



Social resources facilitate pulling actions toward novel social agents than pushing actions in virtual reality

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Abstract

Aims: This study examined the speed of approach-avoidance actions in virtual reality (VR) as an indicator of psychological “readiness” to interact with social avatars.

Methods: Given that fast response is a key psychological factor reflecting a user's interest, motivation, and willingness to engage, we analyzed the response time of pulling or pushing inputs, typical actions showing approach-avoidance tendency, via bare-hand interaction in VR. We specifically investigated how the response time varied according to participants' social resources, particularly the richness of their social lives characterized by broader networks of friends, social groups, and frequent interactions.

Results: Results showed that participants with richer social lives exhibited faster pulling (vs. pushing) actions toward both same- and opposite-sex avatars. These effects remained significant regardless of participants' gender, age, and prior VR experience. Notably, the observed effects were specific to social stimuli (i.e., avatars) and were not revealed with non-social stimuli (i.e., a flag). Additionally, the effects did not occur with other indirect interactions (i.e., a mouse wheel or a virtual joystick).

Conclusion: The findings suggest that social resources may facilitate approach-oriented bodily affordances in VR environments.

Keywords: Approach, avoidance, response time, social resource, virtual reality

1. Introduction

Humans have a fundamental need to connect with others through various types of relationships, such as friends, colleagues, romantic partners, and acquaintances^[1-4]. Every social relationship begins with a process of ‘getting to know’ someone, making our attitudes and behaviors during initial interactions a key component of human sociality^[5]. This process enriches us by expanding our horizons through the exchange of diverse knowledge, perspectives, and skills^[6], and it offers valuable opportunities to achieve our goals^[7]. However, interacting with unfamiliar people can be challenging, as it poses potential threats such as physical harm, disease transmission, social rejection, and reputational damage^[8]. As a result, individuals underestimate the potential enjoyment of new social interactions, sometimes even preferring solitude, which can lead to missed opportunities to form diverse social connections^[9].

The Metaverse offers a compelling alternative by providing a virtual platform for social interaction that mitigates many real-world risks while enabling highly accessible social engagement, unconstrained by time and space^[10-14]. It also allows for customization to suit individual preferences, fostering more tailored social experiences^[15-17]. For instance, an introverted user might prefer a quiet virtual café or a tranquil mountain setting, whereas an extroverted user might enjoy lively social interactions in a soccer stadium filled with cheering spectators^[18].

Despite these benefits, individuals differ significantly in their attitudes toward new social interactions within virtual



environments^[19,20]. While some readily engage with new acquaintances, others may be more hesitant. This raises a crucial research question: “*Who is more open to new social contacts in VR, and under what conditions do these interactions become appealing?*”

To answer this question, we investigated approach-avoidance tendency (AAT), which is a fundamental brain response that drives human social motivation and behavior^[21–24] toward unfamiliar human-like avatars through pulling (approach) and pushing (avoidance) using bare-hand gesture interaction (Figure 1). As the response time of pulling and pushing interaction reflects user’s openness and willingness to interact with the social avatars in a VR setting^[25], we examined how individuals’ social resources (i.e., richness of one’s social life) influence these response times, offering insight into the factors that drive social engagement in the Metaverse.

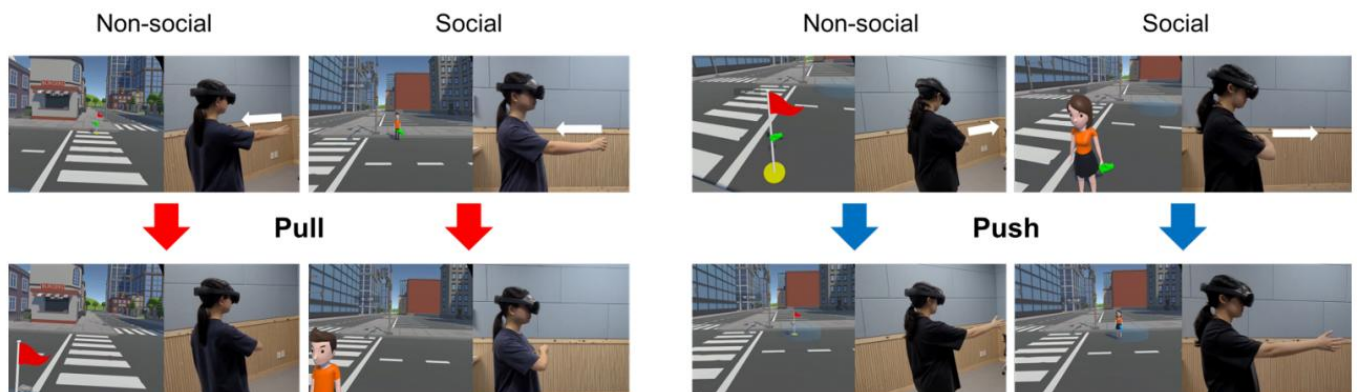


Figure 1. Study settings and environment. These images illustrate the movement of non-social (flag) and social (male and female avatars) targets when participants perform the pulling (left two columns) and pushing (right two columns) actions using bare-hand gesture interactions.

Our study makes the following important contributions:

- 1) We uniquely examined AAT using both human-like avatars and bare-hand gestures—an area not previously explored.
- 2) We utilized the duration of ‘approach-avoidance’ actions toward social avatars as an index of psychological readiness to engage.
- 3) We investigated how individuals’ real-world social patterns shape their interactions with social avatars in VR, which can inform the design of more personalized and engaging VR environments.

2. Related Work

This section reviews prior studies on social interactions in the Metaverse, focusing on pull-push actions, action response times, and the influence of individuals’ social resources on their response patterns.

2.1 Difference between metaverse and real-world

The Metaverse is increasingly recognized as a promising alternative platform for social communication^[10,11,26]. In VR environments, users interact with others through avatars in ways that closely resemble real-life encounters^[12,14,27].

During the recent pandemic, the Metaverse served as a substitute for real-world social interactions, allowing users to meet in virtual spaces with personalized avatars on platforms like [Gather](#)^[28] and [Zep](#)^[29], via text, voice, and video communication. Another example is [Roblox](#)^[30,31], a virtual environment where younger generations participate in creative social interactions.

However, social interactions in the Metaverse differ fundamentally from those in the physical world. In virtual spaces, interactions with unfamiliar individuals are more frequent and dynamic due to the removal of time and spatial constraints, as well as the ability to maintain privacy without revealing personal details. Moreover, unlike real-world interactions, which are rich in non-verbal social cues like eye contact, body gestures, and physical proximity, virtual communication depends on media devices such as computer screens or Head-Mounted Displays (HMDs)^[32–34]. These considerations lead to critical research questions: “*Who is more inclined to engage in social interactions in the Metaverse? How can broader participation be encouraged? And what methods are most effective in fostering social engagement?*”

2.2 Approach-avoidance tendency

As a promising approach to identifying individual differences in attitudes toward new social contacts in VR, we focused on ‘approach-avoidance’ bodily actions, that are considered to be closely linked to the brain’s primary motivational systems^[21].

2.2.1 Pull vs. push action

The human mind is inherently “embodied,” such that attitudes and preferences often manifest through bodily actions that align with motor movements^[35-37]. For instance, nodding one’s head is associated with agreement^[38,39], and leaning forward typically indicates interest and engagement^[40]. Central to our study is the theory of AAT, which represents two fundamental behavioral responses when interacting with the environment^[21,41]. Affective evaluation of a target automatically predisposes individuals to approach or avoid it^[42], making these actions a reliable indicator of attitudes toward specific targets.

This study aims to investigate people’s attitudes toward social avatars by focusing on this prototypical approach (pulling) and avoidance (pushing) behaviors^[42,43]. However, our research departs from previous work in two key aspects: a) instead of assessing the tendency to pull or push, we measure the time required to execute these actions, and b) we conduct this study in a VR environment, providing a distinct context compared to real-world settings.

2.2.2 Action response time in VR

Response time has been a key metric in the social sciences, indicating that more semantical or affective targets are responded to more quickly^[44-46]. This faster response is due to stronger associative connections or semantic similarity, which facilitates quicker and easier decisions. As such, analyzing response times for pull-push actions provides an implicit measure of individuals’ attitudes toward the target^[47]. Given existing evidence supporting the reliability and validity of response time to attitude^[48], the response time to pull-push actions toward novel social targets would serve as a reliable indicator of individuals’ interest.

Several studies have explored AAT using joystick-based pull-push actions in a Personal Computer (PC) environment^[49-51], showing that the speed of these actions reflects individuals’ interests and willingness to engage. For instance, Wittekind *et al.*^[52] found that participants who consumed chocolate frequently pulled images of chocolate faster than non-chocolate images, linking faster pulling action to a stronger desire for chocolate. Similarly, Kim and Lee^[50] observed that heavy social drinkers took longer to push in an alcohol-related VR environment compared to a non-alcohol-related one, indicating a slower avoidance response correlated with their interest in alcohol. Rink and Becker^[54] also found that individuals with spider phobia performed pushing actions towards spider images significantly faster than those without the phobia. Heuer *et al.*^[49] further showed that highly anxious individuals were quicker to push facial images, reflecting their avoidance motivation.

While prior research on AAT has primarily been conducted in joystick-based settings, other interfaces were also used for studying social interactions. Zech *et al.*^[53] compared joystick- and smartphone-based pull-push actions and found no significant differences in user behavior between these devices. Degner *et al.*^[54] also compared HMD-based one-step walking interactions with desktop-based keyboard interactions for approaching or avoiding stimuli (e.g., butterflies, spiders). They found that participants avoided spiders faster in both modalities, but approached butterflies more quickly using keypress interactions.

Recent studies have further explored AAT in 3D virtual environments, focusing on natural walking-based approach and avoidance behaviors toward 3D agents. For instance, Mousas *et al.*^[55] found that participants maintained greater distance and faster movement from zombie characters compared to other types of agents, such as mannequins, humans, and robots. Lange and Pauli^[56] examined social anxiety in relation to walking toward virtual agents with neutral and angry expressions, demonstrating that socially anxious participants exhibited stronger avoidance behaviors with higher speed compared to non-anxious participants.

In summary, faster response times toward novel social avatars in VR may indicate a higher level of mental “readiness,” which includes interest, motivation, and willingness to engage. Conversely, longer response times may reflect hesitation, lower interest, or decreased willingness. This raises a key research question: *Which individuals are more likely to perceive new social targets in VR as appealing and exhibit faster pulling (italic>vs. pushing) actions toward them?* Understanding these individual differences could provide valuable insights into social engagement within virtual environments.

2.3 Social resource and attitudes

One key factor driving individual differences in response times is the availability of social resources, which encompasses access to supportive networks, frequent interactions, and strong community ties^[57,58]. Social resources enhance the cognitive processing of social stimuli, enabling individuals to make more efficient and faster decisions in social contexts. Those with rich social resources, through frequent exposure to social interactions, sharpen their social navigation skills, fostering openness and positive attitudes toward new encounters^[59]. Regular engagement with social goals and motivations allows individuals with rich social resources to perceive novel social targets as more approachable and rewarding.

This framework aligns with research on resource depletion. For example, studies show that physical resource depletion, such as carrying a heavy backpack, causes individuals to perceive their environment as more challenging, with hills appearing steeper and goals seeming farther away, diminishing their willingness to engage with the task^[60]. Similarly, reduced social resources may limit individuals’ openness to new social experiences. Conversely, abundant social resources allow unfamiliar social contacts to be perceived as less demanding and more rewarding, thereby increasing motivation to engage. Individuals with rich social networks

have been shown to be more responsive and positive toward social stimuli compared to those experiencing social isolation^[25]. This heightened interest in social environments may manifest as faster approach-oriented actions, such as pulling social avatars closer, rather than avoidance actions like pushing them away.

2.4 Hypothesis

From the literature reviews, we hypothesized that **“individuals with richer real-world social resources would demonstrate faster pulling actions toward social avatars in a virtual environment (Figure 2)”**. To test the robustness of this hypothesis, we considered two boundary hypotheses:

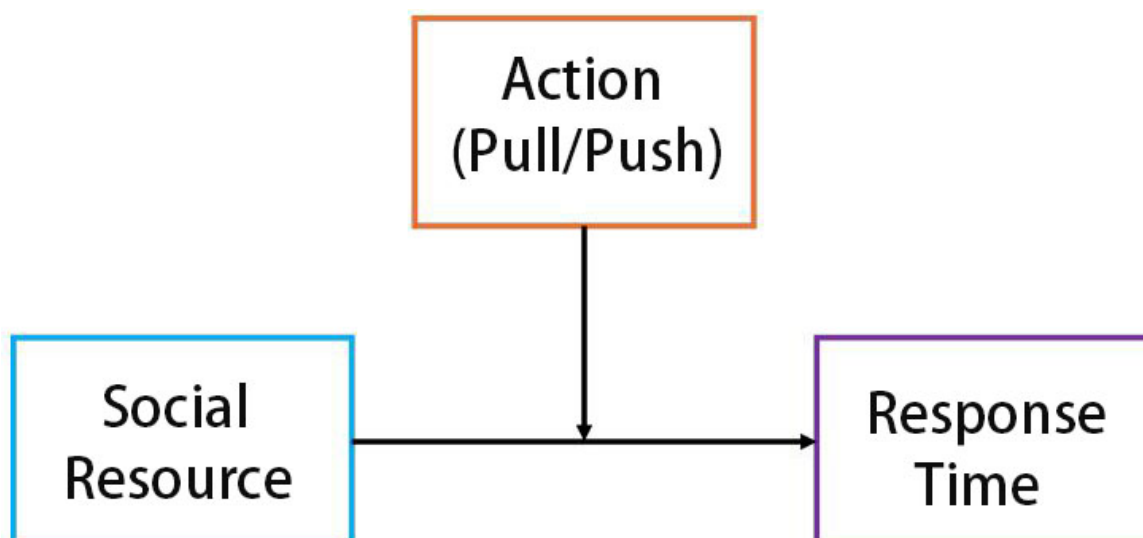


Figure 2. Hypothetical model.

- 1) We predict that the faster pulling actions by individuals with richer social resources will be specific to social targets (avatars), and will not generalize to non-social objects (e.g., a flag in the main study).
- 2) We hypothesize that direct bare-hand pull-push actions, which more closely resemble real-world approach avoidance movements, will yield stronger effects compared to these actions performed via indirect input devices (mouse-wheel and virtual joystick interactions in the follow-up study).

3. Main Study

The primary aim of this study was to investigate whether real-world social resources facilitate individuals' approach tendencies toward novel social avatars in VR. Building on the well-established AAT paradigm and psychological research on attitudes^[25,38,42,51,59], we analyzed the response time of pulling (vs. pushing) actions as an indicator of participants' mental readiness to approach (or avoid) a target. To enhance the realism of social engagement, participants were informed that the avatars they interacted with represented the other participants. To examine possible differences by the gender of the target avatars, both male and female avatars were included in the study. All participants were heterosexual, allowing us to compare responses in both same- and opposite-sex conditions.

The study employed a mixed method design, incorporating both between-subject factors (action: pulling vs. pushing) and within-subject factors (target: non-social object, same-sex avatar, opposite-sex avatar). Participants were evenly assigned to either the pulling or pushing condition and were asked to perform the actions 25 times for each target. The study received approval from the institutional review board of the first author's university.

3.1 Participants

Participants were recruited via email, poster advertisements, and a website. To mask the true purpose of the study, participants were informed that the study involved object manipulation in VR. A power analysis using G*Power^[61] indicated that a total sample size of 104 participants would provide adequate power (0.80) to detect medium-sized effects. Among the 104 participants (52 female and 52 male) from local undergraduate and graduate students, one female participant was excluded due to a system error, resulting in a final sample of 103 participants. Of these, 38 had no prior VR experience, while the remaining 65 had used VR at least once. Participants' ages ranged from 19 to 31 years ($M = 22.89$, $SD = 2.60$). All participants identified themselves as heterosexual.

3.2 Apparatus

We utilized the Unity game engine (version 2022.3.13f1) with the [Meta XR All-in-One SDK 59.0.0](#) package to develop the virtual environment and study system. The system was operated on a gaming laptop (Microsoft Windows 11, Intel Core i7-11800H Processor at 2.30 GHz CPU, 32 GB of RAM, and NVIDIA GeForce RTX 3060 Laptop GPU), which was wirelessly connected to a [Meta Quest Pro](#) HMD. The HMD featured hand-tracking sensors and binocular displays with a resolution of $1,800 \times 1,920$ pixels per eye, and a 106° horizontal field of view for enhanced immersion. Wireless connectivity between the PC and HMD was maintained through a Wi-Fi adapter (ipTIME A604MU) to log experimental data and allow participants to complete tasks without cable interference.

3.3 Study environments

The study environment was set up in an empty room (3.6×6.4 m, [Figure 3](#)). Three desks were arranged: one for participants to complete questionnaires and two for the VR setup. A yellow square area (50×50 cm) was marked at the center of the room, where participants stood while performing the experimental tasks. The virtual environment ([Figure 1](#)) was prepared by importing and modifying pre-made 3D assets, including [male](#) and [female avatars](#), a [city landscape](#), and a [flag](#). Participants experienced the environment from a first-person perspective while executing pulling and pushing actions.



Figure 3. Physical environment for a user study. Participants were asked to stand in a designated yellow square area (50×50 cm) during the task.

3.4 Condition

In this mixed-subject design, the type of actions (pulling vs. pushing) served as a between-subjects factor, while the type of targets (a flag, same-sex avatar, opposite-sex avatar) served as a within-subjects factor. To ensure participants remained attentive and engaged, two virtual environments (a city and a park) were randomly assigned; however, these environments were not expected to influence the results.

3.4.1 Action (between-subject)

Participants performed either approach ($n = 53$) or avoidance actions ($n = 50$) using bare hand pulling or pushing motion. To ensure that the participants fully experienced the pulling and pushing target, they were instructed to move their hand more than 25 cm in the depth direction during the pulling and pushing actions. In our system, one stroke of pulling or pushing action was registered when the hand depth movement was more than 25 cm.

3.4.2 Target stimuli (within-subject)

Participants were presented with both social and non-social stimuli ([Figure 4](#)) as a within-subject design factor to compare action response times. For the social stimuli, we selected male and female avatars that were neither overly realistic nor likely to evoke strong emotional inducements. Their skin tone, clothing, and hair color were standardized to control for any potential confounding effects. The avatars were set at a height of 1.3 meters, shorter than all participants, to prevent feelings of intimidation. The order of avatar presentation was counterbalanced using a balanced Latin Square design. A flag was chosen as the non-social target stimulus to provide a clear contrast with the social avatars.



Figure 4. Target stimuli for the main study: two virtual avatars (male and female) and a flag.

3.5 Task

The study was divided into two phases: a practice phase and an experimental phase. In the practice phase, participants completed a training task in which they pulled or pushed a virtual tree to familiarize themselves with the mechanics before proceeding to the experimental tasks. In the experimental phase, participants either pulled or pushed a target (i.e., social avatars or the flag) using a virtual hand that mirrored their real hand movements.

In this task, the target either approached (pull) or departed (push) from the participant. In the pulling condition, participants pulled a target initially positioned at 5 m away, until it reached 1 m using a hand pulling interaction with a grabbing hand pose (Figure 5). In the pushing condition, participants pushed a target initially positioned away from them to 5 m away using a hand pushing gesture interaction with a grabbing pose. This design fixed the target movement range between 1 m and 5 m, minimizing any potential confounds (e.g., the visual size of the target). These distances were determined with reference to Hall's interpersonal space^[62], where the 5 m and 1 m distances correspond to public and personal spaces respectively; so the target was moved from public to personal space in the pulling condition, and from personal to public space in the pushing condition.

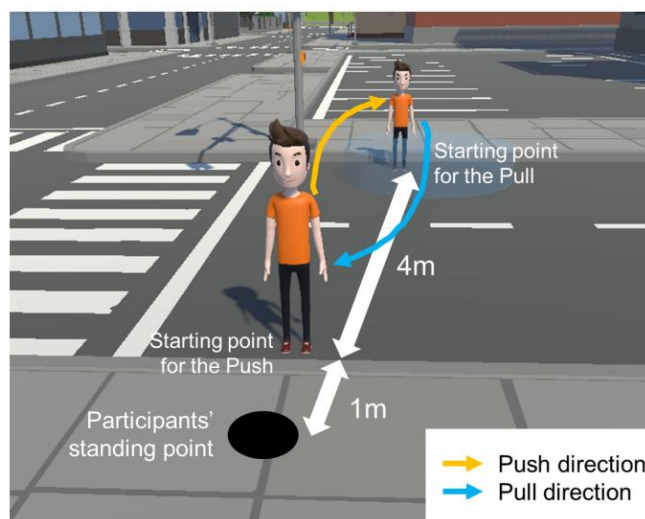


Figure 5. The directions of the movement for push and pull conditions in the task. In both conditions, the target moves only between the two points.

To ensure smooth and achievable animations across the 1 and 5-meter distance, the system amplified participants' real-world hand movements. Additionally, target movement during the pulling and pushing interaction was restricted to a pre-defined ground line, slightly tilted to the right from the participant's first-person perspective.

Visual feedback was incorporated into the pulling and pushing animations, altering the color of both the virtual hand and the destination. The virtual hand, initially incarnadine, turned green upon entering the grabbing zone and blue once the target was grabbed. Upon release, it returned to its original incarnadine color. The destination was visually represented by a 70% transparent sky-blue podium. After the target was released at the destination, it disappeared and reappeared at the initial position after a 1.2

seconds delay, ready for the next action. Each participant completed 25 pulling or pushing actions per target, resulting in a total of 75 actions during the experiment.

3.6 Procedure and data collection

The procedure is outlined in the flowchart in Figure 6. Upon arrival, participants completed a consent form and then filled out a pre-questionnaire, which included demographic information and a measure of the richness of their social resources, adapted from Deri, Davidai, and Gilovich^[63]. To measure the richness of their social resources, they were asked to rate themselves on a scale from 1 to 7 by answering three questions: “How often do you participate in social gatherings or meetings?” “How many friends do you have?” and “How many groups or organizations do you belong to?” The participants were provided with relative descriptions for the questions from the source^[63] for ease of rating (e.g., 1 = I have many fewer friends/meetings/groups than others do; 4 = I have about as many friends/meetings/groups as others do; 7 = I have many more friends/meetings/groups than others do). Measuring social resources through a concise questionnaire has been widely accepted in psychology and health studies^[64–66], and its reliability has been validated through Cronbach’s alpha coefficient. The Cronbach’s alpha for the measurement we used was $\alpha = 0.79$ ^[63], indicating acceptable reliability of measuring social resources. These questions served as indicators of the availability of social resources.

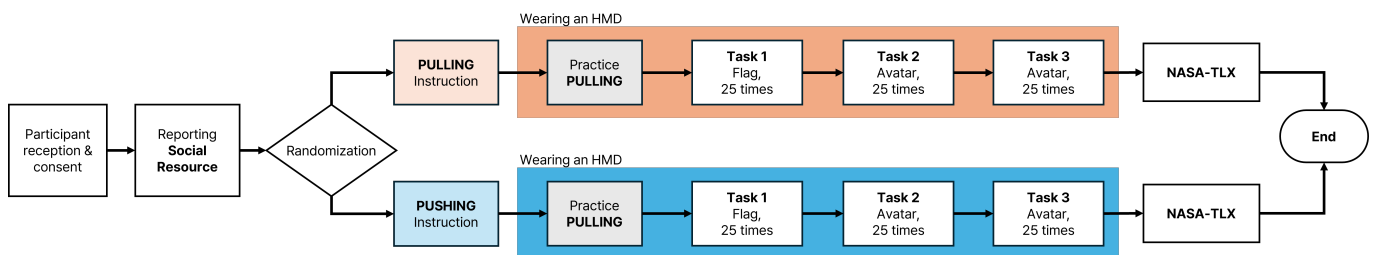


Figure 6. Flowchart depicting the main study procedure. Participants first reported their social resource levels and were then randomly assigned to either the Pulling or Pushing action. After a training session, they completed three tasks while wearing a HMD. Task 1 involved interacting with a flag, followed by task 2 and 3, which involved interacting with avatars. The order of same-sex and opposite-sex avatars was counterbalanced across participants. The study concluded with the completion of the NASA-TLX questionnaire to assess workload. HMD: head-mounted display; NASA-TLX: NASA Task Load Index.

After completing the pre-questionnaire, participants were informed: “This study will be conducted simultaneously and remotely with two other participants, but they have not arrived yet. Could you wait for a moment?” This statement was intended to make participants believe that the avatars they would interact with in the VR environment represented real participants, rather than system-generated avatars.

Participants were then guided to stand in a designated square (Figure 3) and watched an instructional video that explained how to perform the pulling and pushing tasks corresponding to their assigned condition. During the video, they were allowed to practice the pulling or pushing actions. Finally, participants wore the HMD with the assistance of an experimenter to ensure they are comfortable, after which the practice phase began.

In the practice phase, participants trained on either a pulling or pushing action, according to their assigned action, with a virtual tree, until they felt comfortable performing it. In addition, this phase served to confirm that the system worked well and the participants were ready for the experiment.

The experimental phase included pulling or pushing three targets: a flag, a male avatar and a female avatar, with the order of targets counterbalanced across participants. Each target was pulled or pushed 25 times, resulting in a total of 75 times for the three targets. System log data was collected to measure the response time in milliseconds. Response time for each target is the sum of the 25 times of pulling or pushing durations, excluding any duration in which neither pulling nor pushing action was performed. After completing three rounds for three targets, participants removed the HMD and completed a post-questionnaire, NASA Task Load Index (NASA-TLX)^[67], to evaluate the task load associated with the pulling or pushing action. The entire experiment lasted approximately 30 minutes per participant, and participants were compensated with a mobile gift valued at around eight US dollars.

4. Results

A moderation analysis was conducted to assess whether the relationship between social resources and response time varied depending on the type of action (pulling vs. pushing). Additionally, participants’ ratings for task load were analyzed to compare the pulling and pushing actions with each target.

4.1 Descriptive statistics for response time

Descriptive statistics (Figure 7) indicate that the mean response time was 48.60 seconds ($SD = 10.72$) for the same-sex avatar, 49.05 seconds ($SD = 11.39$) for the opposite-sex avatar, and 58.84 seconds ($SD = 15.49$) for the non-social flag.

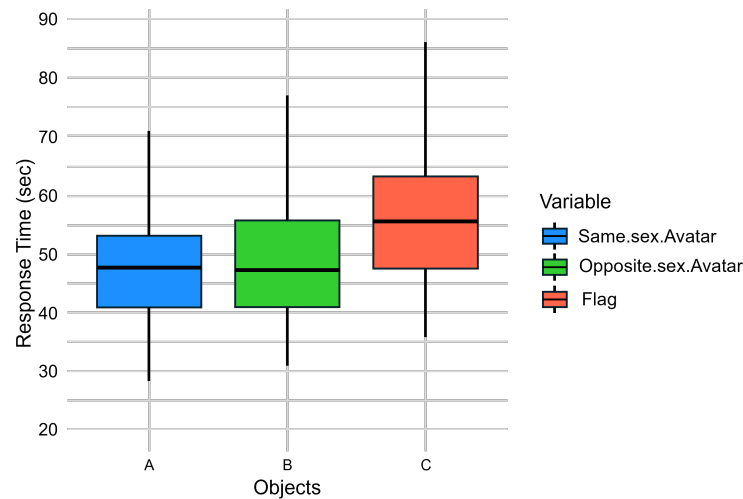


Figure 7. Response Times for each target.

For each target, independent samples *t*-test were conducted to examine any differences in response times between male and female participants. No significant differences in response times between male and female participants were found (same-sex avatar: male: $M = 48.25$, $SD = 10.34$; female: $M = 48.95$, $SD = 10.12$; $p = .796$; opposite-sex avatar: male: $M = 49.40$, $SD = 11.28$; female: $M = 48.69$, $SD = 10.77$; $p = .465$; flag: male: $M = 59.17$, $SD = 15.63$; female: $M = 58.51$, $SD = 13.36$; $p = .499$).

4.2 Moderation effect of action

Our key question was whether individuals' real-world social resources influenced their response times during pulling versus pushing actions toward social targets in VR. We first analyzed the distribution of reaction durations for each of the 25 reactions per participant to examine any variability. Shapiro-Wilk tests showed that all times were normally distributed for all participants (all $p > .05$). Therefore, participants' response time of each target was considered as the sum of the total 25 times of pulling or pushing duration. A simple moderation analysis was conducted using the PROCESS macro (Hayes^[68]; 10,000 bootstrapped samples). Social resources served as the independent variable, response time as the dependent variable, and action type as the moderator.

As expected, the relationship between participants' social resources and their response times toward social avatars varied depending on the type of action (Figure 8). For same-sex avatars, a significant moderation effect was observed, b (SE) = 3.88 (1.69), $p = .024$, 95% CI = [0.52, 7.23], along with a significant main effect of social resources on response times, b (SE) = -7.35 (2.75), $p = .009$, 95% CI = [-12.82, -1.89]. Response times, however, did not differ across actions ($p = .822$). As shown in the left of Figure 8, participants with richer social resources exhibited significantly faster response times when pulling same-sex avatars, b (SE) = -3.48 (1.25), $p = .007$, 95% CI = [-5.97, -0.99], but not when pushing ($p = .726$).

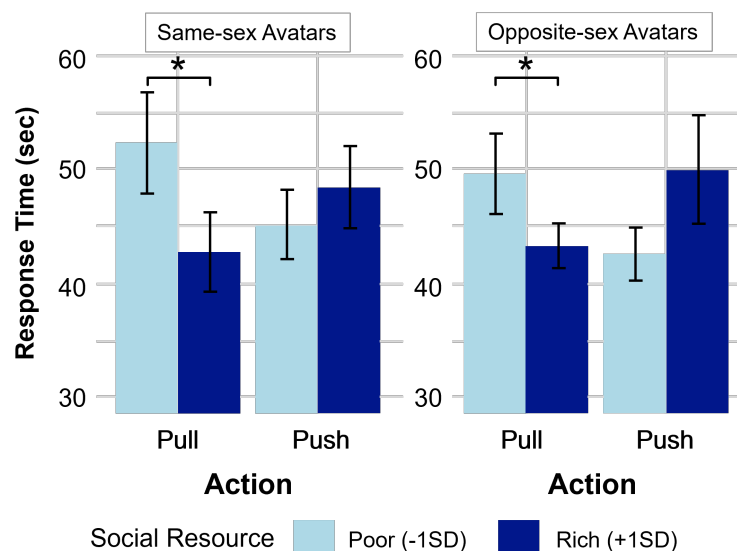


Figure 8. Interaction effect of Action (Pulling vs. Pushing) and Social Resources (Poor vs. Rich) on Response Time. The asterisks indicate significant interaction (* = $p < .05$).

To rule out the possibility that the faster response times in pulling (vs. pushing) by those with richer social lives were a byproduct of other variables, we added four relevant co-variates (age, sex, past VR experience, and order of target presentation) to the model. The moderation effect remained significant, b (SE) = 4.67 (1.66), p = .006, 95% CI = [1.37, 7.96].

Similar findings were observed for opposite-sex avatars. A significant main effect of social resources was observed, b (SE) = -7.21 (2.95), p = .016, 95% CI = [-13.06, -1.35], and response times did not differ across actions (p = .682). More importantly, the effect of social resources on response times was moderated by action type, b (SE) = 4.22 (1.81), p = .022, 95% CI = [0.62, 7.81]. As shown in the right of Figure 8, participants with richer social resources showed shorter response times when pulling opposite-sex avatars, b (SE) = -2.99 (1.34), p = .029, 95% CI = [-5.65, -0.32], but not when pushing (p = .313). Again, the moderation effect persisted even after controlling for the four co-variates, b (SE) = 4.34 (1.81), p = .018, 95% CI = [0.75, 7.93]. Overall, these findings suggest that social resources may specifically facilitate faster response times during pulling actions toward social avatars.

To test the robustness of the moderation effect and determine its scope, the analysis was repeated using the non-social target (flag). In contrast to social avatars, the relationship between social resources and response times did not vary by action type, b (SE) = 3.56 (2.46), p = .152, 95% CI = [-1.33, 8.45], nor were there significant main effects of action or social resources (action: p = .066; social resource: p = .187). These findings indicate that the faster pulling actions observed in individuals with richer social resources are specific to social targets but do not extend to non-social objects.

4.3 Task load

Task load was measured to ensure it did not influence response times (Table 1). Mann-Whitney U test (α = .05) was conducted to compare task load ratings (NASA-TLX) between groups. The test revealed no significant differences in task load between the pushing and pulling conditions (Z = .583, p = .560), nor between male and female participants (Pull: Z = -.053, p = .957; Push: Z = -.047, p = .962). Further analysis, incorporating task load as a covariate, confirmed that the moderation effect remained significant across conditions (same-sex avatar: b (SE) = 4.30 (1.68), p = .012, 95% CI = [0.96, 7.64]; opposite-sex avatar: b (SE) = 4.54 (1.79), p = .013, 95% CI = [0.98, 8.10]).

Table 1. Results of NASA-TLX from the main study.

Participants	Action	M	SD
All	Pull	20.708	11.932
	Push	22.533	12.174
Male	Pull	21.173	12.222
	Push	22.000	12.164
Female	Pull	20.224	11.845
	Push	23.067	12.411

NASA-TLX: NASA Task Load Index.

5. Follow-Up Study

In the main study, it was observed that participants with richer social resources exhibited faster pulling actions toward social stimuli (same-sex and opposite-sex avatars), but not toward non-social stimuli (a flag). This pulling action was executed through natural, bare-hand interactions that closely mimic real-world approach behaviors. Although natural interactions have been shown to enhance immersion and improve the user experience in VR^[69], many current social VR platforms still rely on indirect device-based inputs (e.g., a controller) for avatar movement, likely due to their widespread availability and ease of use.

To explore a second boundary condition, whether these effects extend to indirect methods of interaction, we conducted a follow-up study using alternative interfaces such as a mouse wheel and a virtual joystick. By introducing these indirect interaction methods, we aimed to determine whether the faster pulling actions observed by individuals with richer social resources could extend beyond bare-hand based interactions.

As this was a follow-up study, several study design components were kept identical to the first study, such as the two target stimuli (male and female avatars), the experimental environment (PC, a HMD, desks and chairs), the pulling and pushing tasks (25 pulling or pushing trials for each stimulus with a 25 cm depth threshold), the measurements (task load and the relationship between social resource and response time), and the VR background (a city and a park). The difference was the disposal of the flag stimulus (because it did not show an interaction effect between response time and social resource in the bare-hand interaction), the number of participants, and the types of interaction.

5.1 Participants

Similar to the main study, participants were recruited via email, posters, and a website, and the true purpose of the study was masked by informing them that the study was about object manipulation in VR. 52 participants (37 female and 15 male, $M = 23.77$, $SD = 4.16$) were recruited from local undergraduate and graduate students who had not participated in the main study. Of these, 15 had no prior VR experience, while 37 had experience with VR.

5.2 Condition and task

In preparing the indirect interaction methods, our primary consideration was ensuring compatibility with the current VR systems that support high mobility and allow users to stand and move. Three indirect interaction methods were prepared: one finger-mouse wheel and two virtual joystick interactions, one using a controller and the other using a hand, for pulling or pushing avatars ([Figure 9](#)).

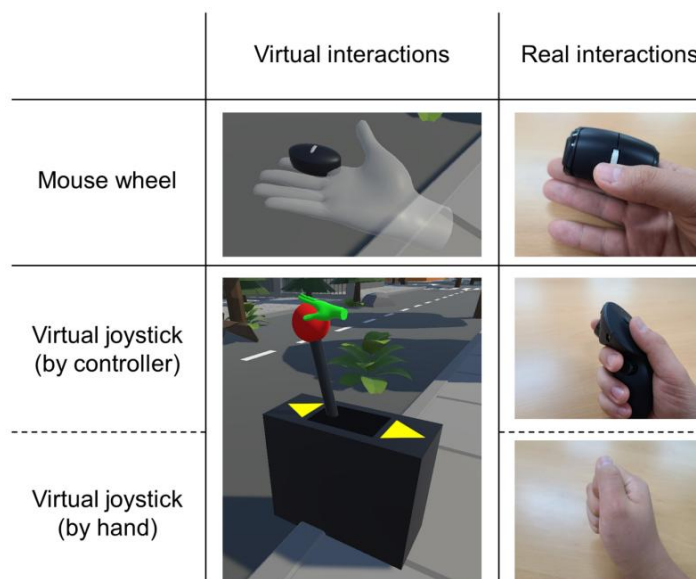


Figure 9. Three indirect interaction methods for the follow-up study.

5.2.1 Wheel condition

The wheeling interaction is commonly used for depth control, such as zooming in or out^[70], or moving objects forward or backward^[74]. We aimed to assess whether this familiar method of depth control would influence participants' pulling and pushing actions, as well as their effects on avatars. In this condition, participants wore a Geyes Finger Mouse II ([Figure 9](#)) on their index finger and scrolled the wheel with their thumb. Participants were required to keep their hands above waist level, consistent with other interaction methods, but without extending their arms. Scrolling the wheel outward was designated as a push action, while scrolling inward was considered a pulling action.

The pushing or pulling action was completed only after scrolling fully at least three times, as this method is considerably faster and requires less physical effort compared to the other interaction methods. Additionally, the finger mouse and a semi-transparent virtual hand (to reduce occlusion effects) were visually represented in this condition.

5.2.2 Two joystick conditions (controller/hand)

The joystick interaction has been widely used in several traditional studies for AAT^[49-51]. Accordingly, we implemented it in a virtual environment as a virtual joystick to avoid reducing mobility with a physical joystick. With the virtual joystick, we implemented two versions: a controller-based and a hand-based interaction.

The virtual joystick (see bottom left of [Figure 9](#)) was positioned in front of participants for easy access. To perform pulling and pushing actions, a participant needs to hold the one-meter height handle first with a virtual hand. This holding interaction was performed by pressing a trigger button on a controller (Meta Quest Touch Pro Controller; see center of [Figure 9](#)) or by a grabbing hand motion when the virtual hand is on the handle. For pulling or pushing a target, the handle should be pulled or pushed around 25 cm, respectively. If the distance of the handle movement was less than 25 cm, it was not completed. Upon completions, the handle returned to its initial position, which was 10 cm in front of a participant for pushing action, or 35 cm away for pulling. To release the virtual handle, participants had to release the trigger button or let go with their hand.

Note that both the controller and user's hand for the joystick interaction were visualized as a virtual hand in a virtual environment, ensuring that the holding, pushing, and pulling animations in the virtual environment were identical across the two virtual joystick conditions.

5.3 Procedure and data collection

The procedure of this follow-up study is similar to that of the main study. Upon arrival, participants signed the consent form and then completed the pre-questionnaire, as in the main study. The participants were also informed that two other participants will join this study as the male and female avatars, consistent with the main study (Section 3.6). Unlike the main study, no instruction video was provided, instead the experimenters gave live instructions on how to operate the mouse wheel and the virtual joystick interactions with the dedicated devices. During instruction, participants stood in the designated square area and practiced the pulling or pushing interaction corresponding to the condition (pull or push) to which they were randomly assigned.

After wearing the HMD, participants performed three sets of practice and experimental phases corresponding to the three conditions. In the practice phase, participants performed pulling or pushing a virtual tree (same as in the main study) according to their assigned condition, until they felt comfortable performing the action. Once familiarized, participants started the experimental phase, in which they pulled or pushed two targets: male and female avatars, presented in the counterbalanced order. Each target was pulled or pushed 25 times per assigned condition. This sequence of practice and experiment phases was repeated three times for three conditions, resulting in a total of 150 times of pulling or pushing actions ($25 \text{ times} \times 2 \text{ targets} \times 3 \text{ conditions}$) per participant.

Response times for the pulling and pushing actions for every condition and target were recorded in the same manner as in the main study. The overall experiment lasted approximately 40 minutes per participant and they were each compensated with a mobile gift valued at around eight US dollars.

5.4 Results

Moderation analyses were conducted to determine whether the observed moderation effect of action type (pulling vs. pushing) from the main study remained significant when participants used indirect interaction methods. The result is shown in Figure 10.

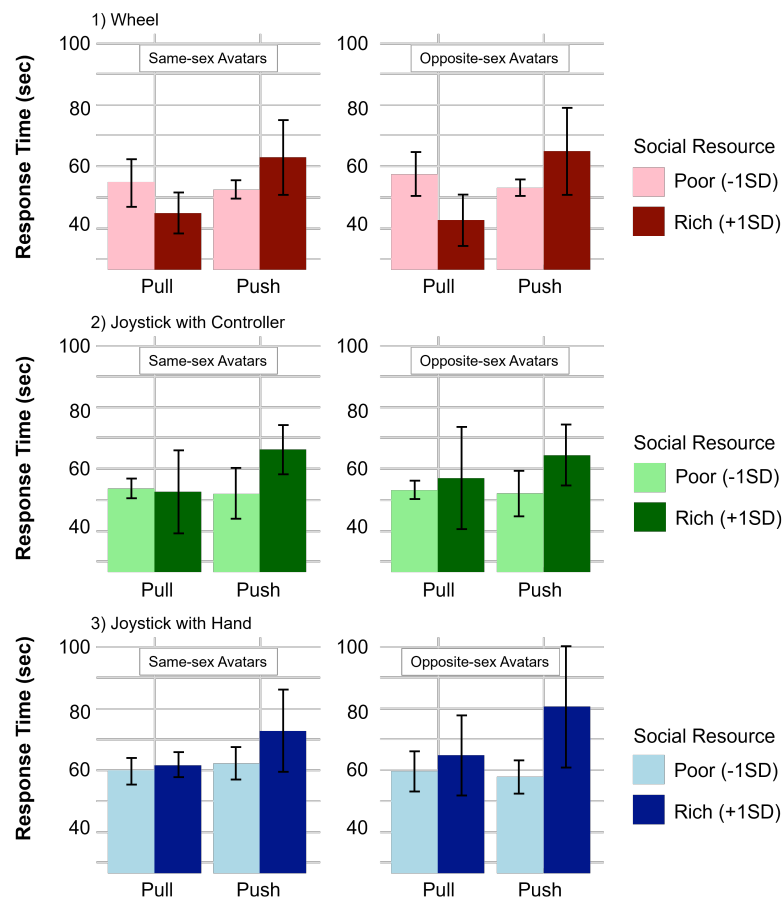


Figure 10. Interaction between Social Resources (Poor vs. Rich) and Action (Pulling vs. Pushing) on Response Time for Same-sex and Opposite-sex Avatars across different indirect methods. All interactions were non-significant.

The primary purpose of our follow-up study was to examine the interaction between social resource levels and action type across three indirect methods: mouse wheel, joystick with a controller, and joystick with a hand. As in the previous analysis, the moderation effect was examined using the same primary variables: social resource, action type, and response time. In this analysis, an additional co-variate (order of indirect method presentation) was included alongside the four previously used co-variables (age, sex, VR experience, and order of avatar presentation) to assess whether the moderation effects persisted. For all indirect methods, as shown in Figure 10, the interaction between action and social resources was not significant for both same-sex and opposite-sex avatars (for same-sex avatar: Wheel, $p = .953$; Joystick with controller, $p = .861$; Joystick with hand, $p = .938$; for opposite-sex avatar: Wheel, $p = .451$; Joystick with controller, $p = .989$; Joystick with hand, $p = .552$). Including the five co-variables in the moderation analysis did not alter the findings; the interaction remained non-significant across all indirect methods (for same-sex avatar: Wheel, $p = .979$; Joystick with controller, $p = .983$; Joystick with hand, $p = .982$; for opposite-sex avatar: Wheel, $p = .416$; Joystick with controller, $p = .732$; Joystick with hand, $p = .675$).

These findings suggest that the moderating effect of action type in the VR environment is evident only in bare-hand interactions that are similar to real-world movements. This implies a potential link between an individual's real-world social resources and their response times to social avatars in VR via bodily actions. In summary, the findings indicate that in VR environments, the type of bodily action (pulling vs. pushing) significantly moderates the relationship between an individual's social resource levels and responsiveness, but only when interacting with social avatars through bare-hand interaction.

6. Discussion

Every relationship begins with the process of “getting to know” someone. As the metaverse emerges as a compelling platform for social interaction, understanding individual differences in attitudes toward new social contacts in VR becomes increasingly important. One significant factor influencing these differences is the availability of real-world social resources. Drawing on established theories that individuals with richer social networks exhibit more positive attitudes toward unfamiliar social interactions^[49,59], we investigated whether this dynamic extends to VR interactions with social avatars. To explore this, we focused on the fundamental dimensions of social attitudes (approach and avoidance tendencies) measured through pulling and pushing actions as indicators of participants' mental readiness to engage with new social avatars.

Specifically, we analyzed response times of these actions as an implicit measure of participants' mental readiness and openness toward new social contacts in VR. Given that shorter response times indicate greater interest and willingness to engage^[50,51], we hypothesized that participants with richer social resources would display faster pulling (vs. pushing) actions toward novel social avatars. Consistent with our hypothesis, across two studies, participants with richer social resources indeed pulled both same- and opposite-sex avatars faster.

This effect was domain-specific^[72], with faster response times observed exclusively for social avatars and not for non-social objects, such as a flag. This finding aligns with our first boundary hypothesis, which predicted that the influence of social resources would be limited to human-like avatars. The specificity of this effect to social avatars underscores the importance of social context in VR and suggests that social resources play a crucial role when individuals engage with human-like targets, as opposed to inanimate objects.

Moreover, the influence of social resources on pulling actions was observed only in the bare-hand interaction condition, while indirect methods, such as using a mouse wheel or virtual joystick, did not produce the same effect. This confirms our second boundary hypothesis, highlighting that naturalistic, embodied interactions are essential for eliciting real-world social behaviors in VR. The absence of this effect in indirect interaction methods emphasizes the need for immersive, realistic interactions to foster genuine social engagement in virtual environments.

Additionally, by using implicit measures such as response times for pulling and pushing actions, our study provides an advantage in assessing social attitudes. This implicit assessment offers greater reliability and construct validity by capturing information that may not be accessible through self-report measures^[73]. Implicit measures are less likely to be influenced by participants' intentional behavior or social desirability biases, which can distort self-reported data. Therefore, this approach allows for a more accurate representation of participants' true feelings and experiences, particularly regarding their openness and readiness to engage with social avatars in VR.

Furthermore, the distinction between approach (pulling) and avoidance (pushing) behaviors revealed important nuances in how social resources influence social interactions. While richer social resources were associated with faster approach behaviors, they did not appear to influence avoidance behaviors. This may be due to the fact that approach behaviors are often explicit and socially overt, making them more easily recognizable. Thus, the pulling avatar in our study, which featured explicit pulling animation, is well-matched with real-world approach behavior in its explicitness. In contrast, avoidance behaviors are typically more subtle and may not be as easily captured through pushing actions in VR. This difference suggests that pulling actions may better reflect real-world approach tendencies, whereas pushing actions may not fully represent the complexity of real-world avoidance behaviors.

In comparison with previous studies^[49-52,56], which largely focused on populations with specific psychological conditions, such as

phobia^[51] or addiction^[50], our findings offer greater generalizability. Our sample consisted of participants without any specific psychological inclinations, representing a demographic likely to use future metaverse systems. Additionally, the use of bare-hand interactions and human-like avatars further increases the ecological validity of our findings, as these components are expected to be integral to future VR environments. Previous studies were often limited to PC-based setups or used less immersive stimuli, such as 2D images rather than 3D avatars, making our findings more relevant to modern VR systems.

In summary, our study contributes to the growing research on social interaction in virtual environments by demonstrating that individuals' real-world social resources significantly influence their openness to new social contacts in VR. These findings have important implications for the design of social VR platforms. Specifically, they suggest that prioritizing naturalistic, embodied interactions and human-like avatars can enhance user engagement by replicating real-world social dynamics. Furthermore, the domain-specific nature of our findings highlights the importance of designing VR environments that cater to human-like interactions to foster meaningful social connections.

7. Limitation and Future Work

While our study offers valuable insights into the role of social resources in shaping approach and avoidance behaviors in VR, several limitations warrant consideration. First, although the sample consisted of university students, which provides a degree of generalizability, the participants were relatively homogeneous in terms of age and background. This limits the broader applicability of our findings to more diverse populations. Future research should replicate this study across a wider range of demographic groups, including older adults, individuals from different cultural backgrounds, and users with varying levels of VR experience. This approach would provide a more comprehensive understanding of how social resources influence behavior in diverse contexts.

Second, the VR environment used in our study was relatively simple and focused primarily on interactions with human-like avatars. While this setup was effective for testing our core hypotheses, future metaverse systems are likely to involve more complex and dynamic social settings. It remains to be seen how the richness of social resources affects behavior in these more immersive and interactive environments, where social cues could be more nuanced and varied. Further studies should therefore explore these dynamics to determine whether our findings extend to more sophisticated virtual environments.

Third, while pulling and pushing actions served as useful indicators of approach and avoidance tendencies, they may not fully capture the complexity of real-world social interactions. These actions, though common in studies of social behavior, may oversimplify how individuals approach or avoid others in everyday life. Future research should incorporate a broader range of interaction types or more naturalistic behaviors to investigate how different forms of social engagement unfold in VR environments.

Fourth, although we demonstrated a clear link between social resources and faster approach behaviors (pulling), we did not explore the psychological mechanisms underlying these effects. It remains unclear whether factors such as self-confidence, social motivation, or personality traits mediate the relationship between social resources and social openness in VR. Future studies could address this gap by incorporating additional measurements, such as self-reported social motivations or qualitative interviews, to gain a deeper understanding of the mechanisms driving these behaviors.

Finally, our study relied primarily on bare-hand interactions to reflect naturalistic behavior in VR. However, other input methods, such as different interaction metaphors^[74-76], hand-held controllers, or more advanced gesture recognition systems, may influence user behavior in different ways. As VR technology continues to evolve, future research should examine how various interaction modalities affect social openness, particularly as these technologies become more intuitive and integrated into everyday social experiences.

In conclusion, while our study offers an initial understanding of how real-world social resources influence social behavior in VR, further research is needed to explore these dynamics across a broader range of contexts, populations, and technological platforms. Addressing these limitations will allow future studies to build on our findings, deepening our understanding of social engagement in increasingly sophisticated virtual environments.

8. Conclusion

This study demonstrated that individuals with greater social resources exhibited stronger approach tendencies toward human-like avatars in VR, whereas no such effects were observed for non-social objects. Importantly, these findings emerged only in the bare-hand condition, underscoring the role of embodied and naturalistic interaction in eliciting authentic social behaviors. Collectively, the results suggest that VR can both reflect and shape real-world social dynamics in meaningful ways. For designers of social VR systems, these findings highlight the importance of incorporating naturalistic modalities and accounting for individual differences in social resources to foster more inclusive and engaging virtual environments. In conclusion, our findings highlight the potential for VR to mirror real-world social dynamics, offering valuable implications for the design of future metaverse systems that prioritize naturalistic interactions.

Declarations

Authors contribution

Jeong J, Lee H, Kim D: Conceptualization, methodology, data curation, formal analysis, investigation, interpretation of data.

Shin J, Kim S: Conceptualization, methodology, formal analysis, interpretation of data, resources, supervision.

Kang S: Data curation, investigation.

Lee GA: Conceptualization, resources, supervision.

Kim SH, Yang HJ: Resources, supervision.

Conflicts of interest

Gun Lee and Seungwon Kim serve as Associate Editors of *Empathic Computing*. The other authors declare no conflicts of interest.

Ethical approval

Chonnam National University Institutional Review Board approved our study under Application No. 1040198-231122-HR-174-02.

Consent to participate

Written informed consents to participate in the study were obtained from all participants.

Consent for publication

Written informed consents for publication were obtained.

Availability of data and materials

Not applicable.

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References

1. Baumeister RF, Leary MR. The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychol Bull.* 1995;117(3):497-529. [[PubMed](#)]
2. Sprecher S. Acquaintanceships (weak ties): Their role in people's web of relationships and their formation. *Pers Relatsh.* 2022;29(3):425-450. [[DOI](#)]
3. Okabe-Miyamoto K, Walsh LC, Ozer DJ, Lyubomirsky S. Measuring the experience of social connection within specific social interactions: The Connection During Conversations Scale (CDCS). *PLoS ONE.* 2024;19(1):e0286408. [[DOI](#)]
4. Moreton J, Kelly CS, Sandstrom GM. Social support from weak ties: Insight from the literature on minimal social interactions. *Soc Pers Psychol Compass.* 2023;17(3):e12729. [[DOI](#)]
5. Ferguson MJ, Bargh JA. How social perception can automatically influence behavior. *Trends Cogn Sci.* 2004;8(1):33-39. [[DOI](#)]
6. Aron A, Steele JL, Kashdan TB, Perez M. When similars do not attract: Tests of a prediction from the self-expansion model. *Pers Relatsh.* 2006;13(4):387-396. [[DOI](#)]
7. Orehek E, Forest AL, Wingrove S. People as means to multiple goals: Implications for interpersonal relationships. *Pers Soc Psychol Bull.* 2018;44(10):1487-1501. [[DOI](#)]
8. Neel R, Lassetter B, Lam EQY. Threats and opportunities: Independent dimensions of goal relevance shape social cognition and behavior. *Am Psychol.* 2023;78(9):1079-1090. [[DOI](#)]
9. Epley N, Schroeder J. Mistakenly seeking solitude. *J Exp Psychol Gen.* 2014;143(5):1980-1999. [[DOI](#)]
10. Al-Kfairy M, Alomari A, Al-Bashayreh M, Alfandi O, Tubishat M. Unveiling the Metaverse: A survey of user perceptions and the impact of usability, social influence and interoperability. *Helyon.* 2024. [[DOI](#)]
11. Hennig-Thurau T, Aliman DN, Herting AM, Cziehso GP, Linder M, Kübler RV. Social interactions in the metaverse: Framework, initial evidence, and research roadmap. *J Acad Mark Sci.* 2022;51(4):889-913. [[DOI](#)]
12. Cheng R, Wu N, Varvello M. Are we ready for metaverse? A measurement study of social virtual reality platforms. In: *Proceedings of the*

- 22nd ACM Internet Measurement Conference; 2022 Oct 25-27; Nice, France. New York: Association for Computing Machinery; 2022. p. 504-518. [DOI]
13. Han E, Miller MR, DeVeaux C, Jun H, Nowak KL, Hancock JT, et al. People, places, and time: A large-scale, longitudinal study of transformed avatars and environmental context in group interaction in the metaverse. *J Comput Mediat Commun*. 2023;28(2):zmac031. [DOI]
 14. Hide M, Hatada Y, Kuzuoka H. "Closer than Real": How Social VR Platform Features Influence Friendship Dynamics. In: Yamashita N, Evers V, Yatani K, Ding X, Lee B, Chetty M, Toups-Dugas P, editors. *Proceedings of the 2025 CHI Conference on Human Factors in Computing Systems*; 2025 Apr 26 - May 1; Yokohama, Japan. New York: Association for Computing Machinery; 2025. p. 1-17. [DOI]
 15. Schmidt S, Köysürenbars I, Steinicke F. Frankenstein's monster in the metaverse: User interaction with customized virtual agents. *IEEE Trans Visual Comput Graphics*. 2024;30(11):7162-7171. [DOI]
 16. Mourtzis D, Panopoulos N, Angelopoulos J, Wang B, Wang L. Human centric platforms for personalized value creation in metaverse. *J Manuf Syst*. 2022;65:653-659. [DOI]
 17. Wu S, Xu L, Dai Z, Pan Y. Factors affecting avatar customization behavior in virtual environments. *Electronics*. 2023;12(10):2286. [DOI]
 18. Oishi S, Talhelm T, Lee M. Personality and geography: Introverts prefer mountains. *J Res Pers*. 2015;58:55-68. [DOI]
 19. Nikolaou A, Schwabe A, Boomgaarden H. Changing social attitudes with virtual reality: A systematic review and meta-analysis. *Ann Int Commun Assoc*. 2022;46(1):30-61. [DOI]
 20. Wölfer R, Hewstone M. What buffers ethnic homophily? Explaining the development of outgroup contact in adolescence. *Dev Psychol*. 2018;54(8):1507-1518. [DOI]
 21. Lang PJ, Bradley MM, and Cuthbert BN. Motivated attention: Affect, activation, and action. In: Lang PJ, Simons RF, Balaban MT, editors. *Attention and orienting: Sensory and motivational processes*. United Kingdom: Psychology Press; 2013. p. 97-135.
 22. Grasso-Cladera A, Madrid-Carvajal J, Walter S, König P. Approach-avoidance bias in virtual and real-world simulations: Insights from a systematic review of experimental setups. *Brain Sci*. 2025;15(2):103. [DOI]
 23. van Alebeek H, Kahveci S, Rinck M, Blechert J. Touchscreen-based approach-avoidance responses to appetitive and threatening stimuli. *J Behav Ther Exp Psychiatry*. 2023;78:101806. [DOI]
 24. Eder AB, Krishna A, Sebald A, Kunde W. Embodiment of approach-avoidance behavior: Motivational priming of whole-body movements in a virtual world. *Motiv Sci*. 2021;7(2):133-144. [DOI]
 25. Cacioppo JT, Hawkey LC. Perceived social isolation and cognition. *Trends Cogn Sci*. 2009;13(10):447-454. [DOI]
 26. Mystakidis S. Metaverse. *Encyclopedia*. 2022;2(1):486-497. [DOI]
 27. Kyriltsias C, Michael-Grigoriou D. Social interaction with agents and avatars in immersive virtual environments: A survey. *Front Virtual Real*. 2022;2:786665. [DOI]
 28. Lo CK, and Song Y. A scoping review of empirical studies in gather.town. In: 2023 11th International Conference on Information and Education Technology (ICIET); 2023 Mar 18-20; Fujisawa, Japan. New York: IEEE; 2023. pp. 1-5. [DOI]
 29. Kang J, Rhee H. Gender identity and perception in virtual spaces: The impact of avatar gender transition on the ZEPETO platform. *Front Virtual Real*. 2025;6:1505624. [DOI]
 30. Kang D, Choi H, Nam S. Learning cultural spaces: A collaborative creation of a virtual art museum using roblox. *Int J Emerg Technol Learn*. 2022;17(22):232. [DOI]
 31. Fraser E. The future of digital space: Gaming, virtual reality, and metaversal thinking. *Dialog Hum Geogr*. 2023;14(2):347-351. [DOI]
 32. Kang S, Lee GA, Yang HJ, Kim SH, Shin J, Jeong J, et al. Design and evaluation of a virtual agent for interpersonal emotion regulation in VR. In: 2025 IEEE International Symposium on Mixed and Augmented Reality (ISMAR); 2015 Oct 8-12; Daejeon, South Korea. New York: IEEE; 2025. p. 1554-1564. [DOI]
 33. Jeong J, Lee GA, Yang HJ, Kim SH, Shin J, Suh G, et al. Three techniques for enhancing emotional expression on embodied avatar face in VR. In: 2025 IEEE International Symposium on Mixed and Augmented Reality (ISMAR); 2015 Oct 8-12; Daejeon, South Korea. New York: IEEE; 2025. p. 23-33. [DOI]
 34. Kim S, Huang W, Oh CM, Lee G, Billingham M, Lee SJ. View types and visual communication cues for remote collaboration. *Comput Mater Contin*. 2023;74(2):4363-4379. [DOI]
 35. Niedenthal PM. Embodying emotion. *Science*. 2007;316(5827):1002-1005. [DOI]
 36. Aupperle RL, McDermott TJ, White E, Kirlic N. The neuropsychology of anxiety: An approach-avoidance decision-making framework. In: Brown GG, King TZ, Haaland KY, Crosson B, editors. *APA handbook of neuropsychology: Neurobehavioral disorders and conditions: Accepted science and open questions*. Washington: American Psychological Association; 2023. p. 767-787. [DOI]
 37. Cheval B, Ceravolo L, Zimmermann O, Igloi K, Sander D, van Ruitenbeek P, et al. Neural correlates of approach-avoidance tendencies toward physical activity and sedentary stimuli: An MRI study. *Imaging Neurosci*. 2025;3:IMAG.a.28. [DOI]
 38. Mehrabian A, Williams M. Nonverbal concomitants of perceived and intended persuasiveness. *J Pers Soc Psychol*. 1969;13(1):37-58. [DOI]
 39. Wells GL, Petty RE. The effects of over head movements on persuasion: Compatibility and incompatibility of responses. *Basic Appl Soc Psychol*. 1980;1(3):219-230. [DOI]
 40. Mota S, and Picard RW. Automated posture analysis for detecting learner's interest level. In: 2003 Conference on Computer Vision and Pattern Recognition Workshop; 2003 Jun 16-22; Madison, USA. New York: IEEE; 2003. p. 49-49. [DOI]
 41. Social Motivation. Cambridge.: Cambridge University Press; 2004. [DOI]
 42. Chen M, Bargh JA. Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Pers*

- Soc Psychol Bull. 1999;25(2):215-224. [DOI]
43. Solarz AK. Latency of instrumental responses as a function of compatibility with the meaning of eliciting verbal signs. *J Exp Psychol.* 1960;59(4):239-245. [DOI]
44. Storbeck J, Clore GL. The affective regulation of cognitive priming. *Emotion.* 2008;8(2):208-215. [DOI]
45. Charlesworth TES, Navon M, Rabinovich Y, Lofaro N, Kurdi B. The project implicit international dataset: Measuring implicit and explicit social group attitudes and stereotypes across 34 countries (2009-2019). *Behav Res.* 2022;55(3):1413-1440. [DOI]
46. Pombo M, Corradi GB, Elliot AJ, Velasco C. EXPRESS: When and how visual aesthetic features influence approach-avoidance motivated behavior. *Q J Exp Psychol.* 2025;18:17470218251371660. [DOI]
47. Greenwald AG, McGhee DE, Schwartz JLK. Measuring individual differences in implicit cognition: The implicit association test. *J Pers Soc Psychol.* 1998;74(6):1464-1480. [DOI]
48. Cunningham WA, Preacher KJ, Banaji MR. Implicit attitude measures: Consistency, stability, and convergent validity. *Psychol Sci.* 2001;12(2):163-170. [DOI]
49. Heuer K, Rinck M, Becker ES. Avoidance of emotional facial expressions in social anxiety: The Approach-Avoidance Task. *Behav Res Ther.* 2007;45(12):2990-3001. [DOI]
50. Kim DY, Lee JH. Development of a virtual approach-avoidance task to assess alcohol cravings. *Cyberpsychol Behav Soc Netw.* 2015;18(12):763-766. [DOI]
51. Rinck M, Becker ES. Approach and avoidance in fear of spiders. *J Behav Ther Exp Psychiatry.* 2007;38(2):105-120. [DOI]
52. Wittekind CE, Bleichert J, Schiebel T, Lender A, Kahveci S, Kühn S. Comparison of different response devices to assess behavioral tendencies towards chocolate in the approach-avoidance task. *Appetite.* 2021;165:105294. [DOI]
53. Zech HG, Rotteveel M, van Dijk WW, van Dillen LF. A mobile approach-avoidance task. *Behav Res.* 2020;52(5):2085-2097. [DOI]
54. Degner J, Steep L, Schmidt S, Steinicke F. Assessing automatic approach-avoidance behavior in an immersive virtual environment. *Front Virtual Real.* 2021;2:761142. [DOI]
55. Mousas C, Kollias A, Rekabdar B, Kao D, Anastaslou D. Toward understanding the effects of virtual character appearance on avoidance movement behavior. In: 2021 IEEE virtual reality and 3D user interfaces (VR); 2021 Mar 27-Apr 1; Lisboa, Portugal. New York: IEEE; 2021. p. 40-49. [DOI]
56. Lange B, Pauli P. Social anxiety changes the way we move—A social approach-avoidance task in a virtual reality CAVE system. *PLoS One.* 2019;14(12):e0226805. [DOI]
57. Cohen S. Social relationships and health. *Am Psychol.* 2004;59(8):676-684. [DOI]
58. Lin N, Ensel WM, and Vaughn JC. Social resources and strength of ties: Structural factors in occupational status attainment. *Am Sociol Rev.* 1981;46(4):393-405. [DOI]
59. On perceptual readiness. *Psychol Rev.* 1957;64(2):123-152. [DOI]
60. Proffitt DR. Affordances matter in geographical slant perception. *Psychon Bull Rev.* 2009;16(5):970-972. [DOI]
61. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods.* 2007;39(2):175-191. [DOI]
62. Hall ET. *The hidden dimension.* 1st ed. New York: Doubleday & Company, Inc.; 1966.
63. Deri S, Davidai S, Gilovich T. Home alone: Why people believe others' social lives are richer than their own. *J Pers Soc Psychol.* 2017;113(6):858-877. [DOI]
64. Lee RM, Robbins SB. Measuring belongingness: The social connectedness and the social assurance scales. *J Couns Psychol.* 1995;42(2):232-241. [DOI]
65. Gordon NP, Stiefel MC. A brief but comprehensive three-item social connectedness screener for use in social risk assessment tools. *PLoS One.* 2024;19(7):e0307107. [DOI]
66. Secker J, Hacking S, Kent L, Shenton J, Spandler H. Development of a measure of social inclusion for arts and mental health project participants. *J Ment Health.* 2009;18(1):65-72. [DOI]
67. Hart SG, Staveland LE. Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. *Adv Psychol.* 1988;52:139-183. [DOI]
68. Hayes AF. *Introduction to mediation, moderation, and conditional process analysis: A regression-based approach.* 3rd ed. New York: The Guilford Press; 2013.
69. Bowman DA, Kruijff E, LaViola JJ, Poupyrev I. *3D user interfaces: Theory and practice.* 2nd ed. United States: Addison-Wesley Professional; 2017.
70. Rantamaa HR, Kangas J, Kumar SK, Mehtonen H, Järnstedt J, Raisamo R. Comparison of a vr stylus with a controller, hand tracking, and a mouse for object manipulation and medical marking tasks in virtual reality. *Appl Sci.* 2023;13(4):2251. [DOI]
71. Krichenbauer M, Yamamoto G, Taketom T, Sandor C, Kato H. Augmented reality versus virtual reality for 3d object manipulation. *IEEE Trans Visual Comput Graphics.* 2018;24(2):1038-1048. [DOI]
72. Barrett LF. Emotions are real. *Emotion.* 2012;12(3):413-429. [DOI]
73. Holden RR, Fekken GC. The NEO five-factor inventory in a Canadian context: Psychometric properties for a sample of university women. *Pers Individ Differ.* 1994;17(3):441-444. [DOI]
74. Jeong J, Kim SH, Yang HJ, Lee GA, Kim S. GazeHand: A gaze-driven virtual hand interface. *IEEE Access.* 2023;11:133703-133716. [DOI]
75. Yu D, Lu X, Shi R, Liang HN, Dingler T, Velloso E, et al. Gaze-supported 3d object manipulation in virtual reality. In: *Proceedings of the*

- 2021 CHI Conference on Human Factors in Computing Systems; 2021 May 8-13; Yokohama, Japan. New York: Association for Computing Machinery; 2021. p. 1-13. [DOI]
76. Jeong J, Kim SH, Yang HJ, Lee G, Kim S. GazeHand2: A gaze-driven virtual hand interface with improved gaze depth control for distant object interaction. *Electronics*. 2025;14(13):2530. [DOI]

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