

RESEARCH ARTICLE

Regulation of interpersonal distance in virtual reality: Implications for socio-emotional functioning in late adulthood

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Abstract

Objective

Accurately interpreting emotional states from facial expressions is crucial for effective social interactions. This study investigates age-related differences in interpersonal distance (IPD) regulation and emotion recognition using a virtual reality (VR) environment. We examined how younger and older adults adjust their IPD in response to emotional expressions from virtual agents.

Methods

Eighty participants, divided into older adults (OA) and younger adults (YA), took part in the study. Participants were immersed in a VR setup where they engaged in social interactions with happy or angry looking virtual agents. This behavioral task was complemented by a standardized emotion recognition task (ERT).

Results

Results showed that both YA and OA preferred larger distances from angry-looking virtual agents compared to happy ones. No significant differences in IPD were found between the age groups. However, older adults were less accurate in recognizing facial expressions.

Conclusion

These findings suggest that older adults can effectively regulate their social distance despite potential challenges in emotion recognition. The study underscores the importance of considering cognitive, perceptual, and motivational factors when

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examining the dynamics of emotional recognition and interpersonal distance in social contexts.

Introduction

Forming an accurate representation of someone else's emotional states from facial expression is fundamental for social interactions and survival [1]—for example, to retreat from a potentially threatening social interaction or to help someone in need. A growing body of research underscores the inherently social nature of emotions: they often emerge during interpersonal interactions, are regulated according to social norms and objectives, are expressed within social contexts, and significantly influence the behaviors and perceptions of others [2,3]. In addition, expressions shape behavior; they promote tendencies to approach or avoid. Specifically, distinct emotional expressions, such as anger or happiness, can elicit predictable, emotion-specific responses from observers, shaping their judgments and decision-making processes across various domains [4].

One effective approach to studying the impact of emotions on social interactions is to assess preferred interpersonal distance and the regulation of that distance in response to facial expressions. Interpersonal distance (IPD) is a physical distance that individuals choose to maintain between themselves and others during social interactions [5]. IPD acts as a nonverbal communicative mechanism and is dynamically adjusted based on the emotional cues perceived from interaction partners [6–9]. Virtual reality (VR) has emerged as a powerful tool for investigating how IPD is influenced by the social valence of stimuli [4,10,11]. For instance, Bönsch et al. [4] demonstrated that participants maintained larger distances from angry virtual agents compared to those displaying happiness, as well as from groups versus individuals. Additionally, Zibrek et al. [10] examined how perceived gender and the attractiveness of motion affect proximity in VR, revealing that attractive movements resulted in decreased proximity, while character gender did not have a significant effect. Iachini et al. [11] further clarified that both reachability and comfort distances are modulated by social factors, indicating a shared motor nature between these two dimensions.

However, research involving older adults remains limited and somewhat outdated. Studies examining IPD in late adulthood reveal complex patterns influenced by various factors. While some studies suggest that older adults maintain greater distances compared to younger individuals [12,13], evidence also indicates that IPD in old age may vary based on familiarity with the other person [14]. Specifically, a study by Mirlisenna et al [14] identifies two distinct developmental patterns in IPD: with strangers, there is a non-linear decrease from childhood to late adulthood, whereas with familiar individuals, a stepped decline occurs from pre-adolescence to adolescence, remaining stable until late adulthood. These discrepancies may arise from shifts in motivation as individuals age, specifically regarding the need for affiliation and personal feedback, and adherence to cultural norms [13]. Additionally, declines in physical and sensory capabilities associated with aging can significantly

affect older adults' use and control of personal space [15,16]. As older adults often experience changes in their perceptual systems, their ability to respond effectively to environmental stimuli may be compromised. Thus, older adults may struggle to establish an appropriate interpersonal distance, potentially leading to discomfort in social interactions [14].

Notably, healthy older adults aged 65 and above exhibit a marked decline in accuracy when recognizing facial expressions in computerized tasks [17–19]. This decline is particularly pronounced for negative emotions such as anger, fear, and sadness, while recognition of happiness remains relatively unaffected by aging. Recent studies cast doubt on this position and suggest that OAs' cognitive and motivational resources are not fully utilized in typical computerized emotion recognition tasks. When contextual elements are incorporated—such as dynamic videos or multimodal facial-vocal cues—age-related deficits appear to diminish [20,21]. Enhancing the ecological validity of the stimuli may increase the personal relevance of the tasks, thereby fostering greater motivation and engagement among older participants [22,23]. Furthermore, research utilizing embodied conversational agents indicates that interactive environments can more effectively capture age-related variations in emotional perception [24,25].

Given the complex interplay of emotional recognition, interpersonal distance, and age, it is essential to investigate these dynamics within a more ecologically valid framework. This study aims to provide new insights into how different age groups manage social interactions and interpret emotions, highlighting the potential of VR to enhance our understanding of these processes. VR has gained recognition in psychological research for its capacity to enhance ecological validity and experimental control [26,27]. This technology is particularly relevant for exploring socio-emotional functions in older adults, where traditional methodologies often fail to capture the complexities of naturalistic settings. One of VR's key advantages is its capacity to study social behavior under highly controlled conditions, allowing for consistent programming of virtual confederates to invade participants' personal space in a standardized manner while maintaining external validity [28]. This balance between experimental control and ecological validity is crucial for advancing our understanding of social interactions in spatial contexts [28].

This study aims to address two research questions. Firstly, we examine how both young and older adults adjust their interpersonal distance (IPD) in response to a virtual agent expressing anger or happiness within an immersive VR environment. This methodological approach permits an analysis of the dynamic changes in IPD, providing insights into the influence of emotional expressions on social behavior. We hypothesize that both YAs and OAs will adjust their IPD based on the avatar's facial expression [4]. Secondly, we examine the relationship between individual differences in IPD regulation and emotion recognition in both age groups, emphasizing how these groups adapt their social interactions in response to emotional cues from others. We hypothesize that IPD regulation will correlate with emotion recognition across both age groups, suggesting that OAs may face challenges not only in recognizing emotions but also in effectively regulating their interpersonal distance.

Materials and methods

Participants

Eighty ($N=80$) participants took part in the experiment in return for partial course credit or monetary compensation. The sample was divided into two groups: older adults (OA) ($n=40$, $\bar{M}_{age}=67.03$, $SD_{age}=4.20$, Age range: 60–76 years) and younger adults (YA) ($n=40$, $\bar{M}_{age}=25.89$, $SD_{age}=3.52$, Age Range= 18–34 years). Participants were recruited via advertisements on the campus of the Johannes-Gutenberg University Mainz, Germany and associated online communities. Older participants were involved in the University for Seniors at Johannes-Gutenberg University Mainz and none of them had cognitive problems as screened by the Mini Mental Status Test [29] (cutoff ≤ 24). Of the 40 OAs, 16 had a university degree, mostly in the natural sciences (i.e., math, physics, computer science, medicine). Thirty-three participants in the YA sample were enrolled in Bachelor's ($N=11$) or Master's degree programs ($N=21$). All participants were Caucasian.

Visual acuity was assessed using the Freiburg Visual Acuity Test – FrACT [30]. The average visual acuity (VA) score was .89 ($SD=.30$) in OA and 1.46 ($SD=.27$) in YA. The visual acuity was significantly higher in younger adults compared

to older adults ($p < .001$). Therefore, the differences between YA and OA were analyzed by taking visual acuity (VA) measurements into account as a covariate (see below).

Interpersonal distance in VR

Virtual agents. Four different Caucasian virtual agents (two female and two male) were used to present a variety of social stimuli. The virtual agents were designed using Makehuman 1.1.0 Nightly Build, and their facial expressions were modulated in 3DSMAX in Autodesk to mirror Ekman pictures [31] (see Fig 1A). Research supports the notion that virtual agents can be used as proxies for real faces for emotion recognition [32]. The virtual agents were dressed uniformly in gray shirts and black pants (see Fig 1B). Agents were presented with either happy or angry facial expressions during the interactions. This standardized appearance and controlled variation in emotional expression were designed to isolate the effects of emotional expression on interpersonal distance (IPD) while minimizing other potential confounding variables.

Apparatus and stimuli

Participants saw stereoscopic full-scale simulations on a large rear-projection screen (2.60 m wide \times 1.95 m high). We used a 3D projector (projection design F10 AS3D) with a color resolution of 8 bits per channel, a display resolution of 1400 \times 1050 (horizontal \times vertical) pixels, and a refresh rate of 120Hz. Participants wore LCD shutter glasses (XPAND X102) synchronized via an infrared emitter, such that each eye received 60 frames per second. Participants' individual inter-pupillary distance was measured by means of a pupil-distance meter and taken into account when computing the stereoscopic disparity of the VR environment. Measured from a distance of 2.35 m from the screen, the geometric field of view (FOV) was 58° horizontally and 45° vertically. The virtual FOV corresponded to the geometric FOV. The VR environment resembled the surrounding laboratory (see Fig 2A). The participants' movement was tracked with a sampling frequency of 30 Hz using an infrared sensor (Microsoft Kinect®). The reference position was the participant's spine. The accuracy of this method was previously validated in Hecht et al [33].

The virtual starting position of the characters was 15 cm behind the projection screen throughout all trials (see Fig 1B). To account for the influence of body height on IPD, the body height of the participant and the virtual agent were matched in all experiments by scaling the height of the virtual agents accordingly. To control for effects of gaze direction, the virtual agent's eyes were dynamically adjusted so that they looked directly onto the observer's bridge of the nose following the participant's movement. Stimuli were presented using the VR software Vizard 5.

Participants were positioned standing on a platform in front of a large screen, facing the virtual agent. The initial interpersonal distance between the participant and the virtual agent was set at 250 cm, with the agent positioned 15 cm behind the projection screen and the participant standing 235 cm from it.

We manipulated two experimental factors within participants: virtual agent gender (two male, two female) and emotional expression (happy, angry). Each factor combination was repeated five times, resulting in 40 trials. Trials were presented in random order.

Prior to the main experiment, participants completed eight training trials with virtual agents showing neutral facial expressions, two trials for each virtual agent. The participants were instructed to walk towards the virtual agent until they reached a distance they considered comfortable for initiating a conversation with a stranger (e.g., asking for directions). Then, the participant confirmed the position and the IPD was logged.

After each trial, a black screen appeared, signaling participants to return to their starting positions. No time limit was given. Participants were instructed both in written and verbal form.

Emotion recognition task (ERT)

The ERT is a computer-based forced-choice test where participants recognize the emotional facial expression of morphed faces [34]. It uses dynamic video clips, each showing a specific facial expression: anger, sadness, surprise, disgust, fear and happiness. The facial expression is morphed from neutral to full expression, at different levels of emotion intensity

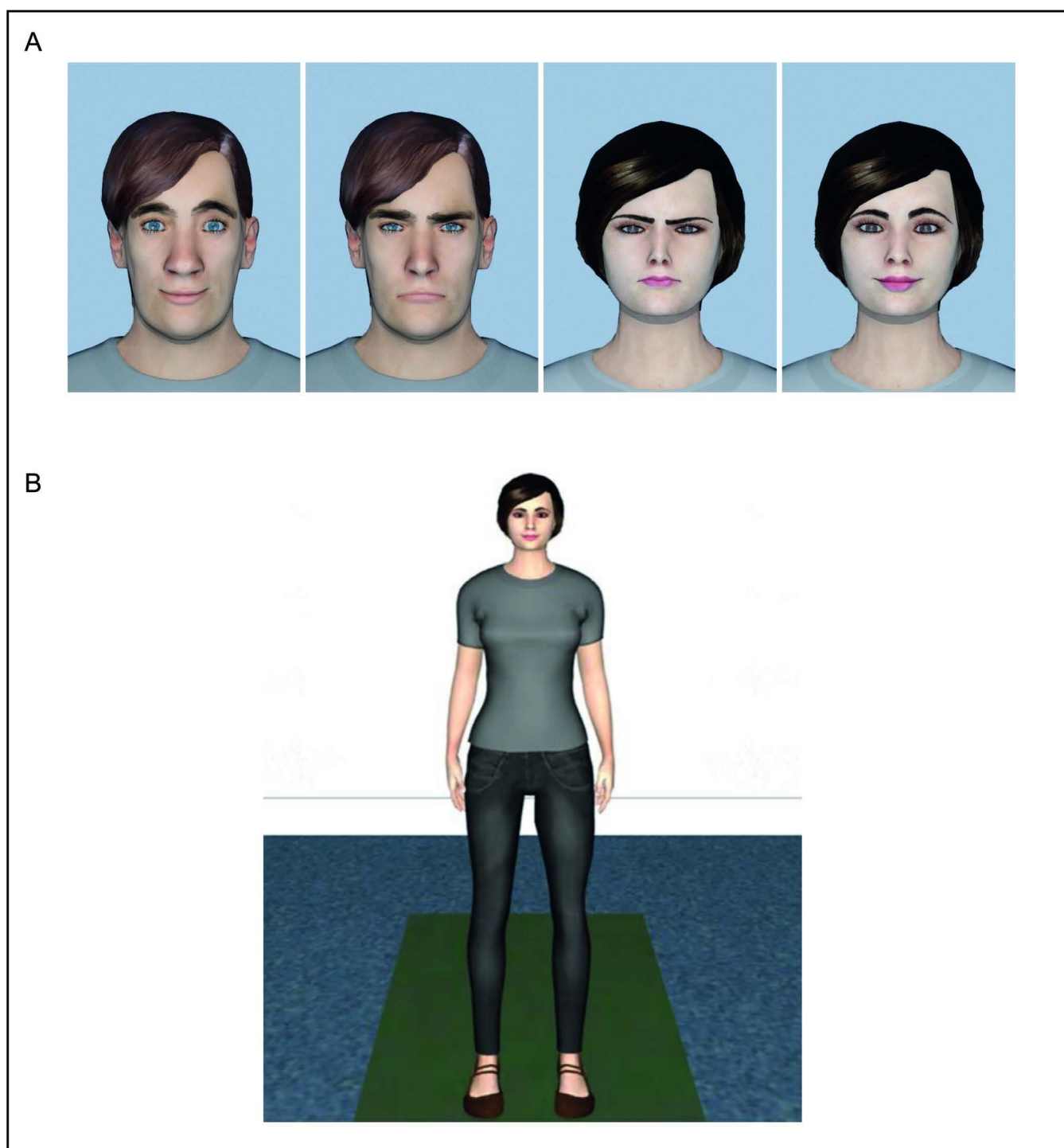


Fig 1. Virtual Agents. A) An example of the virtual agents with happy and angry facial expressions. B) An example of the full body of the virtual agents. Note that the body posture was neutral, and the size of the stimuli was adapted to the participant's height.

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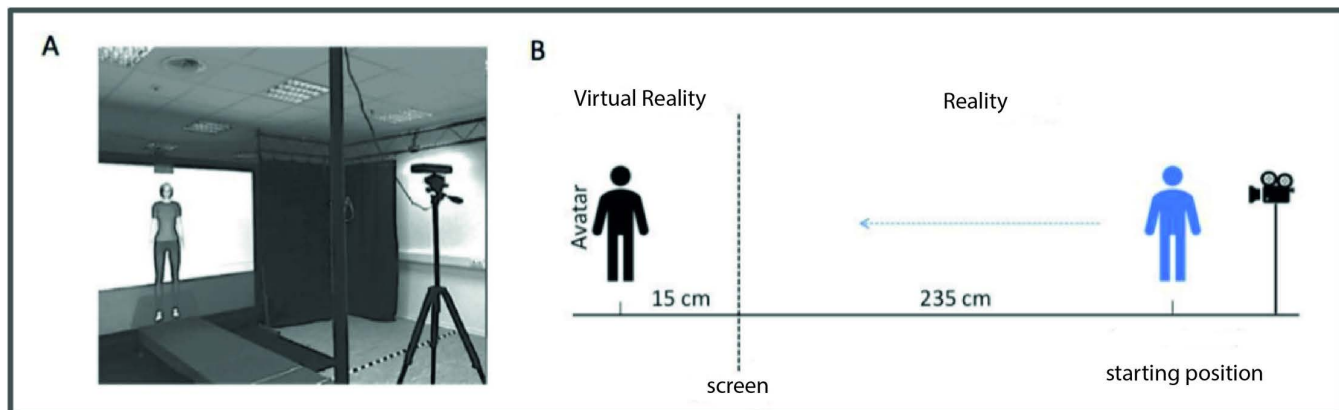


Fig 2. Experimental Setup A) VR environment. B) Procedure for measuring interpersonal distance (IPD).

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(0–40%, 0–60%, 0–80% and 0–100%). The number of frames and the video length ranges from 1–3 sec depending on the emotional intensity presented [34]. These video clips were shown for four individuals (two male, two female), which resulted in 96 trials. The ERT took about 12 minutes to complete.

Procedure. The demographic questionnaires, FrACT, and emotion recognition test were administered prior to the VR experiment. All tests were conducted individually in a lab setting. An experienced experimenter was present at all times to provide technical support and instructions for the participants. Data collection took place between March 20, 2019, and March 14, 2022.

Ethics statement. In accordance with the Declaration of Helsinki, all participants provided written informed consent prior to the study. Information about the study's aims, methods, sources of funding, any possible conflicts of interest, and the institutional affiliations of the researchers was provided in written form, and participants were debriefed after the experiment. The procedure for the study was approved by the Ethics Committee of the Johannes-Gutenberg University Mainz, Germany.

Statistical and power analysis

We aimed to investigate group differences in Interpersonal Distance (IPD) and emotion recognition, as well as the correlation between these variables. Given the significant age-related differences in visual acuity (see Participants section), we analyzed the data using repeated measures ANOVA to assess age and emotion-related differences, and ANCOVA to control for age-related differences in visual acuity.

Power calculations (using the power analysis module of Statistica 14.0.0.15, Tibco Soft Inc.) indicated that a sample size of $N=73$ participants was sufficient to detect a standardized estimated population mean difference (OA<YA) of $d=0.80$, with a power of $1-\beta=0.9$ for $\alpha=.05$. This suggests that our sample size was adequate to identify between-group differences. However, a sample size of $N=100$ is required to calculate a correlation coefficient for an expected population correlation of $r=.20$, and $\alpha=.05$ with a power of .5. Therefore, correlations calculated with a sample size of $N=80$ may not reliably detect expected effects.

Prior to conducting data analysis, we performed the Lilliefors test to assess the assumption of normality for the depended measures (IPD and emotion recognition). The results revealed no violation of normal distribution for IPD (Kolmogorov-Smirnov $d=.07$, $p>.20$; Lilliefors $p>.20$), IPD happy (Kolmogorov-Smirnov $d=.06$, $p>.20$; Lilliefors $p>.20$), IPD angry (Kolmogorov-Smirnov $d=.06$, $p>.20$; Lilliefors $p>.20$), nor for ERT mean score (Kolmogorov-Smirnov $d=.08$,

$p > .02$; Lilliefors $p > .20$). However, there was violation from normal distribution for recognition of happy (Kolmogorov-Smirnov $d = .23$, $p < .01$; Lilliefors $p < .01$) and angry (Kolmogorov-Smirnov $d = .15$, $p < .05$; Lilliefors $p < .01$) emotional expression. These findings reflect ceiling effects reported elsewhere. The study was not pre-registered. All data are available at OSF: https://osf.io/cdsj3/?view_only=9dfd0a0e8a4f4334a722eb4b1dcba286

Results

Descriptive statistics and general effects

Descriptive statistics for all dependent measures, along with the results of a t -test comparing the performance of young and older adults on these measures, are shown in [Table 1](#).

Age related differences in interpersonal distance (IPD) and IPD-regulation

We computed a rmANOVA on the individual mean IPDs (pooled across all virtual agents for every participant and facial expression) with Age group as a between-subjects factor and Facial expression as a within-subjects factor. Participants preferred larger distances towards angry-looking as compared to happy-looking virtual agents ($F(1, 78) = 50.5$, $p < .001$, $\eta^2 = .39$). The main effect of Age group, $F(1, 78) = 2.41$, $p = .13$, $\eta^2 = .03$, was not significant, nor was the Age group x Facial expression interaction $F(1, 78) = 1.24$, $p = .26$, $\eta^2 = .01$. Thus, the effect of facial expression remained unaffected by Age group ([Fig 3A](#)).

Next, we conducted an analysis of covariance (ANCOVA) with mean IPD as the dependent measure, Age group as the between-subject factor, and Visual acuity (VA) as the covariate. The results showed no significant differences in IPD between YA and OA ($F(1, 77) = 1.46$, $p = .22$) and no significant effect of VA on IPD ($F(1, 77) = .002$, $p = .88$). This was also confirmed in an ANCOVA with IPD to happy and angry faces as the dependent measures (all $p > .10$).

Age related differences in Emotion Recognition (ER)

We calculated a repeated-measures analysis of variance (rmANOVA) on the percentage of correct (pc) responses with Facial expression (6; Anger, Disgust, Fear, Happiness, Sadness, Surprise) as a within-subjects factor and Age group as a between-subjects factor. The main effects of Age group, $F(1, 78) = 35.67$, $p < .001$, $\eta^2 = .31$ and Facial expression, $F(5, 390) = 152.49$, $p < .001$, $\eta^2 = .66$, were significant. These main effects were qualified by an Age group x Facial expression interaction, $F(5, 390) = 7.16$, $p < .001$, $\eta^2 = .08$. Post-hoc t -tests revealed significant differences in recognition of Anger ($t(1, 78) = 50.26$, $p < .001$), Fear ($t(1, 78) = 7.13$, $p < .01$), Happiness ($t(1, 78) = 13.28$, $p < .001$), Sadness ($t(1, 78) = 19.39$, $p < .001$) and Surprise ($t(1, 78) = 11.95$, $p < .001$), but not in recognition of Disgust ($t(1, 78) = .20$, $p = .64$). The percent of correct responses as well as the error types in YA and OA are shown in [Fig 4](#).

Table 1. Descriptive Statistics and Main effects of Age. IPD=interpersonal distance in meters (m); ERT=emotion recognition. The ERT score is calculated as the mean percentage correct (pc) across all six basic emotions.

	Young adults		Older adults		t-test (p)
	Mean	SD	Mean	SD	
IPD	1.30	.22	1.21	.29	.13
IPD happy	1.24	.18	1.16	.26	.16
IPD angry	1.37	.27	1.26	.34	.12
ERT	.68	.08	.56	.09	.001*
ERT happy	.96	.05	.91	.06	.16
ERT angry	.92	.10	.68	.19	.001*

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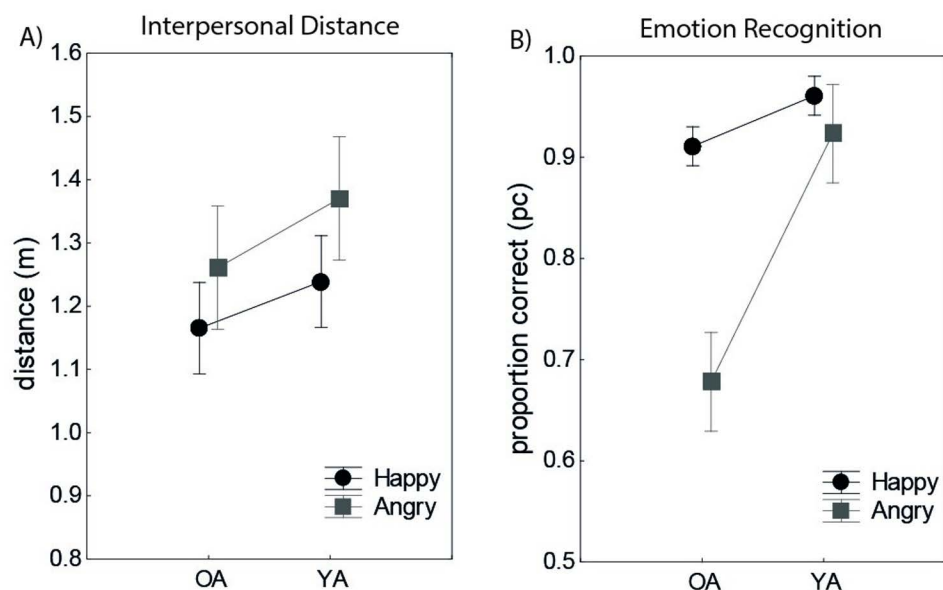


Fig 3. Results. A) No significant differences were found between young adults (YA) and older adults (OA) in interpersonal distance (IPD) or in its regulation based on the emotional expression of the virtual agent in virtual reality. B) Older adults were less accurate than young adults in recognizing angry ($\eta^2 = .39$) and happy ($\eta^2 = .14$) emotional expressions in a standardized face emotion recognition test (ERT).

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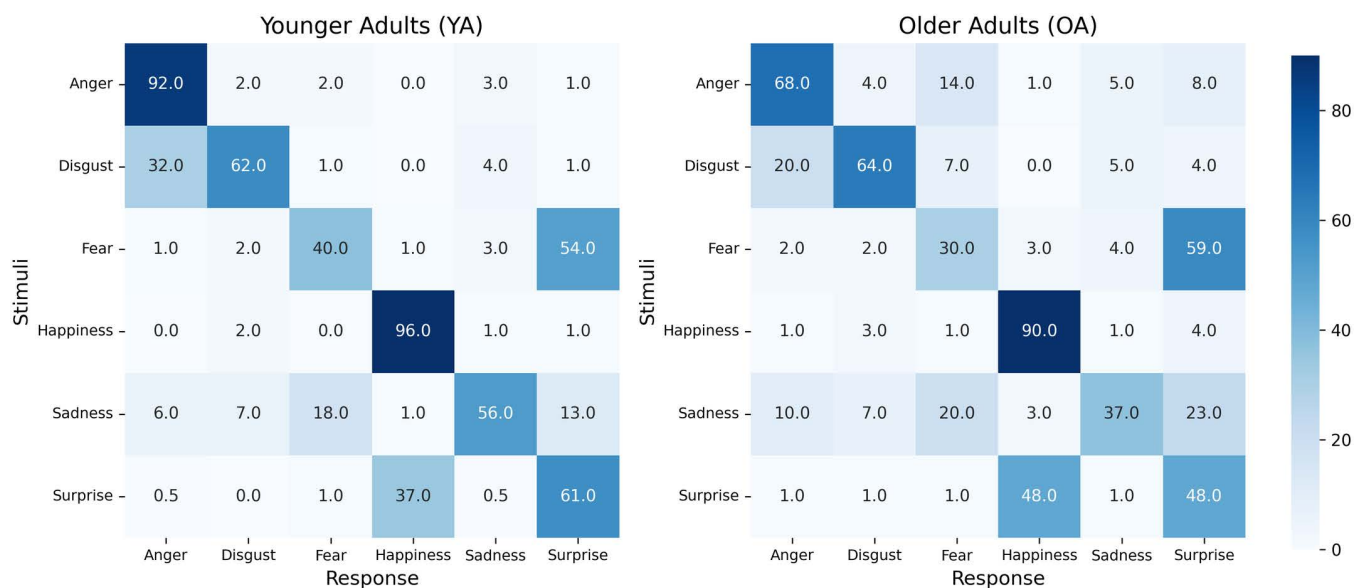


Fig 4. Emotion Confusion. In YA, anger was recognized accurately and was barely confused with other emotions. In OA, angry faces were categorized as fearful in 14% of all responses. Happiness was accurately recognized in both age groups. Very rare confusions occurred with disgust in YA and with disgust and surprise in OA.

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Table 2. Correlation matrices. correlations among interpersonal distance (IPD) and emotion recognition test (ERT) measures. the analysis was conducted with a sample size OF $N=80$.

	IPD	IPD happy	IPD Angry
ERT	$r(80)=.01, p=.93$	$r(80)=-.04; p=.70$	$r(80)=.05; p=.67$
ERT happy	$r(80)=.02; p=.88$	$r(80)=-.002; p=.99$	$r(80)=.03; p=.79$
ERT angry	$r(80)=.17; p=.13$	$r(80)=.16; p=.14$	$r(80)=.17; p=.12$

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Next, we conducted an analysis of covariance (ANCOVA) with mean percentage (pc) of emotion recognition across all emotions, and pc for happy and angry faces as the dependent variables, Age group as the between-subject factor, and Visual acuity (VA) as the covariate. Overall, emotion recognition was more accurate in young adults (YA) than in OA ($F(1,77)=23.1, p<.001, \eta^2=.23$), and there was no significant effect of VA on emotion recognition ($F(1,77)=.066, p=.41, \eta^2=.008$). However, recognition of anger was marginally affected by VA ($F(1,77)=3.5, p=.06, \eta^2=.04$), while this was not the case for happy faces ($F(1,77)=.04, p=.83, \eta^2=.0$).

Correlation between IPD and ER

Next, we conducted a correlation analysis to examine the relationship between emotion recognition, recognition of angry and happy facial expressions, and interpersonal distance to happy and angry faces (see Table 2). However, none of the correlations proved to be statistically significant (all $p>.10$), suggesting no relationship between emotion recognition and the regulation of interpersonal distance to emotional virtual agents.

Discussion

In the present study, we investigated age-related differences in interpersonal distance (IPD) regulation and emotion recognition using a virtual reality (VR) environment. Our findings revealed that both younger and older adults adjusted their IPD based on the emotional expressions of virtual agents, preferring larger distances from angry-looking virtual agents compared to happy-looking ones. However, there were no significant differences in IPD between the age groups. Additionally, older adults demonstrated lower accuracy in recognizing angry facial expressions compared to younger adults, while only marginal age-related differences were found for happy expressions. These results align with previous research indicating that older adults experience challenges in recognizing negative emotions such as anger, while their ability to recognize positive emotions like happiness remains relatively intact [17–19]. The lack of significant age-related differences in IPD suggests that older adults can effectively regulate their social space in a manner similar to younger adults, despite potential deficits in emotion recognition. Furthermore, the results align with recent studies indicating a relative stability in IPD throughout the adult lifespan [14]. In the following sections, we will discuss several possible explanations for our findings.

Cognitive and Perceptual Decline. The observed deficits in recognizing expressions among older adults could be attributed to age-related declines in cognitive and perceptual abilities [17,20,35,36]. One possible explanation is that OA's cognitive resources are not utilized in relatively artificial laboratory tasks such as the ERT [37]. Note that, when social vigilance and richness of social information is high, as in our virtual environment, differences between age-groups in social behavior vanish [38]. Furthermore, VR provides high social and sensory immersion and may particularly benefit older adults by enhancing engagement and emotional responses [24]. Alternatively, according to perceptual degradation hypothesis, older adults' ability to perceive and process facial cues relevant for emotion detection might be negatively affected by the loss of visual acuity [35]. Our study provides some evidence, albeit not strong, for this hypothesis. Visual acuity was positively associated with difficulties in recognizing angry but not happy facial expressions. This finding adds

to a body of evidence suggesting that age deficits in low-level vision can negatively impact cognitive and perceptual processes [39–41].

Compensatory Mechanisms. The fact that older adults adjusted their interpersonal distance [IPD] appropriately may suggest that compensatory mechanisms, such as increased reliance on contextual cues or prior social experience, may be at play. Research has shown that social-cognitive skills improve through midlife and often continue to advance into later adulthood. For instance, older adults tend to reason more effectively about everyday interpersonal problems [42] and use a greater variety of problem-solving strategies, demonstrating greater sensitivity to situational contexts [43]. These strategies are often adaptive and reflect the specific experiences and life circumstances of middle-aged and older adults [44]. Moreover, automatic threat detection remains intact in older age [45]. In contrast to younger adults, older adults are generally more effective at navigating their social environment, likely due to years of accumulated social experience [37,44]. Thus, it is important to interpret deficits among age groups in terms of practical relevance. An age-related loss of 10–15% accuracy in emotion recognition may not overwhelm expertise in social interaction behavior acquired over a lifetime, which is consistent with our findings of IPD in virtual reality (VR). However, it is important to note that our study does not offer direct evidence regarding how these compensatory mechanisms may influence the regulation of IPD in VR.

Social Isolation and Loneliness. The physical distancing requirements imposed by COVID-19 led to an increased preferred interpersonal distance (IPD), a trend that may continue even after the pandemic [46]. During this period, the global preferred IPD increased by 54%, with more pronounced increases observed among individuals who are particularly vulnerable to disease [47]. Furthermore, chronic loneliness, which is reported more frequently among older adults, is linked to a greater interpersonal distance [48]. Consequently, we cannot exclude the possibility that the findings of the present study reflect differences in COVID-19 distancing behaviors between younger and older adults, as well as potential long-term effects. However, the impact of COVID-19 on interpersonal distance is multifaceted. For instance, Cartaud et al. [49] found that IPD decreased when interacting with virtual agents wearing face masks, likely due to an increase in perceived trustworthiness. Thus, it remains an open question how social isolation and loneliness may have influenced interpersonal distance (IPD) and obscured potential differences in IPD between younger and older adults.

Emotion Confusion. Emotion confusion can be conceptually defined as an individual's tendency to misinterpret one facial expression as another (e.g., perceiving a happy face as sad) [50]. Error patterns in facial emotion recognition may reveal distinct deficits in emotion recognition that contribute to these misinterpretations. Confusion matrices, typically relevant in neurodiverse samples such as individuals with schizophrenia and dementia, can help determine whether specific error patterns exist across different groups [50,51]. In these studies errors were predominantly observed in response to negative emotions. These incorrect responses primarily occurred between emotions within the same valence dimension (e.g., fear vs. anger) and seemed to involve subtle discrimination errors, rather than between different valence dimensions (e.g., happiness vs. sadness) [52]. Consequently, errors primarily occur with emotions that are perceptually similar. Focusing on error profiles, our findings demonstrate that the types of errors made regarding target emotions are similar across age groups. However, older adults are more likely to confuse anger with fear, while young adults rarely mix anger with other emotions. Both age groups consistently differentiate between anger and happiness. The capacity of both older and younger adults to accurately differentiate between positive and negative valence in emotional stimuli [53] may serve as a potential explanation for the absence of age effects observed in the IPD measure while age effects were observed in the emotion recognition measure. OA may have chosen larger IPD for angry vs. happy avatars despite confusing anger and fear because both of these emotions are negative and signal threat.

Limitations

When discussing virtual reality (VR), many people typically picture an immersive and interactive experience involving headsets and various interactive devices. In this study, however, the equipment and environment were centered around a

3D projector, which may differ from conventional VR setups. Still, the application of VR adds a level of ecological validity and control that is valuable.

Additionally, the Interpersonal Distance (IPD) task and the Emotion Recognition Test (ERT) used different types of stimuli. The ERT focused on real human faces to evaluate dynamic facial emotion recognition, while the IPD task utilized computer-generated (static) faces. This variation in stimuli might contribute to the lack of correlation observed between the two tasks, as well as our relatively small sample size.

Conclusions

In conclusion, our study demonstrates that older adults, despite facing challenges in recognizing negative emotions, can effectively regulate their interpersonal distance in social interactions in response to the emotional expression of others. Moreover, while social behavior in VR is inherently artificial and may not necessarily correspond to real-life behavior, research suggests that IPD effects typically do not differ between real and virtual environments [33,54]. This underscores the utility of VR as a tool for studying social interactions in a controlled yet ecologically valid manner. Our findings also emphasize the importance of considering various factors—cognitive, perceptual, and motivational—in future studies examining the relationship between emotion recognition and social functioning in older adults.

Author contributions

Conceptualization: Bozana Meinhardt-Injac, Isabelle Boutet, Laurence Chaby, Christoph von Castell, Robin Welsch.

Formal analysis: Bozana Meinhardt-Injac.

Investigation: Christoph von Castell, Robin Welsch.

Methodology: Bozana Meinhardt-Injac, Christoph von Castell, Robin Welsch.

Project administration: Robin Welsch.

Resources: Robin Welsch.

Software: Robin Welsch.

Supervision: Bozana Meinhardt-Injac.

Visualization: Bozana Meinhardt-Injac.

Writing – original draft: Bozana Meinhardt-Injac, Isabelle Boutet, Laurence Chaby, Robin Welsch.

Writing – review & editing: Bozana Meinhardt-Injac, Isabelle Boutet, Laurence Chaby.

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