



## OPEN Self-dialogue with age-congruent versus age-incongruent avatars in immersive virtual reality

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Perspective-taking in virtual reality has been exploited in different areas, including using avatars for self-dialogue. We explore the effect of performing self-dialogue in VR, alternating between a non-lookalike 'self' and an age-congruent or age-incongruent 'other'. We used an independent-sample design, with 28 females aged 18–35, starting a conversation in their 'self' avatar while describing a stressful daily-life problem, swapping immediately after with the 'other' (either young or mature-looking) avatar to listen and respond. Results showed that the importance of the change regarding their problem immediately after the experiment was significantly higher for the mature avatar condition ( $p = 0.01$ ), an effect not found at follow-up. Further, there is a trend towards specific factors of embodiment (e.g., self-recognition and body recognition) being related to understanding their problem better or how helpful the exercise was perceived. To conclude, while the mature avatar showed a short-term advantage, long-term effects were not observed. Future studies with tighter controls are warranted.

**Keywords** Self-distancing, Self-dialogue, Virtual reality, Avatars, Body ownership, Agency

Avatars, here defined as virtual representations of human users in a virtual world<sup>1</sup>, have been considered an optimal medium to navigate immersive virtual reality (VR) environments<sup>2</sup>. It has been suggested that embodying an avatar in immersive VR potentially influences the user's cognition, attitudes, and behavior in real life, even after leaving the virtual environment<sup>3</sup>. Several studies have provided evidence that avatars, lookalike or not, are valuable tools to improve people's lives. A study where participants embodied a current or aged-progressed version of themselves in VR showed that those who embodied their older selves were less likely to cheat<sup>4</sup>. Avatars have also been studied as tools to reduce prejudice and social stereotypes based, for instance, on age and skin color<sup>5–7</sup>. Others have focused on the use of embodiment to improve empathy towards vulnerable groups, including domestic violence victims<sup>8,9</sup>. Some research has been devoted to using avatars for cognition improvement through the embodiment of personalities like Albert Einstein<sup>10</sup>. Finally, embodying avatars has proven helpful in reducing symptoms of psychological morbidities like anorexia nervosa<sup>11</sup>, and studies have taken place on their usefulness in self-dialogue for mental health improvement<sup>12</sup>.

### Related work

The benefits of self-dialogue have been widely studied. In therapeutic contexts, techniques such as the empty chair, where individuals switch seats to converse with two parts of themselves, have been shown to increase self-compassion and help reduce self-criticism and symptoms of psychological morbidities<sup>13,14</sup>. These effects have been enhanced by VR: Convicted offenders, alternately embodying a present and future version of themselves, reported decreased self-defeating behaviors and more future-oriented decisions<sup>15</sup>. Body-swapping between a crying virtual child and a compassionate virtual adult led to significant reductions in depression symptoms and self-criticism<sup>16</sup>. Osimo et al. studied self-dialogue about personal problems by comparing body-swapping with Dr. Sigmund Freud versus a duplicate lookalike<sup>17</sup>. Both increased self-compassion and improved mood and happiness, but embodying Freud produced better results<sup>17</sup>. However, it was unclear whether using Freud was critical for this<sup>17</sup>. Slater et al. extended this work by comparing scripted dialogue with Freud against self-dialogue with the psychoanalyst<sup>12</sup>. Self-dialogue led to overall stress reduction and substantial changes in feelings, behaviors, and thoughts one week after the exercise<sup>12</sup>. However, they identified the need to study whether the paradigm's success depended on the participants' avatar being a lookalike<sup>12</sup>.

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Furthermore, prior studies used interlocutor avatars somewhat associated with wisdom, being an aged version of the participant<sup>16</sup> or a reputed wise person (Sigmund Freud)<sup>12,17</sup>. This raises the question of whether the paradigm would work if body-swapping with any other person or if a ‘wise’ interlocutor was essential. Definitions of ‘wisdom’ tend to vary. A study found that most people associate wisdom with age, and almost half with education<sup>18</sup>. Older adults are typically described as wise, caring, and knowledgeable, while younger adults are seen as healthy, energetic, and willing to learn<sup>19</sup>. These “stereotypes” are mirrored in peer evaluation, as young adults perceive their peers as less wise, and older adults perceive their peers as wiser<sup>19</sup>. Some authors have also noted that modern isolation of the elderly may reduce chances of wisdom passing to the younger generations<sup>18</sup>, potentially shifting these stereotypes and the effectiveness of wiser interlocutors in self-dialogue.

These open questions motivate our study. It is our objective to investigate (1) whether the paradigm remains effective if the participants embody a non-lookalike and self-dialogue with a common, non-reputed interlocutor; (2) whether the interlocutor’s age, a characteristic culturally associated with wisdom, influences outcomes. As a secondary research goal, we also examine (3) whether the perceived effectiveness of self-dialoguing through body-swapping relates to the participants’ self-reported sense of embodiment. We designed a self-dialogue exercise following a similar structure to Osimo et al. and Slater et al.<sup>12,17</sup>, where participants embodied a non-lookalike avatar and body-swapped with a younger or mature-looking virtual person. We hypothesized that 1. participants would report positive results from the self-dialogue while virtually represented by a non-lookalike avatar; 2. the outcomes would be more positive when dialoguing with a mature-looking avatar; and 3. that self-reported embodiment would be related to the perceived effectiveness of the self-dialogue.

## Methods

### Study design

This was an independent sample study with a two-level independent variable based on the avatar they swapped bodies with during the self-dialogue experiment: (1) the avatar of a young adult female (Young Condition), (2) a mature-looking (~55) female avatar (Mature Condition). Numbers 1–30 were randomly allocated into two groups using Random.org<sup>20</sup>. Participants were then assigned to groups based on the order in which they accepted the invitation. The final participant was placed into a specific group to maintain balance between groups. Participants were not informed that two conditions existed. However, experimenters were necessarily aware to activate the appropriate scenario (YC/MC) and provide the corresponding questionnaire. They agreed to participate by signing online and paper Informed Consents in both online and face-to-face sessions. This study was approved by the Data Protection and Ethics Committee of the University of Madeira on January 18th, 2024 (N° 104/CEUMA/2024), and it was conducted in accordance with the Declaration of Helsinki as revised in 2023.

### Participants and recruitment

This study was conducted in Portugal. Participants were eligible for this study if they (1) were women between 18 and 35 years old, and (2) were familiar with the Portuguese social environment by residing in Portugal for three years or longer. Thirty-one women were recruited from the general population through email invitations, online posts, posters, fliers and word of mouth. However, 3 participants did not complete all the sessions, making 28 participants eligible for analysis: 14 in the Mature Condition (MC) group and 14 in the Young Condition (YC) group.

### Materials

We used a Meta Quest 2 head-mounted display, with binocular optics of 1832×1920 per-eye resolution that displays a 3D video scene and a horizontal field of view of 97 degrees. The participants’ head and hand movements were tracked in real-time through the headset and two Oculus Touch controllers, both 6-degrees-of-freedom tracking devices. The virtual environment was developed using the Unity Game Engine (version 2021.3.21f1). It consisted of a room with a panoramic window and a door decorated with some furniture and decorative items. There was a desk, two benches (one at each end) and two mirrors (each tilted towards opposite ends of the desk) in the middle of the room. On opposite sides of the desk, two different avatars sat: the user’s *self* and that representing the *other* (a young adult or a more mature-looking woman, depending on the condition). In front of each avatar, on top of the desks, an interface displayed the number of body changes left and a button to trigger the body change (Fig. 1).

All avatar models (*self*, and young and mature *other*) were created and customized via the Ready Player Me Hub (avatar creator). The final models were then imported into Unity using the Ready Player Me Unity SDK (version 1.2.0). All avatars were given casual attire. The user’s *self* avatar was an olive-skinned, black-haired woman wearing a grey long-sleeved sweater, blue jeans, and black boots (Fig. 2a). The *other* young avatar was a light-skinned, short-brown-haired woman wearing a white blouse, black pants, and black shoes (Fig. 2b). The *other* mature avatar was a light-skinned, grey-haired woman wearing a white t-shirt, beige pants, white shoes, and glasses (Fig. 2c). More images available in a public repository<sup>21</sup>.

The headset and controllers tracked the participants’ movements, and they were later mapped onto the avatars using Unity’s Animation Rigging and an inverse kinematics algorithm. The Ready Player Me built-in eye animation handler was used to randomize blinking and eye movement. The participants’ voices were recorded through the headset’s microphone at a sample rate of 44.1 kHz and mapped to mouth movements in real time using Oculus Lipsync. An algorithm tracked and stored the local position, rotation, and scale of the avatar’s skeletal structure at regular intervals while in the first-person perspective, as well as their voice and lip sync movements. Another algorithm handled the playback of these data (body and mouth movement and audio) on an “empty” avatar. These empty avatars representing the *other* were set to disguise the user’s voice by slightly lowering the pitch during playback. They also adopted an idle animation with built-in randomized blinking and



**Fig. 1.** The virtual scenario. An overview of the scene when the user's virtual *self* (on the left) will self-dialogue with the mature *other* (on the right).



**Fig. 2.** Details on the three virtual bodies or avatars used in the experiment. From left to right: (a) detail of the user's representation in VR, the *self* avatar. (b) detail of the *other* avatar in the Young Condition. (c) detail of the *other* avatar in the Mature Condition.

eye movements while the user embodied the avatar in front of them. Another algorithm controlled the transition between avatars based on user interactions and managed the activation of instructional audio cues that guided the user through the experience. Whether embodying the *self* or the *other*, the interface was set inactive while listening to playback, and was only activated when it was the participant's turn to respond. To switch avatars, participants would point at the virtual button "submit" and press the touchpad's button B. While Slater et al.<sup>12</sup> used only button pressing for avatar switching, we used the interface as a visual cue to instruct users of their turn to talk. Mirrors would activate depending on the avatar the participant was embodying. Images of key project settings, scenarios and interfaces are available in a public repository<sup>21–23</sup>.

#### Procedures

The participants participated in three sessions: an online preparation session within 1–2 weeks before the experiment (Pre-Experiment), a face-to-face experimental session with two assessment points (Experiment), and a follow-up (Post-Experiment) session within 1–2 weeks after the experimental session.

**Pre-experiment** The participants accessed an anonymous and confidential online questionnaire in Microsoft Forms to assess their socio-demographic characteristics and attitudes towards older adults. At the end of the

questionnaire, they were instructed to book the face-to-face VR session with the researcher between 1 and 2 weeks after the initial assessment.

**Experiment** Participants came to the lab and were briefed on the session's steps. Before entering the virtual environment, they were instructed to think and describe a personal problem that caused them stress in daily life, which they would later discuss during the experiment. We adopted this strategy from Slater et al.<sup>12</sup> because it reliably elicits emotionally meaningful and self-relevant content, which was essential for our goal to measure how self-dialogue supported perspective change and problem understanding. To help participants reflect and articulate their problem, they were also asked to state it in a single sentence using the structure from Slater et al.<sup>12</sup>: "When..., I think..., I act/react/do..., and I would like to...". They were also asked questions regarding the level of importance and discomfort of the problem. Before setting them up in the VR environment, they were shown pictures of the two avatars and their roles (e.g., the *self* avatar as themselves and the *other* as an unknown individual) and a brief description of the avatar-swapping dynamic. After this, the headset and controllers were set up for maximum comfort. They were taught how to interact with the virtual interface using their physical touchpads and performed an embodiment exercise. During the embodiment exercise, they would individually embody each avatar (self and other) in front of a virtual mirror and be asked to look at their virtual body, look at themselves in the mirror, and move their left arm up, down, front, left and right. This phase lasted, on average, 40 s per avatar (depending on the participant). They were introduced to the self-dialogue scene where the avatars were in front of each other and practiced a mock conversation guided by the researcher. They practiced using the interface and switching avatars when ready to listen to themselves from the second-person perspective.

Regardless of the condition, the exercise always started with the participants embodying the *self* avatar, introducing themselves and discussing their problem. It always ended in the *self* avatar listening to the *other* avatar's concluding line. They were informed that the exercise had 5 interactions or body swaps and that a panel on their left kept track of the remaining interactions. They were instructed to wrap up the conversation and say goodbye once the remaining interactions were zero. Once comfortable doing the exercise independently, they performed the self-dialogue privately. Before leaving the room, the researcher advised them to introduce themselves and the situation they wanted to discuss during their first interaction and reminded them that their speech could extend within the 6-turn limitations, having to wrap up the dialogue when the remaining turns were 0. A demonstration video is available in an open repository<sup>24</sup>. After the self-dialogue experience, participants filled in a hard-copy post-VR experience questionnaire. This included questions on their levels of immersion, presence, body-ownership illusion, self-dialogue experience, and outcomes regarding the personal problem presented.

**Post-Experiment** A week after the experimental session, the participants were sent a scan of the problem they wrote and discussed in the experimental session via e-mail and asked to respond to the last questionnaire in Microsoft Forms format within a week. It included questions regarding the outcome of the problem presented and a debrief on the ultimate rationale and goal of the study.

#### Data collected

Three questionnaires collected information about the users and the dependent variables.

The socio-demographic data included the participants' age, biological sex, marital status, scholarship, country of residence, years of residence, type of residential environment, and employment status. This section aimed to verify that our sample met the inclusion criteria and compare the sociodemographic characteristics of both groups, so it was not used for analysis. To account for the potential confounding role of our participants' attitudes towards older adults in our results, we used the Portuguese translation of Kogan's Attitudes toward Older People (ATOP) scale<sup>25,26</sup>, which assesses explicit prejudice and stereotypes towards older people. It comprises 17 pairs of logical opposites, positive and negative, that use a 6-point Likert scale: 1 Strongly Disagree and 6 Strongly Agree. The values are reversed for negative items. The scale returns a score from 34 to 238; the higher the score, the more positive the respondent's attitude toward the elderly<sup>25</sup>. Despite its limitations, this scale was chosen for its widespread research use, reported reliability, and validity<sup>27</sup>. The questions were mixed with other items in a scrambled order, and a 15-min response limit was set to reduce the participants' control over any incongruence in their position.

Because our study is similar to that performed by Slater et al.<sup>12</sup>, and to facilitate future comparisons, we used the same VR/Self-dialogue questionnaires to assess the participants' presence, body-ownership illusion, self-dialogue experience and outcomes related to their personal problem. Each item was scored individually. The questionnaire included: (a) 9 items assessing immersion and presence (for reference only); and (b) 7 items assessing body-ownership illusion and agency 4 while in the *self* character and 3 while in the *other* character), analyzed for exploratory purposes; (c) 6 items regarding the self-dialogue experience in VR; and (d) 5 questions regarding the outcomes of the problem presented, to assess perceived changes after their experience. Sections c and d constitute our primary analysis. Table 1 shows all questionnaire variables, items, scoring ranges and anchors. The research team translated all items into Portuguese for this study.

## Results

Since most of our data is ordinal, central tendency and dispersion are presented here through the median and interquartile range. Categorical data is to be presented as frequencies and percentages. Effect sizes ( $r$ ) were computed as  $Z/\sqrt{N}$ . The criteria for interpreting the effect are 0.1 = small, 0.3 = medium, and 0.5 = large. All statistical comparisons were based on a significance threshold of  $\alpha = 0.05$  (5%) and computed using IBM SPSS v.28.0.0<sup>28</sup>. A post-hoc sensitivity analysis using G\*Power v.3.1<sup>29</sup> indicated that, with 28 participants ( $n = 14$  per group),  $\alpha = 0.05$ , and power = 0.80, the minimum detectable effect size for related and independent-samples tests

Category	Variable	Questionnaire item	Scale	Anchors
Embodiment	<i>SelfRecognition</i>	Did you recognize yourself in the first character's body?	7-point (-3 to 3)	-3 = Totally disagree, 3 = Totally agree
		<b>Self</b>		
	<i>Down</i>	I felt that the virtual body I saw looking down was my own body.	Same item, referring to second avatar	
	<i>Mirror</i>	I felt that the virtual body that I saw when I looked towards the mirror was my own body.	Same item, referring to second avatar	-3 = Totally disagree, 3 = Totally agree
	<i>Agency</i>	I felt that the movements of the virtual body were caused by my own movements.	Same item, referring to second avatar	
Self-dialogue outcomes	<i>Knowledge</i>	I feel that now I have more knowledge about my problem	7-point (-3 to 3)	Same as above
	<i>Understand</i>	I think that, after this experience in the virtual consultation, I am able to better understand my problem	7-point (-3 to 3)	Same as above
	<i>Newideas</i>	I think I can have new ideas on how to solve my problem	7-point (-3 to 3)	Same as above
	<i>Bettercontrol</i>	I feel that I control my problem better	7-point (-3 to 3)	Same as above
	<i>Helped</i>	This dialogue helped me to have a new perspective on my problem	7-point (-3 to 3)	Same as above
	<i>Perspective</i>	Every time I changed the avatar and observed the situation from the perspective of the second avatar, I understood my problem better	7-point (-3 to 3)	Same as above
Problem-related outcomes	<i>Importance</i>	What is the level of importance of the problem in your current life?	5-point (0-4)	0 = Not at all important, 4 = Extremely important
	<i>Discomfort</i>	What is the level of discomfort induced by the problem in your current life?	5-point (0-4)	0 = Does not disturb or affect me, 4 = Disturbs and incapacitates me greatly
	<i>Help</i>	How much did the intervention help you as regards to the problem?	6-point (0-5)	0 = Not sure, 5 = Made things a lot better
	<i>Notable</i>	How important or significant to you personally do you consider this change to be?	5-point (1-5)	1 = Nothing important, 5 = Extremely important
	<i>Changes</i>	Are you doing, feeling, or thinking differently from the way you did before?	Dichotomous	Yes / No

**Table 1.** List of variable names, items, scoring range and anchors for the questionnaires on self-recognition, body ownership and agency; their self-dialogue experience in VR; and the personal problem discussed.

was  $d = 1.13$  (two-tailed) and  $d = 0.99$  (one-tailed), corresponding to  $r \approx 0.49$ , indicating a very large effect. For the repeated measures tests, the minimum detectable effect size was  $f = 0.31$  (equivalent to  $\eta^2 \approx 0.09$ ), corresponding to a medium-to-large effect. Finally, for the correlations, the minimum detectable correlation was  $\rho \approx 0.50$ , corresponding to a large effect. Therefore, smaller effects may not have been reliably detectable with the current sample size.

### Sample characteristics

All of our participants were Portugal residents, either native or living in the country for 3 years or longer. Our YC group was, on average,  $25.3 \pm 3.5$ ; most were single ( $n = 12$ , 85.7%), with higher education ( $n = 13$ , 92.9%), and residing in urban areas ( $n = 12$ , 85.7%). They were mostly students ( $n = 9$ , 64.3%), followed by employed women ( $n = 4$ , 28.6%). The MC group was, on average,  $27.4 \pm 4.3$ , most were also single ( $n = 11$ , 78.6%), with higher education ( $n = 14$ , 100%), residing in urban areas ( $n = 13$ , 92.9%). Most were employed women ( $n = 6$ , 42.9%), closely followed by students ( $n = 5$ , 35.7%). Statistical comparisons between groups showed no significant differences in terms of age ( $p = 0.15$ ), marital status, education, residence ( $p = 1.0$ ) or employment ( $p = 0.40$ ). Regarding their Attitudes Towards Older People, the Mann–Whitney U test was used to compare the scores between the two conditions and determine possible effects. The YC group obtained a score of 143.50 (IQR = 29), and the MC of 142 (IQR = 12), with no statistical differences found.

### Motion sickness, immersion and presence

The scores of *sick* and *sounds* variables were very low, being *sick* at -3 (IQR = 3) and *sounds* at -2 (IQR = 3). Even though the YC group showed the best results, these differences were insignificant. Regarding all the presence-related variables, the scores were generally above-average, between 1.5 and 2. A comparison between groups using the Mann–Whitney U test yielded no significant results (Supplementary Table S1).

### Self-recognition, body-ownership illusion, and agency

Scores for all embodiment-related variables were above-average for the *self* avatar, with *selfdown* and *selfmirror* being 1.5 and 2 for *selfrecognition* and *selfagency*. For the *other* avatar, these variables were also above-average,

with a 2 for *otheragency*, while *otherdown* and *othermirror* scored 0.5. A comparison between the two conditions using the Mann–Whitney U test yielded no statistically significant results (Supplementary Table S2).

We performed a within-group comparison of the scores given to the *self* avatar (*selfdown*, *selfmirror* and *selfagency*) and those to their counterparts in the *other* avatar (*otherdown*, *othermirror*, *otheragency*) using Wilcoxon's test, with Holm correction applied to adjust for multiple comparisons. When analyzing the YC group, body recognition when looking down was higher when embodying the *self* (Mdn = 1.5, IQR = 3) than the young *other* avatar (Mdn = 1, IQR = 2). Although this difference was initially significant, with  $T = 0.0$ ,  $p = 0.04$ , and  $r = -0.6$ , it was lost after corrections (Table 2). There were no further significant differences between the two avatars in this group. Regarding the MC group, no significant differences were found between the avatars, except for the variables *selfagency* and *otheragency*, with  $T = 0.0$ ,  $p = 0.04$ , and  $r = -0.6$ . However, this significance was also lost after corrections (Table 2).

Regarding the perceived age of the *other*, most of the YC group perceived the young avatar as 25–34 ( $n = 6$ , 21.4%) or 35–44 years old ( $n = 6$ , 21.4%). The remaining two participants considered her 18–24 or 45–54 years old. On the other hand, most of the MC group perceived the mature avatar to be either 55–64 ( $n = 4$ , 14.3%) or over 65 years old ( $n = 4$ , 14.3%). The remaining participants varied in the *other's* age perception from 45 to 54 ( $n = 3$ , 10.7%), 35–44 ( $n = 2$ , 7.1%), and 25–34 years old ( $n = 1$ , 3.6%).

### Self-dialogue experience in VR

Our sample reported above-average scores of 2 for *knowledge*, *understand*, *newideas*, *helped* and *perspective*, and 1.50 for *bettercontrol*. The MC group reported slightly higher scores for *newideas* (Mdn = 2, IQR = 2), *helped* (Mdn = 2.5, IQR = 2) and *perspective* (Mdn = 2, IQR = 2), and the YC group somewhat higher scores in *bettercontrol* (Mdn = 2, IQR = 2). However, these differences were insignificant after between-group comparisons using the Mann–Whitney U test (Supplementary Table S3).

#### Outcomes of the problem presented between conditions

The top two categories of personal problems discussed were Social Anxiety and Insecurity ( $n = 9$ , 32.14%) and Time Management and Work/Life Balance ( $n = 9$ , 32.14%). The other two minor categories were Performance and Self-Demand ( $n = 6$ , 21.43%), and Specific Stressful Situations ( $n = 4$ , 14.29%). For examples of these topics, see Supplementary Text S4. Mann–Whitney U tests were used to compare the two groups (YC vs. MC) on all variables related to the daily-life problem or personal issue participants chose to discuss during the experiment. Holm correction was applied to adjust for multiple comparisons.

At PreVR, both groups reported similar levels of *importance* (YC: Mdn = 2, IQR = 1; MC: Mdn = 2, IQR = 2) and *discomfort* (YC: Mdn = 2.5, IQR = 2; MC: Mdn = 2, IQR = 2) with no significant differences found between groups (Table 3).

At PostVR, average scores for *importance* and *discomfort* remained at 2 for both groups, with no significant differences shown. No statistically significant differences were found for *help* either, with both groups reporting a 4 (IQR = 0). However, the MC group reported significantly higher scores (Mdn = 3.5, IQR = 1) than the YC group (Mdn = 2, IQR = 1) ( $U = 149.0$ ,  $p = 0.01$ ,  $r = 0.5$ ) for the variable *notable*, a significance that persisted after corrections, providing robust evidence for a group difference (Table 3). Both groups were not significantly different at FollowUp. All other variables' scores (*importance*, *discomfort*, *help*) showed no significant differences between groups at Follow-Up.

The proportion of positive responses to the variable *changes* was the same in both groups at PostVR ( $n = 10$ , 71.4%) and FollowUp ( $n = 8$ , 57.1%). Considering the high similarity between groups, no inferential tests were performed for this variable.

#### Outcomes of the problem presented within groups over time

Friedman's test measured significant differences within groups across three different assessment points. For variables showing a significant Friedman result, post-hoc pairwise comparisons were performed using Wilcoxon signed-rank tests, with Holm corrections applied to adjust for multiple comparisons within each variable. In the

Group	Variable name	Self	Other	$p$ (raw)	$r$	$p$ (Holm-adj.)
YC	<i>Selfrecognition</i>	1.50 (2)	–	–	–	–
	<i>_Down</i>	1.50 (3)	1 (2)	0.038*	– 0.6	0.114
	<i>_Mirror</i>	2 (3)	0.50 (3)	0.083	– 0.5	0.166
	<i>_Agency</i>	2 (1)	2 (2)	0.257	– 0.3	0.257
MC	<i>Selfrecognition</i>	2 (1.8)	–	–	–	–
	<i>_Down</i>	1.50 (2)	0 (3)	0.185	– 0.4	0.185
	<i>_Mirror</i>	1 (3)	0.50 (2)	0.074	– 0.5	0.148
	<i>_Agency</i>	2.50 (1)	1.50 (2)	0.038*	– 0.6	0.114

**Table 2.** Comparison of variables on self-recognition, body ownership and agency over their virtual *self* and *other* avatar within each group. All items were scored on a 7-point Likert scale, where -3 means the least agreement and 3 the most agreement. Scores for each variable and condition are shown as Medians and Interquartile range (Mdn (IQR)). YC = Young avatar condition, MC = Mature avatar condition,  $r$  = Pearson's effect sizes. \* Significant raw effects ( $p < 0.05$  (two-tailed)), but did not survive after Holm adjustment.

Variable	Time point	YC	MC	<i>p</i> (raw)	<i>r</i>	<i>p</i> (Holm-adj.)
<i>Importance</i>	PreVR	2 (1)	2 (2)	0.317,	−0.1	0.317
	PostVR	2 (1)	2 (2)	0.285,	−0.1	0.57
	FollowUp	2 (1)	2 (2)	0.227,	−0.1	0.681
<i>Discomfort</i>	PreVR	2.50 (2)	2 (2)	0.285	−0.1	0.855
	PostVR	2 (2)	2 (2)	0.384	−0.1	0.768
	FollowUp	2 (1)	2 (2)	0.437	−0.0	0.437
<i>Help</i>	PreVR	–	–	–	–	–
	PostVR	4 (0)	4 (0)	0.500	0.0	0.500
	FollowUp	4 (1)	4 (0)	0.241	0.2	0.482
<i>Notable</i>	PreVR	–	–	–	–	–
	PostVR	2 (1)	3.50 (1)	0.009*	0.5	<b>0.018</b>
	FollowUp	2 (2)	2.50 (2)	0.105	0.2	0.105

**Table 3.** Comparison of variables regarding the personal problem discussed in self-dialogue between the young and mature avatar conditions. Variables were scored on a 5 to 6-point Likert scale, depending on the item (Refer to Table 1). All time points per item are one family for Holm within-family comparisons. 1-tailed significant effects for the expected hypothetical advantage of MC over YC. Scores for each variable and condition are shown as Medians and Interquartile range (Mdn (IQR)). YC = Young avatar condition, MC = Mature avatar conditions, *r* = Pearson's effect sizes. \* Significant effects ( $p < 0.05$  (1-tailed)). Significant effects after Holm correction are highlighted in **bold**.

Group	Test	Variable	PreVR	PostVR	FollowUp	<i>p</i> (raw)	<i>r</i>	<i>p</i> (Holm-adj.)	
YC	Friedman	<i>Importance</i>	2 (1)	2 (1)	2 (1)	0.115	–	0.230	
		<i>Discomfort</i>	2.50 (2)	2 (2)	2 (1)	0.819	–	0.819	
	Wilcoxon	<i>Help</i>	–	4 (0)	4 (1)	0.317	−0.3	0.634	
		<i>Notable</i>	–	2 (1)	2 (2)	0.380	−0.2	0.380	
MC	Friedman	<i>Importance</i>	2 (2)	2 (2)	2 (2)	0.032*	–	0.064	
	(Pairwise Wilcoxon post-hoc)	<i>Importance comparisons</i>							
		<i>Follow-Up vs PostVR</i>	–	2 (2)	2 (2)	0.219	–	0.438	
		<i>Follow-Up vs PreVR</i>	2 (2)	–	2 (2)	0.108	–	0.324	
		<i>PostVR vs PreVR</i>	2 (2)	–	2 (2)	0.705	–	0.705	
		<i>Discomfort</i>	2 (2)	2 (2)	2 (2)	0.692	–	–	
	Wilcoxon	<i>Help</i>	–	4 (0)	4 (0)	1.000	0.0	1.000	
<i>Notable</i>		–	3.50 (1)	2.50 (2)	0.038*	0.6	0.076		

**Table 4.** Comparison of variables regarding the personal problem discussed in self-dialogue within groups across three assessment points. Variables were scored on a 5 to 6-point Likert scale, depending on the item (Refer to Table 1). Wilcoxon signed-rank tests were performed after a significant Friedman's test (variable *importance*). Holm correction applied across the pairwise comparisons. Scores for each variable and condition are shown as Medians and Interquartile range (Mdn (IQR)). YC = Young avatar condition, MC = Mature avatar conditions, *r* = Pearson's effect sizes. \* Significant effects ( $p < 0.05$  (2-tailed)), but did not survive after Holm adjustment.

YC group, no significant differences were found in the *importance* of the personal problem discussed during their self-dialogue across the three assessment points, with a mean of 2 (moderately important). The variable *discomfort*, although a 2.5 PreVR, decreased to 2 at PostVR and FollowUp, with no statistical significance. Significant differences were initially found in *importance* across the three assessment points ( $F(2) = 6.87$ ,  $p = 0.03$ ) for the MC group. However, this significance was not maintained after Holm corrections. The variable *discomfort* remained at 2 (disturbs me moderately) across the three assessment points, with no significant differences detected.

Wilcoxon tests were performed to detect significant differences within groups between PostVR and FollowUp, with post-hoc Holm corrections. For the YC group, *help*'s score remained a 4 (made things somewhat better) and *notable* a constant 2 (a bit important), with no significant differences. In the MC group, although a significant decrease of  $T = 8.0$ ,  $p = 0.04$ , was initially found in *notable* (PostVR: 3.5 (moderately-very important) vs. FollowUp: 2 (a bit important), it did not remain significant after Holm correction (Table 4). The variable *help* did not differ significantly between PostVR and FollowUp, remaining at 4 (made things somewhat better) (Table 4).

Variable	Self-recog	Self down	Self mirror	Self agency	Other down	Other mirror	Other agency
Knowledge	0.073	-0.041	-0.289	0.129	0.140	-0.286	-0.045
Understand	0.148	-0.009	-0.248	0.098	0.194	-0.212	-0.006
Newideas	0.001	-0.132	-0.359	0.168	-0.005	-0.368	0.045
Bettercontrol	0.151	-0.019	-0.214	0.009	0.065	-0.120	-0.141
Helped	0.234	0.179	-0.095	0.181	0.345	-0.050	-0.003
Perspective	0.459*	0.376*	0.115	0.393*	0.420*	0.043	0.170

**Table 5.** Correlation between variables on self-recognition, body ownership and agency over their own and other avatar, and variables on their self-dialogue experience in VR.  $r_s$  = Spearman's correlation coefficient. \* Correlation is significant ( $p < 0.05$  (2-tailed)), but not significant after Benjamini–Hochberg FDR correction.

Variable	PostVR				FollowUp			
	Importance	Discomfort	Help	Notable	Importance	Discomfort	Help	Notable
Selfrecog	0.128	0.010	0.381*	-0.103	-0.022	0.157	0.055	-0.015
Selfdown	0.110	0.000	0.449*	-0.147	-0.085	0.118	0.053	-0.047
Selfmirror	0.006	-0.087	-0.035	-0.145	-0.139	-0.061	-0.194	-0.273
Selfagency	-0.239	-0.199	0.112	-0.069	-0.292	-0.122	0.345	0.120
Otherdown	0.134	0.001	0.373	-0.099	-0.016	0.199	.092	-0.160
Othermirror	0.150	-0.093	-0.042	-0.078	0.027	0.133	-0.123	-0.315
Otheragency	-0.107	-0.183	0.005	-0.117	-0.129	0.073	0.192	-0.009

**Table 6.** Correlation between variables on self-recognition, body ownership and agency over their own and other avatar, and variables on the outcomes of the personal problem discussed in self-dialogue. Correlations for two separate families: embodiment and PostVR, and embodiment with FollowUp.  $r_s$  = Spearman's correlation coefficient. \* Correlation is significant ( $p < 0.05$  (2-tailed)), but not significant after Benjamini–Hochberg FDR correction.

Regarding the variable *change*, there was a reduction of 2 individuals between PostVR and FollowUp responding positively in both groups (Table 4). No statistical tests were performed considering the similar frequencies in both assessment points.

#### *Relationship between the quality of embodiment, the self-dialogue experience, and the outcomes of the problem presented*

Spearman's correlation coefficient was used to identify significant relationships between the participants' levels of body-ownership illusion, their self-dialogue experience in VR and the outcomes of the problem presented, with post-hoc Benjamini–Hochberg FDR corrections for multiple comparisons<sup>30</sup>. At first, the self-dialogue experience-related variable *perspective* showed moderate positive correlations with *self-recognition* ( $r_s = 0.459$ ,  $p = 0.014$ ), *selfagency* ( $r_s = 0.393$ ,  $p = 0.04$ ), and *otherdown* ( $r_s = 0.420$ ,  $p = 0.03$ ), and a weak correlation with *selfdown* ( $r_s = 0.376$ ,  $p = 0.049$ ). However, such significance was lost after corrections (Table 5).

Similarly, initial significant positive correlations between the problem outcome-related variable *help* and embodiment-related variables *selfrecognition* ( $r_s = 0.381$ ,  $p = 0.05$ ) and *selfdown* ( $r_s = 0.449$ ,  $p = 0.02$ ) at PostVR did not survive corrections (Table 6).

## Discussion

We performed a study facilitating a self-dialogue exercise where the participants embodied a non-lookalike avatar and body-swapped with the avatar of either a young adult or a mature-looking woman. Our participants reported positive outcomes from the self-dialogue exercise even when represented by a non-lookalike avatar and body-swapping with a non-reputable other, suggesting that the paradigm remains effective under these conditions. The group that self-dialogued with a mature woman reported more significant changes regarding the personal problem they discussed immediately after the experience. However, no substantial evidence was found that the interlocutor's age affected the exercise and problem outcomes in the long term. Further, our secondary analyses showed a trend for specific embodiment-related factors related to the success of self-dialoguing that needs to be studied further and more rigorously.

Regarding the participants' experience of self-dialogue in VR, no differences were found between our two conditions. Though not significant, the self-dialogue experience was considered slightly more helpful, and changes in perspective after swapping were more meaningful for those in the MC group. When compared to Slater's study, which used the same questions to evaluate the outcomes of the virtual self-dialogue, our groups obtained slightly higher scores for all these variables<sup>12</sup>. However, they were both similar in showing a positive impact of the self-dialogue exercise immediately after VR. In our sample, this positive impact was only seen

in the MC group. These findings suggest a possible short-term benefit of body swapping with a mature avatar compared to an age-congruent one, but its mechanisms remain uncertain.

When analyzing the outcomes of the problem presented, differences were seen between self-dialoguing with a young or a mature virtual *other* when asked about the significance of the change regarding their problem presented, PostVR. While the notability of the change was a bit important for the YC group, it was from moderately to very important to our MC group. There is no evidence that the avatar's age affected our participants' self-dialogue experience. However, body-swapping with the mature avatar had an immediate advantage. Retrospectively, we speculate that the other's attire could have modulated these outcomes. Although we tried to have *other* avatars dressed similarly, the young *other's* attire (white blouse and black trousers) might have seemed more professional. In contrast, the mature avatar's attire (white shirt, beige pants, glasses) may have seemed informal. A study showed that wearing lab coats increased children's identity and self-efficacy as scientists<sup>31</sup>. Following this line, one could have expected the young *other* to be perceived as more knowledgeable than the mature one, and, arguably, lead to better immediate outcomes, which was not the case. A similar argument would have to be brought up in Osimo et al.'s, since Freud's attire was likely more formal than some users' (black trousers and vest, long-sleeved army green blouse, glasses)<sup>17</sup>. Another study showed that high team visual similarity reduced feelings of being distinct from the other members<sup>32</sup>. Following this line, our participants could have felt more identified with the mature avatar, raising the argument that the immediate benefits obtained could be based on feelings of peer support and empathy rather than wisdom or knowledgeability. Again, the greater success of body-swapping with Freud had over any of our *other* avatars does not seem to support this idea. These post-hoc explanations should be interpreted with caution, and future studies with tighter controls on these variables are needed to provide more definite answers.

Our MC group was the most similar to Slater et al.'s SelfConversation sample, which might suggest a slight advantage of self-dialoguing with Freud or a mature avatar over an age-congruent one. A study by Osimo et al. compared self-dialoguing with Freud against body-swapping with their duplicate, and greater improvements were found when self-dialoguing with the psychoanalyst<sup>17</sup>. Taken together, these results could indicate that self-dialogue in VR could bring greater benefits when embodying a wiser and more knowledgeable person. Research on wisdom and ageism has shown that all age groups are confronted with stereotypes of their age and that specific characteristics were typically attributed to older adults (wise, caring, calm, knowledgeable, generative) and others to young adults (energetic, healthy, willing to learn)<sup>19</sup>. A study examined the impact of the avatar's age on the time needed to walk a certain distance in the real world, and those who embodied an old avatar showed a decrease in speed immediately after exposure<sup>3</sup>. Post-hoc, one could hypothesize that, in our case, the mature avatar might have been seen as wiser or more knowledgeable than the young one due to social stereotyping. Cognitive emulation of the mature avatar might have led to perceived wiser reflection, resulting in stronger immediate feelings of change. These interpretations are speculative and require targeted studies to confirm. Our sample's scores on the outcomes regarding the problem were also very similar to the raw scores obtained by Slater et al.'s SelfDistancing sample<sup>12</sup>. Self-dialoguing with Freud, or a young or mature avatar, led to the problem remaining of moderate importance and discomfort, and the intervention equally helped make things somewhat better for both our sample and Slater et al.'s.

Variations between our results and those of Slater et al. are more marked when considering FollowUp data. The significance of the change regarding the problem was maintained, with a score of 3 one week after self-dialoguing with Freud<sup>12</sup>. However, our group that self-dialogued with a mature avatar showed a trend towards reducing this significance after a week. The proportion of people reporting changes in their feelings and behaviors after the intervention was also slightly higher in Slater et al.'s sample: 86% of their SelfConversation group reported these changes, compared to 71.4% in our sample immediately after VR<sup>12</sup>. However, while these proportions were maintained one week after VR in Slater et al.'s sample, our YC and MC groups' percentages were reduced to 51%. This pattern might suggest that self-dialoguing with a mature *other* might not have been as impactful or memorable as with the renowned Sigmund Freud. Alternatively, one could hypothesize that self-dialoguing with a mature *other* who resembles a real older person whom participants keep in high regard helps maintain the experience's impact long-term. The participant's attribution of wisdom to the *other* avatar could also impact self-dialogue outcomes in VR. This study's participants were 18–35 years old, a factor that might have affected not only self-identification with the self-avatar, but also their perception of the other as wise or knowledgeable. Since perceived wisdom was not measured in our study, we can only speculate, and further studies on the topic are certainly needed for conclusive answers. The participants' neutral attitudes towards older adults might also have indirectly influenced the MC group's experience. The mature avatar could have been considered a stronger wisdom figure if participants had a much higher positive attitude toward older people. Different sample sizes may explain these variations as well.

As part of our secondary research, we analyzed whether embodiment scores in both avatars could modulate their interpretation of the self-dialogue exercise or any changes regarding the problem they presented. Correlation analyses initially showed moderately positive and significant relations between the extent to which they felt they understood their problem better after body-swapping and three aspects of body ownership: self-recognition, agency in the *self*-avatar, and body-recognition when looking down at the *self* and *other* avatars. Furthermore, there were weak-to-moderate significant correlations between the extent to which self-dialoguing helped them have a new perspective and understanding of their problem at the PostVR assessment point and self-recognition and body recognition rates when looking down at the *self* avatar. Regardless, such significance was not maintained after Benjamini–Hochberg FDR corrections. These findings should be interpreted with caution, as they only suggest a trend towards some aspects of self-recognition and body ownership influencing how the virtual self-dialogue exercise is perceived and how helpful the exercise felt for our participants. Strong subjective feelings of body ownership illusion have been shown to influence the participants' cognition, perception and behavior<sup>8,33</sup>. Embodying avatars visually different from their real selves might have helped isolate the problem, make it belong

to a virtual *self*, and facilitate changes in behavior by adopting a stranger's perspective when listening to the *self's* problem. Future studies with larger samples and tighter controls are needed to confirm these trends.

Although secondary, embodiment-related outcomes of this study are still interesting and worthy of discussion. Our participants' scores of body ownership were above-average for the virtual *self*. Both groups showed above-average scores of self-recognition, body ownership and agency, which suggests acceptable body ownership. Our participants saw themselves from the first-person perspective, and they could see their bodies move synchronously with their actual movements. Even though some literature suggests that the first-person perspective and lookalike (e.g., scanned avatars) lead to higher embodiment levels<sup>4,34,35</sup>, others support visual synchrony as the most essential factor in achieving body ownership and agency<sup>36</sup>. Overall, our secondary outcomes are somewhat consistent with studies suggesting that high levels of body ownership can be obtained even when embodying an avatar different from them<sup>37</sup>.

The importance, or not, of look-alikeness is interesting when comparing our results with Slater et al.'s. Scores of self-recognition in the *self* avatar for our sample were higher than those in Slater et al.'s SelfConversation condition<sup>12</sup>. Slater et al. created virtual characters that resembled their participants using a whole-body scan<sup>12</sup>. Arguably, embodying a scan of their body and face should have led to greater self-recognition than our non-lookalike *self* avatar. Scores of recognizing themselves in the mirror while embodying the *self* in our YC group were similar to those obtained by Slater et al.<sup>12</sup>. One would have also expected much higher rates of self-recognition on a mirror with a lookalike scanned avatar than with a non-lookalike, like ours. A study highlighted that, despite scanned avatars being considered more "realistic" than wooden ones, the scanned ones were slightly more eerie and less attractive, which they attributed to the Uncanny Valley effect<sup>35</sup>. This raises the hypothesis that the Uncanny Valley effect could have influenced self-recognition in Slater et al.'s sample. However, our study was not designed to test this directly, and further research with controlled comparisons is needed to clarify the role of the Uncanny Valley effect in self-recognition and the self-dialogue scenario.

In our study, the average embodiment in the *self* avatar was slightly higher than when embodying the *other*. When comparing the YC and MC groups, there were no significant differences in the extent to which they felt embodied in the *other* avatars. However, initial analyses showed that some values (body-recognition in the YC and agency in the MC group) were significantly lower when embodying the *other*. Although such significance was lost after corrections, it suggests a tendency for better body recognition and agency in one than the other. Further, the extent to which they recognized themselves when looking down at themselves and in the mirror was the closest to neutral. Despite participants switching to the opposite avatar the same number of times, this habituation and always starting conversation as the *self* might have influenced body ownership. One could argue that successfully portraying someone other than us in situations of self-dialogue might inevitably translate into not quite recognizing that body as yourself, but studies controlling this particular variable are needed. Agency had above-average scores in both conditions, whether embodying the *self* or the *other*. This seems to support studies showing a tendency for users to report higher levels of agency than body ownership<sup>36</sup>.

As to why body recognition when looking down tended to be lower for the young *other* than their virtual *self*, we hypothesize that differences in their attire could have played a role. A study comparing drumming with a casually dressed dark-skinned or a formally dressed light-skinned male avatar found that the more embodiment they felt in the formally dressed light-skinned avatar, the less varied and frequent their body movements were<sup>33</sup>. Apart from the possible influences of stereotyping, it was also suggested that formal attire could have had an effect<sup>33</sup>. Other studies have indicated that wearing lab coats increased children's identity and self-efficacy as scientists under the right circumstances<sup>31</sup> and that high team visual similarity reduced feelings of being distinct from the other members<sup>32</sup>. Hypothetically, our virtual *self's* light grey sweater and blue jeans with heart-shaped patterns might have seemed more youthful and similar to what some of our participants usually wore, potentially facilitating body recognition. Further, although the young *other* was casual, her white blouse and black trousers might have seemed more professional, possibly making the participants feel out of place and affecting body recognition. The clothes factor might also explain the lack of significant differences in body recognition between the *self* and the mature *other*, since the latter wore a more informal white t-shirt, but we can only speculate to what extent.

When body swapping with the mature-looking avatar, the average weaker scores of agency given to the *other* could potentially be due to the Proteus Effect, which states that an individual's behavior conforms to that associated with their virtual body in real-time, even if the body is different from their own<sup>38,39</sup>. Lin and Wu compared elderly participants embodying sex-congruent older or younger avatars and discovered that embodying a younger avatar led to greater perceived exercise exertion, self-efficacy and physical activity<sup>40</sup>. Other studies comparing young participants embodying an age-congruent and incongruent avatar reported that those who embodied the latter showed changes in social motivation and took longer to cover distances<sup>3,41</sup>. Such results were attributed to the Proteus Effect and stereotypical expected behaviors of older adults<sup>3,40</sup>. Post-hoc, we speculate that our participants might have felt slower or less active when embodying the *mature* avatar. The constant swapping with their young *self* might have made these differences more marked, resulting in a perceived reduced feeling of agency.

Our agency and mirror self-recognition scores in our *other* avatars were similar to those obtained by Slater et al. from their sample that body-swapped with Freud. However, there were more visible differences in body recognition when looking down. Slater et al.'s participants reported a score of 2<sup>12</sup>. In contrast, ours reported 0 to 1, the lowest when embodying the mature avatar. A very tentative interpretation could suggest that it was easier for people to recognize their bodies when looking down on Freud than on a random person's body. This might be due to differences in our samples: Slater et al. had similar proportions of women and men, and the latter might have felt physically more identified with Freud. But, despite our *other* avatars being sex-congruent, body recognition was not high. It has been suggested that the success of the Proteus Effect lies in identification via self-similarity and wishful identification: despite dissimilarities, a desirable feature in the avatar can still

result in behavior change<sup>42</sup>. Although the strength of the Proteus Effect was not measured, we postulate that wishful identification could also help body ownership. Admiration of a celebrity like Freud may have helped increase body identification in Slater et al.'s sample. In our study, the *other* avatars were regular people, with the lowest levels of body identification when looking down on a mature woman. Future work is needed to test whether identification mechanisms, such as perception of wisdom, influence body ownership and self-dialogue outcomes.

## Conclusion

This study indicates that regardless of whom they body-swapped with during self-conversation dialogue (age-congruent or incongruent), avatar-aided self-conversation dialogue in VR using a non-lookalike avatar was considered a positive experience and successful in providing the opportunity to change perspective on their personal problem, supporting our first hypothesis. There was a small but significant advantage of body-swapping with a mature-looking avatar immediately after the exercise, which partially supports our second hypothesis. A post-hoc interpretation would be that perceived wisdom may play a role in ensuring this paradigm's success, potentially interacting with the users' attitudes toward older adults. Future research explicitly measuring the participants' perceived wisdom in the avatars and their levels of ageism is essential to study this further. In addition, studies systematically manipulating visual features, such as clothing, will also be necessary to assess the weight of possible confounding variables.

Non-lookalike avatars can invoke above-average self-recognition, body ownership and agency. However, variations in their strength are expected in experiences such as body-swapping for self-dialogue, for reasons that may go from the user's personality traits<sup>43</sup> or having a fixed avatar representing themselves in the virtual environment. Our findings suggest a trend for embodiment factors correlating with how helpful our participants felt perspective-taking was in understanding their discussed personal problem immediately after self-dialogue in VR. However, not enough strong evidence was found to support our third hypothesis. Further studies are required to understand the real effect of embodiment quality on the success of the studied paradigm.

This study has some limitations. First, the limited sample size, as well as the participants' specific nationality, gender and age range, summed up to the fact that it was a lab-controlled study, which affects the generalization of results to other populations and settings. Because neither perceived wisdom nor knowledgeability was measured, it is impossible to determine whether any advantage of body-swapping with a young or mature person was caused by lower or higher wisdom perception. Since no explicit ratings of naturalness or self-recognizability of the pitch-shifted voice in the *other* were collected, our interpretation of potential auditory influence on body ownership or self-dialogue outcomes is limited. As a one-time self-dialogue experience, it is impossible to know if the participants' benefits would increase from repeated virtual self-dialogue. Finally, because the user's stress severity was not measured, we cannot determine to what extent this could have impacted our results.

## Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to ethical restrictions and the informed consent under which the data were collected, which specified that participant data would be used solely for this project and handled only by the research team. In addition, some materials (e.g., Unity project files) cannot be shared due to institutional copyright restrictions. Access to de-identified data may be available from the corresponding author on reasonable request and with appropriate approvals, subject to compliance with the original ethics approval and institutional policies up until 2 years after publication.

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## Author contributions

DM, MSC and AF conceived and designed the work. DM selected the avatars, created the virtual scenarios and collaborated with the programming of the virtual environment. DM collected the data and performed its analysis. DM, MSC, and AF interpreted the data. DM wrote the manuscript. All authors revised and approved the manuscript.

## Additional information

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