. The study reported in [17] explicitly examined how social context modulates the effect of virtual embodiment on bias. They found that when White participants in a Black avatar encountered a negative social situation (such as being socially excluded), their implicit bias did not decrease as it did in neutral/positive scenarios—in fact, it increased relative to baseline in the negative condition. They concluded that negative affective contexts can block or even reverse the usual bias-reducing effect of embodiment, likely because negative emotions hinder the formation of new positive associations with the outgroup. In our study, the trend in the adolescent subgroup was directionally consistent with that pattern, but these changes were not statistically significant. A possible contributing factor is that adolescents appeared to perceive both negative and positive interactions as positive experiences, without reporting adverse effects such as rejection or negative perceptions from others. The crowd manipulation check results suggest that the social context manipulation was not equally differentiated across age groups. Although adults showed clearer differences between positive and negative crowd contexts, adolescents' responses were more variable and showed weaker evidence of perceiving the negative crowd as socially threatening or rejecting. This is important for interpreting the adolescent bias outcomes, because the hypothesized effect depended on adolescents experiencing the negative context as affectively meaningful. The absence of detectable bias change in adolescents may therefore reflect, at least in part, insufficient manipulation strength or age-related differences in how the virtual crowd was interpreted. Additionally, their questionnaire scores varied considerably, suggesting that our manipulation through the VR setup did not effectively convey negative experiences to adolescent participants. This contrasts with adult participants, whose scores better reflected their feelings during positive and negative interactions. Consequently, definitive conclusions cannot be drawn from the current manipulation design as there is no evidence for large effects under the present manipulation and sample size. Additionally, without a control condition we cannot disentangle intervention effects from test–retest influences. It is also essential to consider cultural factors which were not accounted for in this study but could significantly influence participants' experiences. We recommend conducting more detailed and nuanced pilot testing in future studies, particularly focusing on age-related and cultural differences in VR scenario development. We turn to this point later when we discuss baseline individual differences including self-esteem and sensitivity, factors that could have also played a key role in these differences. Regarding the adult group, in our sample they started with lower baseline bias on average, which may have left less room for reduction and could partly explain why the positive scenario did not yield a significant change.

Our measure of explicit bias (subtle and blatant prejudice) also showed no significant changes from pre-test to post-test. This might be attributed to the following reasons. First, explicit attitudes are easier for participants to control or mask; given that our participants knew by the second session that the study involved race (having completed racial attitude measures at baseline), social desirability may have led them to provide low-prejudice answers both at pre- and post, causing a floor effect. Indeed, at baseline our sample's explicit prejudice scores were relatively low, leaving little room for improvement. Second, previous embodiment studies have often found changes in implicit but not explicit attitudes, reinforcing the idea that VR's influence might operate more on unconscious associations than on conscious values. In [36], for example, the authors reported significant IAT changes but no change in explicit self-reported racial attitudes after their avatar intervention (participants, being university students, were largely low on explicit prejudice to begin with). Explicit prejudice scores also showed no statistically detectable pre-to-post changes or AgeGroup × Crowd effects. Although some descriptive changes were observed within the adolescent conditions, these were small and non-significant. Although we cannot make definitive interpretations beyond what our data supports, one possibility is that adolescents may have been reflecting on the experience and adjusting their conscious attitudes slightly. Interestingly, this small decrease was evident even in the negative crowd condition for adolescents (they showed a minor drop in subtle prejudice and a drop in blatant prejudice in the negative scenario). One speculative interpretation is that simply going through the perspective-taking exercise—even if uncomfortable—might have prompted some adolescents to consciously endorse more egalitarian views. This interpretation remains tentative, however, because reflection or social desirability processes were not directly measured.

Although, as discussed earlier, prior studies have reported immediate reductions in implicit bias following brief outgroup embodiment, such effects appear sensitive to contextual and affective features of the scenario. In our study, embodiment and presence were robust, yet implicit and explicit bias did not significantly shift following a single exposure. One plausible explanation is that the social interaction manipulation, while directionally consistent, was comparatively mild and non-interactive (participants were largely passive observers, with no dialog or task), which may be insufficient to drive measurable updating of implicit associations. Although spontaneous behavioral or affective engagement may have occurred, it was not systematically recorded or analyzed. Furthermore, the present VR procedure should not be understood as a purely passive embodiment experience. Before exposure to the crowd, participants completed an active embodiment phase involving first-person body ownership and real-time visuomotor synchrony, which they continued to experience during the virtual crowd scenes. A second possibility concerns developmental and interpretive differences. Our manipulation check suggests adolescents showed weaker and more variable differentiation between the two crowd conditions than adults. One possible explanation is that the negative social cues were less salient or self-relevant to adolescents (e.g., lower perceived judgment/rejection), leading to weaker internalization of the intended hostile meaning. However, the present measures cannot distinguish this possibility from differences in scenario credibility, cue interpretation, or ecological fit. The brief, limited-interaction nature of the crowd sequence may also have weakened the strength of the manipulation, particularly for participants who did not interpret the non-verbal behaviors as personally directed. Finally, our long baseline-to-VR interval (30–60 days) likely introduced additional noise, and the moderate stability of implicit measures can further reduce sensitivity to small changes unless effects are strong or repeatedly sampled.

Taken together, these findings suggest that the present study is informative in helping to identify design conditions, such as interaction depth, social context intensity, and developmental fit, that may be important for future embodiment-based interventions. Next, we discuss how our setup affected body ownership, agency, and presence for our different age groups.

4.2. Body Ownership, Agency, and Presence

Although our embodiment manipulation did not alter bias, participants' responses to the body ownership questionnaire confirm that the illusion was effective across the sample. Both adolescents and adults reported a strong sense of body ownership over the Black virtual body. There were no significant differences in ownership scores between age groups and no main effect of crowd context on ownership illusions. This replicates prior observations that embodiment leads to an illusion of ownership irrespective of skin color. We also included control items (e.g., sensing having two bodies or the body feeling "not me"), which were low, indicating participants understood the illusion vs. reality and were not simply acquiescing to all statements. In short, the VR system and synchronization were sufficient to induce the feeling of "I have become this virtual person," setting the stage for possible psychological effects.

A novel aspect of our study was the inclusion of both adolescents and an adult comparison sample. Interestingly, we found that adolescents reported significantly higher agency over the virtual body than adults at the nominal significance level, although this effect did not survive FDR correction. One possible explanation is that younger participants may adapt more readily to virtual body control, possibly due to greater exposure to video games or simply a more flexible body schema during adolescence [58]. Nevertheless, these possibilities were not directly assessed and should be examined in future studies using age-matched avatars and scenarios. It might also reflect differences in engagement: adolescents, being the target demographic of the school scenario, could have been more immersed in role-playing as the student avatar, thereby "inhabiting" that role more fully, while adults might have maintained a slight psychological distance. However, it is important to note that presence scores were high and no different between age groups, so both samples felt similarly transported into the virtual world. The lower agency in adults did not prevent them from feeling present; it may be a subtle distinction where adults noticed the technology constraints more. Prior studies rarely report age comparisons in VR, so this finding extends the literature by suggesting that embodiment can be effective across a broad age range, but the subjective nuances (like agency) might vary with age. Future research could delve deeper into whether adolescents are in fact more susceptible to body ownership illusions or if this was a result of scenario familiarity.

4.3. Self-Esteem and Sensitivity

We also examined baseline individual differences (self-esteem and sensory processing sensitivity) as factors. Adolescents in our sample had slightly lower self-esteem on average than adults (a difference that approached significance), which is consistent with general developmental trends [59,60]. In our results, however, we did not observe any clear moderation by self-esteem. One reason could be that our sample's self-esteem range was quite restricted—the majority scored within a relatively normal range. Thus, while conceptually intriguing, we cannot draw conclusions about the self-esteem hypothesis from our data. We simply note that future studies should include a broader distribution of self-esteem or ensure enough participants to test this interaction, as it remains a plausible factor—if, say, only low self-esteem individuals benefit from VR embodiment, that would temper how such interventions are deployed or combined with self-esteem training. This was addressed in the study by Banakou and colleagues [27], which demonstrated that self-esteem influenced task performance when participants embodied Einstein's virtual body compared to a neutral-looking virtual body.

Adolescents also had significantly higher sensitivity scores than adults. The sensitivity measure captured how easily one feels hurt or affected by others' opinions and actions, so this age difference implies that teenagers were, as expected, more sensitive to social cues. We statistically controlled for sensitivity in analyses of the VR outcomes, given this baseline gap. One might predict that high sensitivity teens would be especially reactive to the crowd's behavior. Paradoxically, our results showed adults reporting more negative feelings in the negative crowd than adolescents did. It is possible that sensitivity played out differently by age: perhaps the adult participants who remained in the study were those comfortable enough to volunteer (their sensitivity range might have been restricted), whereas adolescent participants, despite higher trait sensitivity, may not have fully believed in or internalized the virtual crowd's attitudes (thus feeling like "it is not real, so it does not bother me" to some extent). Another possibility is that adults have accumulated more social comparisons and anxieties in evaluative situations, causing them to interpret the crowd's actions in a more personal, threatening way than teenagers, who may have been slightly more carefree in VR. Indeed, adults scored themselves as feeling more "judged," "rejected," and "not welcomed" than adolescents did under identical negative crowd conditions. This could reflect that life experience and expectations can shape one's reactions in VR—adults might carry in memories of times they were judged, making the virtual scenario resonate strongly, whereas adolescents (especially the younger ones) might not have a firm expectation of being judged by random peers, so they brush it off more easily.

Despite these age differences in interpreting the crowd, sensitivity as a trait did show an effect across both groups. Baseline sensitivity was nominally associated with lower distance comfort ratings and higher rejection ratings. This finding is important because it points to a limitation in one-size-fits-all VR interventions. For example, the optimal intensity of positive or negative social cues may differ according to participants' sensitivity, with overly negative experiences potentially increasing discomfort and overly subtle experiences failing to engage participants. Future studies could test whether tailoring manipulation intensity improves engagement and intervention outcomes. Nevertheless, because these exploratory covariate effects were not included in the FDR correction, they should be interpreted cautiously.

Lastly, although we did not measure mental health outcomes, identifying conditions under which social exclusion and intergroup attitudes are modifiable in adolescence may have downstream relevance for well-being, given links between discrimination and adolescent socioemotional outcomes.

4.4. Limitations

Several limitations must be acknowledged when interpreting the results. Firstly, our sample was limited to White, non-Hispanic participants, which was necessary for measuring bias against Black people (since we focused on majority-group bias). However, this homogeneity limits generalizability as the findings may not apply to non-White individuals or to biases in other intergroup contexts. Additionally, because recruitment was determined by feasibility in a two-visit lab-based VR study (with adolescents), the sample size within each experimental cell (especially when split by age group and social context condition) was modest and findings should be interpreted as exploratory. As a result, the study was adequately powered only to detect relatively large effects. Our sensitivity analyses indicate adequate power ($\alpha = 0.05$, $1 - \beta = 0.80$) for relatively large effects (approximately Cohen's $f \approx 0.40$; $\eta p^2 \approx 0.14$), whereas small-to-medium effects (e.g., $f \approx 0.25$; $\eta p^2 \approx 0.06$) would be underpowered in the present sample. The age group comparisons should also be viewed as exploratory given the additional subdivision of the sample. Accordingly, no detectable effects on bias measures within the present sample should be interpreted as lack of evidence for large effects in this paradigm, rather than conclusive evidence of no effect.

A further limitation is the absence of a control condition where participants embody either their own race or are placed under different embodiment paradigms in a neutral environment scenario. Without such a control, interpretation relies on baseline-vs-post comparisons and between-group differences to infer the effects of our manipulations, and therefore the present design cannot isolate the specific contribution of racial embodiment from repeated IAT testing, general VR exposure, passage of time, or the valence of the crowd context. Accordingly, any pre–post changes cannot be uniquely attributed to racial embodiment or the VR scenario itself versus test–retest, history, or maturation effects. A more rigorous design would include, for example, a group that does the pre and post-IAT with no intervention, to confirm that any changes are indeed due to our embodiment scenario and not just repeat testing or time. Including such controls in future studies would strengthen causal claims about VR's impact.

The demographic questionnaire recorded self-reported sex, whereas gender identity was not assessed using a dedicated measure. Although one participant additionally self-described as non-binary in an optional demographic field, the available data did not permit analyses of gender identity. The exploratory female–male comparisons therefore concern sex only and should not be generalized to gender-related differences. Furthermore, while we refer to both male and female participants, we did not examine sex differences in detail; our exploratory checks suggested no major effects beyond a slight sensitivity difference. Still, the imbalance (somewhat more females) could influence the generality of subjective responses. Future studies should assess sex and gender identity separately and recruit samples sufficiently diverse and balanced to examine their potentially distinct associations with embodiment and social context responses.

Another limitation was our decision to have a long gap (30–60 days) between baseline and VR was to reduce demand characteristics. However, this long interval also introduced additional noise, as participants' biases or perceptions could have changed naturally over time due to outside influences unrelated to the intervention. The decision for such a gap was partly influenced by the young age of our participants and the practical challenges of recruiting younger participants, which made shorter intervals between sessions difficult to implement. Future studies should address this limitation by exploring ways to reduce the gap without increasing demand characteristics.

While our scenario was meant to simulate a real-life social setting, it still had limitations in realism and engagement. The interaction with the crowd was minimal—participants were essentially passive observers of the crowd's behavior towards them. No dialog or task was involved. This lack of deeper interaction might have made the experience less impactful on participants' social perspective. For instance, one could imagine a more engaging scenario where the participant (as the Black avatar) tries to join a conversation or is either welcomed or snubbed, which might evoke stronger emotions and self-relevant thoughts. In our simpler implementation, the positive condition, although pleasant, might not have been powerful enough to create a strong sense of camaraderie, and the negative condition, while uncomfortable, was also somewhat ambiguous (no one said anything explicitly rude; it was mild exclusion). This ambiguity could lead participants to downplay what happened ("maybe they were just busy"). This limitation may have been especially relevant for adolescents, whose crowd appraisal responses were more variable and less clearly differentiated by social context condition than adults' responses. Relatedly, we did not independently rate the virtual agents' perceived likeability, threat, or racial meaning.

Therefore, we cannot fully disentangle responses to the agents' behavior from responses to their appearance. A clearer, perhaps more intense, interaction might produce clearer effects (though with the risk of causing more distress). Additionally, the scenario placed adults in a teenage context, which could reduce ecological validity for them. This mismatch might have caused some detachment or differences in how seriously they took the peers. In essence, the scenario might not equally fit all ages. Consequently, AgeGroup was partly confounded with scenario and avatar fit, and observed adolescent–adult differences cannot be attributed unambiguously to developmental factors. Future work could tailor scenarios to participant groups (e.g., a workplace discrimination scenario for adults, a school scenario for teenagers) to see if matching context to one's real life yields stronger identification and attitude change. Similarly, future interactions could be made more immersive by incorporating deeper social exchanges, such as brief scripted dialogs, attempts to join an ongoing group conversation, cooperative mini-tasks involving inclusion or exclusion, or a VR Cyberball-style inclusion/exclusion manipulation, which has been widely used to reliably induce experiences of social ostracism [61].

Because participants were recruited and tested in Milan (Italy), it is also important to situate these findings in a European/Italian context. Much prior work on Black–White bias is grounded in the United States, whereas in Italy the social meaning of 'Blackness' may intersect with migration status, citizenship, and local norms about ethnicity and belonging. At the same time, major European and UN bodies document persistent discrimination and harassment affecting people of African descent in Europe and Italy, which indicates that anti-Black bias is not unique to U.S. settings [62,63]. Milan is also a particularly diverse urban area relative to broader national/regional baselines (https://www.cittametropolitana.mi.it/aree-tematiche/statistica/dati-statistici/osservatorio_metropolitano/statistiche_demografiche/dati_demografici_territoriali.html) (accessed 12 December 2025), which may shape contact patterns and how participants interpret subtle inclusion/exclusion cues. In the present study we did not directly measure participants' prior intergroup contact, Italy-specific racial attitudes or perceived social norms, or their individual interpretation of "Blackness." These unmeasured cultural and experiential factors may have influenced both baseline bias and participants' interpretation of the avatar and crowd behaviors, thereby limiting the construct validity and cultural specificity of the findings. Future work should therefore incorporate context-relevant measures (e.g., local intergroup contact, perceived norms, and how participants construe 'Black' in Italy or any given location) and pilot test scenario realism across cultural groups.

We set out to compare adolescents with an adult comparison sample, which is a strength but also introduces an important interpretive limitation. We included adults as a comparison sample tested under the same protocol, rather than as a fully matched developmental contrast. Accordingly, AgeGroup effects should be interpreted cautiously, because they may reflect developmental factors, cohort differences, and differences in ecological fit. Our adolescent sample and adult sample were not perfectly matched in all respects. The adolescents ranged in age (we had early to late teenagers), and the adults were mostly young adults (mean ~23, so more college-age than middle-aged). Thus, our "adult" group might actually be more similar to late adolescents in some ways, and our adolescent group included mid-adolescents who might differ from younger teenagers. This heterogeneity could dilute age effects. A limitation here is that we cannot pinpoint at what developmental stage differences emerge. We found some age group differences (agency, crowd perception), but these need to be interpreted cautiously as they might be due to specific cohorts or context familiarity rather than developmental stage per se. Additionally, including two age groups increased the complexity of the design and required estimation of AgeGroup $\times$ Crowd interactions within modest cell sizes, reducing power for detecting interaction effects. A more focused approach on one age group at a time, or ensuring larger sample size for each, would be ideal to draw firmer conclusions about adolescents specifically. We consider our adolescent findings exploratory given this limitation.

The present null effects likely reflect a combination of low interaction 'dosage' (brief, non-verbal cues; participants largely passive observers) and heterogeneity in how participants interpreted the scenario. Future VR interventions may be strengthened by (a) deeper reciprocal interaction (e.g., dialog or a cooperative/ostracism task), (b) repeated or multi-session exposure to support learning over time, (c) age- and context-matched scenarios (e.g., school-based peer dynamics for adolescents versus workplace or public service contexts for adults), and (d) personalization based on individual differences such as sensory processing sensitivity, by calibrating the intensity/valence to be impactful without being aversive for highly sensitive individuals.

Finally, future studies should integrate more developmental frameworks concerning identity formation and cognitive control maturation and assess related constructs, such as moral judgment, that may help explain age-related variation in embodiment and racial attitudes.

5. Conclusions

In conclusion, the present study found no evidence that implicit or explicit racial bias changed detectably from pre- to post-exposure following a brief, single-session Black avatar VR embodiment scenario presented in either a positive or negative social context. At the same time, the VR procedure elicited strong embodiment, but evidence that the social context manipulation was differentiated as intended was partial and more consistent among adults than adolescents. These results suggest that the absence of bias change should not be interpreted simply as intervention failure, nor as definitive evidence that racial embodiment has no effect, because the present design did not include the control conditions needed to isolate embodiment-specific effects. Rather the findings should serve as evidence that embodiment-based effects are likely sensitive to design features such as interaction depth, social context intensity, developmental fit, and individual differences. Given the modest sample size, these findings provide evidence against large effects under the present paradigm but do not exclude small-to-medium effects. As one of the few studies to examine these questions in adolescents, this work contributes to the growing literature by helping identify boundary conditions and design principles that may guide the development of more effective future VR-based bias interventions.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/virtualworlds5030040/s1, Table S1: Ordered logistic regression results for post-VR embodiment, agency, presence, and crowd- appraisal questionnaire outcomes; Table S2: Cell-level descriptive statistics for post-VR crowd-appraisal items; Table S3: ANCOVA results for pre-to-post changes in subtle and blatant prejudice scores; Table S4: Linear regression and ANCOVA results for Implicit Association Test outcomes.

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Data Availability Statement: The de-identified data supporting the findings of this study are available from the corresponding author upon reasonable request, subject to ethical and data protection considerations. Analyses were conducted in Stata 13, and the available analysis syntax and variable information will be provided alongside the dataset where possible.

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References

1. Pearson, A.R.; Dovidio, J.F.; Gaertner, S.L. The nature of contemporary prejudice: Insights from aversive racism. *Soc. Personal. Psychol. Compass* **2009**, *3*, 314–338. [CrossRef]
2. Huddy, L.; Feldman, S. On assessing the political effects of racial prejudice. *Annu. Rev. Polit. Sci.* **2009**, *12*, 423–447. [CrossRef]
3. Aboud, F.E. The formation of in-group favoritism and out-group prejudice in young children: Are they distinct attitudes? *Dev. Psychol.* **2003**, *39*, 48–60. [CrossRef] [PubMed]
4. Qian, M.K.; Heyman, G.D.; Quinn, P.C.; Fu, G.; Lee, K. Differential developmental courses of implicit and explicit biases for different other-race classes. *Dev. Psychol.* **2019**, *55*, 1440–1452. [CrossRef] [PubMed]
5. Sugden, N.A.; Marquis, A.R. Meta-analytic review of the development of face discrimination in infancy: Face race, face gender, infant age, and methodology moderate face discrimination. *Psychol. Bull.* **2017**, *143*, 1201–1244. [CrossRef] [PubMed]
6. Anzures, G.; Quinn, P.C.; Pascalis, O.; Slater, A.M.; Tanaka, J.W.; Lee, K. Developmental origins of the other-race effect. *Curr. Dir. Psychol. Sci.* **2013**, *22*, 173–178. [CrossRef] [PubMed]
7. Bar-Haim, Y.; Ziv, T.; Lamy, D.; Hodes, R.M. Nature and nurture in own-race face processing. *Psychol. Sci.* **2006**, *17*, 159–163. [CrossRef] [PubMed]
8. Baron, A.S. Bridging the gap between preference and evaluation during the first few years of life. In *Navigating the Social World: What Infants, Children, and Other Species Can Teach Us*; Banaji, M.R., Gelman, S.A., Eds.; Oxford University Press: Oxford, UK, 2013; pp. 281–285.
9. McAuliffe, K.; Dunham, Y. Fairness overrides group bias in children's second-party punishment. *J. Exp. Psychol. Gen.* **2017**, *146*, 485–494. [CrossRef] [PubMed]
10. Fitzroy, S.; Rutland, A. Learning to control ethnic intergroup bias in childhood. *Eur. J. Soc. Psychol.* **2010**, *40*, 679–693. [CrossRef]
11. Gaertner, S.L.; Dovidio, J.F. *Reducing Intergroup Bias: The Common Ingroup Identity Model*; Psychology Press: Hove, UK, 2000.
12. Baron, A.S.; Banaji, M.R. The development of implicit attitudes. *Psychol. Sci.* **2006**, *17*, 53–58. [CrossRef] [PubMed]
13. Williams, A.; Steele, J.R. The reliability of child-friendly race-attitude implicit association tests. *Front. Psychol.* **2016**, *7*, 1576. [CrossRef] [PubMed]
14. Gonzalez, A.M.; Steele, J.R.; Baron, A.S. Reducing children's implicit racial bias through exposure to positive out-group exemplars. *Child Dev.* **2017**, *88*, 123–130. [CrossRef] [PubMed]
15. Dunham, Y.; Baron, A.S.; Banaji, M.R. The development of implicit intergroup cognition. *Trends Cogn. Sci.* **2008**, *12*, 248–253. [CrossRef]
16. Benner, A.D.; Wang, Y. Racial/ethnic discrimination and well-being during adolescence: A meta-analytic review. *Am. Psychol.* **2018**, *73*, 855–883. [CrossRef]
17. Banakou, D.; Beacco, A.; Neyret, S.; Blasco-Oliver, M.; Seinfeld, S.; Slater, M. Virtual body ownership and its consequences for implicit racial bias are dependent on social context. *R. Soc. Open Sci.* **2020**, *7*, 201848. [CrossRef] [PubMed]
18. Botvinick, M.M.; Cohen, J. Rubber hands "feel" touch that eyes see. *Nature* **1998**, *391*, 756. [PubMed]
19. Gallagher, S. Philosophical conceptions of the self: Implications for cognitive science. *Trends Cogn. Sci.* **2000**, *4*, 14–21. [CrossRef] [PubMed]
20. Petkova, V.I.; Ehrsson, H.H. If I were you: Perceptual illusion of body swapping. *PLoS ONE* **2008**, *3*, e3832. [CrossRef] [PubMed]
21. Slater, M.; Pérez Marcos, D.; Ehrsson, H.; Sanchez-Vives, M.V. Towards a digital body: The virtual arm illusion. *Front. Hum. Neurosci.* **2008**, *2*, 6. [CrossRef] [PubMed]
22. Blanke, O.; Slater, M.; Serino, A. Behavioral, neural, and computational principles of bodily self-consciousness. *Neuron* **2015**, *88*, 145–166. [CrossRef] [PubMed]
23. Maselli, A.; Slater, M. The building blocks of the full body ownership illusion. *Front. Hum. Neurosci.* **2013**, *7*, 83. [CrossRef] [PubMed]

24. Kilteni, K.; Normand, J.M.; Sanchez-Vives, M.V.; Slater, M. Extending body space in immersive virtual reality: A very long arm illusion. *PLoS ONE* **2012**, *7*, e40867. [CrossRef] [PubMed]
25. Slater, M.; Spanlang, B.; Sanchez-Vives, M.V.; Blanke, O. First person experience of body transfer in virtual reality. *PLoS ONE* **2010**, *5*, e10564. [CrossRef] [PubMed]
26. Banakou, D.; Groten, R.; Slater, M. Illusory ownership of a virtual child body causes overestimation of object sizes and implicit attitude changes. *Proc. Natl. Acad. Sci. USA* **2013**, *110*, 12846–12851. [CrossRef] [PubMed]
27. Banakou, D.; Kishore, S.; Slater, M. Virtually being Einstein results in an improvement in cognitive task performance and a decrease in age bias. *Front. Psychol.* **2018**, *9*, 917. [CrossRef] [PubMed]
28. Vahle, N.M.; Tomasik, M.J. Younger and older adults' cognitive and physical functioning in a virtual reality age manipulation. *Front. Aging* **2022**, *3*, 851687. [CrossRef] [PubMed]
29. Lin, J.H.T.; Wu, D.Y. Exercising With Embodied Young Avatars: How Young vs. Older Avatars in Virtual Reality Affect Perceived Exertion and Physical Activity Among Male and Female Elderly Individuals. *Front. Psychol.* **2021**, *12*, 693545. [CrossRef] [PubMed]
30. Neyret, S.; Bellido Rivas, A.I.; Navarro, X.; Slater, M. Which body would you like to have? The impact of embodied perspective on body perception and evaluation in immersive virtual reality. *Front. Robot. AI* **2020**, *7*, 31. [CrossRef] [PubMed]
31. Mello, M.; Fusaro, M.; Tieri, G.; Aglioti, S.M. Wearing same- and opposite-sex virtual bodies and seeing them caressed in intimate areas. *Q. J. Exp. Psychol.* **2022**, *75*, 461–474. [CrossRef] [PubMed]
32. Wu, L.; Chen, K.B. Examining the effects of gender transfer in virtual reality on implicit gender bias. *Hum. Factors* **2024**, *66*, 1504–1519. [CrossRef] [PubMed]
33. Seinfeld, S.; Arroyo-Palacios, J.; Iruretagoyena, G.; Hortensius, R.; Zapata, L.E.; Borland, D.; de Gelder, B.; Slater, M.; Sanchez-Vives, M.V. Offenders become the victim in virtual reality: Impact of changing perspective in domestic violence. *Sci. Rep.* **2018**, *8*, 2692. [CrossRef] [PubMed]
34. Bellido Rivas, A.I.; Navarro, X.; Banakou, D.; Oliva, R.; Orvalho, V.; Slater, M. The influence of embodiment as a cartoon character on public speaking anxiety. *Front. Virtual Real.* **2021**, *2*, 695673. [CrossRef]
35. Gorisse, G.; Wellenreiter, S.; Fleury, S.; Lécuyer, A.; Richir, S.; Christmann, O. I am a genius! Influence of virtually embodying Leonardo da Vinci on creative performance. *IEEE Trans. Vis. Comput. Graph.* **2023**, *29*, 4328–4338. [CrossRef] [PubMed]
36. Peck, T.C.; Seinfeld, S.; Aglioti, S.M.; Slater, M. Putting yourself in the skin of a black avatar reduces implicit racial bias. *Conscious. Cogn.* **2013**, *22*, 779–787. [CrossRef] [PubMed]
37. Maister, L.; Slater, M.; Sanchez-Vives, M.V.; Tsakiris, M. Changing bodies changes minds: Owning another body affects social cognition. *Trends Cogn. Sci.* **2015**, *19*, 6–12. [CrossRef] [PubMed]
38. Yee, N.; Bailenson, J.N. The Proteus effect: The effect of transformed self-representation on behavior. *Hum. Commun. Res.* **2007**, *33*, 271–290. [CrossRef]
39. Yee, N.; Bailenson, J.N. Walk a mile in digital shoes: The impact of embodied perspective-taking on reducing negative stereotyping in immersive virtual environments. *Proc. Presence* **2006**, *24*, 1–9.
40. Tajadura-Jiménez, A.; Banakou, D.; Bianchi-Berthouze, N.; Slater, M. Embodiment in a child-like talking virtual body influences object size perception, self-identification, and subsequent real speaking. *Sci. Rep.* **2017**, *7*, 9637. [CrossRef] [PubMed]
41. Christou, C.; Michael, D. Aliens versus humans: Do avatars make a difference in how we play the game. In Proceedings of the 2014 6th International Conference on Games and Virtual Worlds for Serious Applications (VS-GAMES), Valletta, Malta, 9–12 September 2014; pp. 1–7. [CrossRef]
42. Maister, L.; Sebanz, N.; Knoblich, G.; Tsakiris, M. Experiencing ownership over a dark-skinned body reduces implicit racial bias. *Cognition* **2013**, *128*, 170–178. [CrossRef] [PubMed]
43. Greenwald, A.G.; McGhee, D.E.; Schwartz, J.L. Measuring individual differences in implicit cognition: The implicit association test. *J. Pers. Soc. Psychol.* **1998**, *74*, 1464–1480. [CrossRef] [PubMed]
44. Banakou, D.; Parasuram, D.H.; Slater, M. Virtual embodiment of white people in a black virtual body leads to a sustained reduction in implicit racial bias. *Front. Hum. Neurosci.* **2016**, *10*, 601. [CrossRef] [PubMed]
45. Hasler, B.S.; Spanlang, B.; Slater, M. Virtual race transformation reverses racial ingroup bias. *PLoS ONE* **2017**, *12*, e0174965. [CrossRef] [PubMed]
46. Bedder, R.L.; Bush, D.; Banakou, D.; Peck, T.; Slater, M.; Burgess, N. A mechanistic account of bodily resonance and implicit bias. *Cognition* **2019**, *184*, 1–10. [CrossRef] [PubMed]
47. Higgins, S.; Alcock, S.; Aveiro, B.D.; Daniels, W.; Farmer, H.; Besharati, S. Perspective matters: A systematic review of immersive virtual reality to reduce racial prejudice. *Virtual Real.* **2024**, *28*, 125. [CrossRef]
48. Groom, V.; Bailenson, J.N.; Nass, C. The influence of racial embodiment on racial bias in immersive virtual environments. *Soc. Influ.* **2009**, *4*, 231–248. [CrossRef]
49. Pierce, B.H.; Kensinger, E.A. Effects of emotion on associative recognition: Valence and retention interval matter. *Psychon. Bull. Rev.* **2011**, *18*, 116–123. [CrossRef] [PubMed]

50. Priest, N.; Paradies, Y.; Trenerry, B.; Truong, M.; Karlsen, S.; Kelly, Y. A systematic review of studies examining the relationship between reported racism and health and wellbeing for children and young people. *Soc. Sci. Med.* **2013**, *95*, 115–127. [CrossRef] [PubMed]
51. Pluess, M.; Lionetti, F.; Aron, E.N.; Aron, A. People differ in their sensitivity to the environment: An integrated theory, measurement and empirical evidence. *J. Res. Pers.* **2023**, *104*, 104377. [CrossRef]
52. Greven, C.U.; Lionetti, F.; Booth, C.; Aron, E.N.; Fox, E.; Schendan, H.E.; Pluess, M.; Bruining, H.; Acevedo, B.; Bijttebier, P.; et al. Sensory Processing Sensitivity in the context of Environmental Sensitivity: A critical review and development of research agenda. *Neurosci. Biobehav. Rev.* **2019**, *98*, 287–305. [CrossRef] [PubMed]
53. Gall, D.; Roth, D.; Stauffert, J.P.; Zarges, J.; Latoschik, M.E. Embodiment in Virtual Reality Intensifies Emotional Responses to Virtual Stimuli. *Front. Psychol.* **2021**, *12*, 674179. [CrossRef] [PubMed]
54. Rosenberg, M. *Society and the Adolescent Self-Image*, Revised ed.; Wesleyan University Press: Middletown, CT, USA, 1989.
55. Pettigrew, T.F.; Meertens, R.W. Subtle and blatant prejudice in western Europe. *Eur. J. Soc. Psychol.* **1995**, *25*, 57–75. [CrossRef]
56. Aron, E.N.; Aron, A. Sensory-processing sensitivity and its relation to introversion and emotionality. *J. Pers. Soc. Psychol.* **1997**, *73*, 345–368. [CrossRef] [PubMed]
57. Greenwald, A.G.; Brendl, M.; Cai, H.; Cvencek, D.; Dovidio, J.F.; Friese, N.; Hahn, A.; Hehman, E.; Hofmann, W.; Hughes, S.; et al. Best research practices for using the implicit association test. *Behav. Res. Methods* **2022**, *54*, 1161–1180. [CrossRef] [PubMed]
58. Assaiante, C.; Barlaam, F.; Cignetti, F.; Vaugoyeau, M. Body schema building during childhood and adolescence: A neurosensory approach. *Neurophysiol. Clin.* **2014**, *44*, 3–12. [CrossRef] [PubMed]
59. Robins, R.W.; Trzesniewski, K.H. Self-esteem development across the lifespan. *Curr. Dir. Psychol. Sci.* **2005**, *14*, 158–162. [CrossRef]
60. Orth, U.; Erol, R.Y.; Luciano, E.C. Development of self-esteem from age 4 to 94 years: A meta-analysis of longitudinal studies. *Psychol. Bull.* **2018**, *144*, 1045–1080. [CrossRef] [PubMed]
61. Williams, K.D.; Cheung, C.K.T.; Choi, W. Cyberostracism: Effects of being ignored over the Internet. *J. Pers. Soc. Psychol.* **2000**, *79*, 748–762. [CrossRef] [PubMed]
62. European Union Agency for Fundamental Rights. *Being Black in the EU: Experiences of People of African Descent*; Publications Office of the European Union: Luxembourg, 2024. [CrossRef]
63. Office of the United Nations High Commissioner for Human Rights. *Report of Mission to Italy on Racial Discrimination*; United Nations: New York, NY, USA, 2019.