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Let's Do It My Way: Effects of Personality and Age of Virtual Characters

Minsoo Choi, Dixuan Cui, Siqi Guo, Dominic Kao, and Christos Mousas

Fig. 1: The altruistic child virtual character pointed to where the participant should place her puzzle piece to solve the jigsaw puzzle.

Abstract—Designing interactions between humans and virtual characters requires careful consideration of various human perceptions and user experiences. While numerous studies have explored the effects of several virtual characters' properties, the impacts of the virtual character's personality and age on human perceptions and experiences have yet to be thoroughly investigated. To address this gap, we conducted a within-group study ($N = 28$) following a 2 (personality: egoism vs. altruism) $\times$ 2 (age: child vs. adult) design to explore how the personality and age factors influence human perception and experience during interactions with virtual characters. In each condition of our study, our participants co-solved a jigsaw puzzle with a virtual character that embodied combinations of personality and age. After each condition, participants completed a survey. We also asked them to provide written feedback at the end of the study. Our statistical analyses revealed that the virtual character's personality and age significantly influenced participants' perceptions and experiences. The personality factor affected perceptions of altruism, anthropomorphism, likability, safety, and all aspects of user experience, including perceived collaboration, rapport, emotional reactivity, and the desire for future interaction. Additionally, the virtual character's age affected our participants' ratings of the uncanny valley and likability. We also identified an interaction effect between personality and age factors on the virtual character's anthropomorphism. Based on our findings, we offered guidelines and insights for researchers aiming to design collaborative experiences with virtual characters of different personalities and ages.

Index Terms—Virtual reality, virtual character, personality, age, co-solving, jigsaw puzzle

1 Introduction

Over the past decade, virtual reality has evolved rapidly, offering users immersive experiences that integrate seamlessly into daily life. Central to these experiences are virtual characters, which play various roles [39], from instructors providing knowledge to collaborators assisting in task completion [3, 13, 76]. Integrating virtual characters into virtual reality applications has been shown to significantly enhance user engagement and immersion, both of which are crucial for the success of these applications [12, 19].

Understanding how users perceive and interact with virtual characters is a focal point of ongoing research. Researchers have examined the impact of a virtual character's appearance, including rendering styles [48, 53], design elements [15, 29, 52], and demographic features such as age and gender [90]. Others have explored how users relate to virtual characters that resemble themselves [37] and the effects of expressive behaviors, such as facial expressions [20] and upper-body gestures [24]. Also, building on emerging artificial intelligence, virtual characters' capacities have evolved, and researchers have paid attention to how virtual characters interact with humans [14, 16]. As understanding interactions between humans and virtual characters has

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become more essential, several researchers have recently employed artificial intelligence to design virtual characters, with a focus on personality [41, 62], and investigated their effects on user experiences, such as trust [89] or likeness [8].

According to psychological studies, people hold expectations about personality traits based on age [83], such as associating older individuals with lower impulsivity and openness [9]. Moreover, several researchers have found correlations between personality and age [55], including a positive trend in altruism from adolescence to adulthood [72]. These traits are particularly relevant in social interactions, where altruistic behaviors foster collaboration and trust [21], while egoistic behaviors often provoke frustration or stronger emotional responses [40]. Although several psychological studies have examined how personality relates to age in humans, the effects of a virtual character's personality and age on human perception and user experience remain underexplored. Moreover, their combined influence has, to our knowledge, not yet been studied.

To bridge this gap, our study focused on the impact of personality and age in virtual characters within a virtual reality jigsaw puzzle cosolving task (see Fig. 1). We designed two distinct personality markers (i.e., egoism and altruism) and considered two age representations (i.e., child and adult) to examine their effects. Personality markers, such as observable actions and verbal cues, can signify underlying traits like self-serving or selfless behaviors. These markers have been shown to capture various personality characteristics that might not always align with broader trait definitions [67]. The decision to focus on egoism and altruism reflects their contrasting nature in prioritizing self-interest versus the welfare of others, making them ideal for studying user perceptions and experiences in virtual environments. In our study, these markers were conveyed by simulating specific actions and monologues to demonstrate egoistic or altruistic tendencies. Correspondingly, we utilized distinct virtual characters and voice models to accurately represent different ages, ensuring their validity through a preliminary sanity check.

2 Related Work

2.1 Human-virtual Character Interaction

Researchers have studied how humans interact with virtual characters and how such interactions impact human behavior. To date, several studies have focused on the supportive roles of virtual characters in several application domains, including education [26, 75], training [36, 74], and more. Lopez et al. [47] introduced a collaborative virtual training environment with communicative agents. These virtual agents were specifically designed to enhance collaboration by sharing activity progress with users. Terzidou et al. [76] investigated the impacts of pedagogical agents on collaborative educational applications by exploring the pedagogical agents' usefulness and students' performance. Tran et al. [79] researched the effects of virtual agents on older people. They found that their participants performed similarly in a concentration-based game when assisted by virtual agents as they did when assisted by therapists. These prior studies showed that the virtual characters can support humans and perform tasks similarly to humans.

On the contrary, some researchers have explored the impact of competitive virtual characters on user performance. Shaw et al. [69] compared cooperative and competitive virtual trainers for cycle exergames. They found that the competitive virtual trainer motivated participants more effectively than the cooperative one, leading to better performance. Also, Nunes et al. [54] compared participants' performance in virtual exergames between single-player and competitive virtual characters conditions. They reported that their participants performed better playing the game with competitive virtual characters. These studies indicated the necessity of exploring various virtual character designs to enhance human-virtual interaction outcomes.

2.2 Human Perception of Virtual Characters

Ongoing research has consistently focused on how virtual characters are perceived during human interactions. Researchers have particularly concentrated on the appearance of virtual characters, among other factors. Zibrek and McDonnell [91] explored the impacts of the virtual character's rendering styles on human perception of its personality. They provided participants with two rendering styles, cartoon and unappealing ill style, and found that their participants perceived the cartoon style as conveying more agreeable personalities. Ferstl et al. [24] explored how the virtual character's voice, motion, and appearance impacted human perception. They reported that participants rated a virtual character's likability and anthropomorphism higher when exposed to characters with more realistic motion and voice, regardless of any mismatch with appearance.

Furthermore, some researchers focused on virtual characters' expressions, such as facial expressions or behaviors. Dubosc et al. [20] examined how virtual characters' stylization and facial expressions impact human perception. Their participants rated virtual characters with more intense facial expressions as less attractive. Moreover, participants reported that exaggerated facial expressions did not reduce the perceived realism of virtual characters with realistic appearances. Tinwell et al. [78] investigated whether the lack of facial expressions of the virtual characters contributed to their uncanny appearance. Specifically, they focused on the upper part of the virtual character's face. Their participants reported that virtual characters appeared more uncanny when the upper part of their faces lacked facial expressions. Regarding behaviors, Liu et al. [45] explored the impacts of virtual characters' leading and following behaviors on users' experiences. They reported that their participants experienced higher workloads when interacting with virtual characters exhibiting leading behaviors. Last, Schneeberger et al. [65] examined how the physical activeness of a virtual character's actions affected human perception and found that the higher physical activeness made the virtual character appear to be in a more positive mood. The previous studies demonstrated that factors, including appearance, voice, and expression, can influence human perception of virtual characters.

2.3 Personality of Virtual Characters

In human-virtual character interaction, convincing virtual characters have become essential. Researchers consider the personality of virtual characters a critical factor in their believability [46].

Personality, as defined by Allport [2], is the dynamic aspect of individuality, and this comprehensive configuration of traits, including character, temperament, and intellect, serves as a foundation for understanding how virtual characters are perceived. McDougall [49] further describes personality as the integrated whole of an individual's mental and behavioral attributes. In contrast, *character*, a subset of personality, deals explicitly with moral and volitional aspects that show consistent behavior patterns. Personality evolves over time, with personality maturation following distinct patterns throughout the lifespan. This developmental trajectory is crucial in shaping behaviors, interactions, and experiences in various contexts. Soto et al. [3] found that traits such as conscientiousness and agreeableness tend to increase with age, while neuroticism decreases. Similarly, Wagner et al. [80] demonstrated that personality stability varies by age and trait, challenging the cumulative continuity principle. In adolescence, Klimstra et al. [38] observed growth in emotional stability and agreeableness, with notable gender differences, as girls matured earlier than boys. Given these dynamics, researchers have explored how virtual characters' personalities are perceived, often mirroring the complexity found in human personality. Building on these findings, research into virtual characters suggests that age, gender, and other demographic factors are crucial for accurately modeling personality, reflecting the complexity and variability seen in human development.

In terms of virtual characters, Thomas et al. [77] explored how their speech and motion affected human perception of their personalities and found dominant effects of motion on their perceived extroversion. Also, they reported that their participants felt more agreeable and emotionally stable when interacting with recorded human voices rather than synthesized voices through text-to-speech (TTS). Cheng and Wang [10] investigated how virtual characters' outfits influence their perceived personality, focusing on three features: color, design, and type. Their study offered guidelines for designing virtual characters with specific personalities, such as how a turtleneck and black suit enhance perceived

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conscientiousness. McRorie et al. [50] demonstrated that virtual agents with personality-driven behaviors, such as facial expressions and gestures, are more believable and better suited for sustained interactions with human users, which addressed the importance of coherent behavioral characteristics in shaping the perceived personality of virtual characters. These findings revealed that a virtual character's design can influence how its personality is perceived.

Furthermore, some researchers have focused on the impacts of the virtual character's personality on human perception. Pan et al. [57] conducted an experiment comparing people's perceptions and interactions with shy and confident virtual characters. They reported that their participants rated the shy virtual character more positively than the confident virtual character and were more willing to spend time with them. Zhou et al. [89] found that users are likelier to trust and engage with intelligent interviewers who exhibit serious and assertive personalities, particularly in high-stakes contexts like job interviews. This suggests that the perceived personality of virtual characters can significantly influence user trust and interaction quality. Hanna and Richards [31] focused on two personality traits of the virtual character (i.e., extroversion and agreeableness) and compared their impacts on collaborative interactions. They found that the agreeable character enhanced performance more than the extroverted one. In line with these findings, Sonlu et al. [71] posit that virtual agents with higher levels of extroversion and agreeableness are perceived as more engaging and effective, particularly in educational settings. Their findings further addressed the role of personality expression in enhancing the effectiveness of virtual characters across different contexts. Liew and Tan [42] found that adapting the personality of virtual agents to complement rather than match the learner's personality leads to more positive emotional responses and better learning outcomes in virtual environments. This suggests that complementary personalities between users and virtual characters may enhance the overall user experience. The abovementioned studies showed how the personality of the virtual character influences human perception and demonstrate its importance in human-virtual character interaction.

2.4 Age Effects in Virtual Characters

Researchers have considered the age of the virtual character as a key component in virtual character design and investigated their impacts on human perception and user experience [51]. Richards et al. [60] explored demographic features of virtual characters, including age, gender, and ethnicity. They found that over half of their participants preferred characters of a similar age to themselves. Also, Schlesener et al. [64] designed the virtual characters representing different ages and genders and explored how they influence human perception in virtual reality. Specifically, they implemented realistic virtual character models with skin and hair colors that reflected the designated age. They reported that their participants felt higher levels of attraction to the middle-aged virtual character than to the old virtual character.

These preference patterns observed for similar-aged and middle-aged virtual characters can be understood through foundational research on age-related social perceptions, which has established that older individuals are typically viewed through the lens of competence and warmth expectations, often being perceived as warm but less competent [25]. This theoretical framework helps explain why virtual character age preferences are highly context-dependent [73, 88]. For example, older-looking agents are often preferred in healthcare settings where credibility is important [73], while studies on age-related perceptions in virtual environments demonstrate that older virtual characters assume more central and influential roles in social interactions, with both younger and older users preferentially seeking help from older-appearing virtual characters who are perceived as more experienced and authoritative [88]. Notably, immersive environments appear to amplify sensitivity to such demographic features, as increased realism and embodied presence heighten user responsiveness to social cues [39]. These studies stated that the age of the virtual characters can be another factor influencing how humans perceive them in virtual environments.

Furthermore, several studies have focused on human perceptions of the virtual avatar design regarding their age. Schwind and Henze [66] recruited participants from wide age groups and asked them to create virtual face models to understand their preferences regarding age and gender. Their results revealed different virtual face designs from different age groups. Specifically, they found that older people focused on realistic designs that reflected their gender. Also, Mikhailova et al. [51] examined human perception of virtual avatars with varying levels of realism and age in augmented reality. They reported that their participants preferred avatars with younger appearances and higher realism, and also felt a greater social attraction to the younger appearance during face-to-face social interactions. Additionally, Cheong et al. [11] investigated how older adults perceived their virtual avatars regarding their designated ages and found that they rated the younger avatar as having higher trustworthiness. The above findings revealed different human preferences for virtual characters representing themselves, depending on the individual's age in virtual reality.

2.5 Research Questions

We explored two overarching topics with several sub-questions each to understand the impacts of the virtual character's personality and age on the study participants' perceptions and experiences:

- **Perception of Virtual Characters:** How do a virtual character's personality and age factors impact study participants' perceived altruism (**RQ1.1**), uncanny valley (**RQ1.2**), anthropomorphism (**RQ1.3**), likability (**RQ1.4**), and safety (**RQ1.5**) levels?
- **User Experiences:** How do a virtual character's personality and age factors impact study participants' perception of collaboration (**RQ2.1**) and rapport (**RQ2.2**) levels with the virtual character, as well as emotional reactivity (**RQ2.3**) and desire for future interaction (**RQ2.4**)?

2.6 Contributions

The literature on human-virtual character interaction has extensively examined how virtual characters can be used for collaboration [47], learning [26, 75], training [36], and exercising [69] purposes. However, more research is needed to specifically investigate how virtual characters' personality and age factors impact interaction with them. Most studies have explored essential interaction dynamics, but the effects of personality and age differences on user perceptions and experiences still need to be explored. In this research, we aimed to address this gap.

Specifically, our contributions are as follows. First, we designed and implemented a set of behaviors and monologues for virtual characters as markers that distinctly represent egoistic and altruistic personalities across two age groups (i.e., child and adult). Second, we conducted a within-group study to explore how these personality and age markers impact human perceptions and experiences during a virtual reality jigsaw puzzle co-solving task. Based on our findings, we provide insights into the design of virtual characters, highlighting the significance of personality and age markers. These findings could inform practical guidelines for researchers and practitioners aiming to enhance virtual reality interactions through the thoughtful design of virtual characters.

3 Materials and Methods

3.1 Participants

We conducted an *a priori* power analysis using G*Power software [23] to determine the sample size for our study. Based on an $\alpha = .05$ error probability, a medium effect size of $f = .30$ [17], one group with four (2×2) repeated measurements, an $r = .50$ correlation among repeated measures, and an $\varepsilon = .70$ for non-sphericity correction, to achieve an 80% power ($1-\beta$ error probability), the analysis recommended a minimum of $N = 21$ participants. For our study, with our university's institutional review board (IRB) approval, we recruited 28 participants (age: $M = 22.50$, $SD = 4.36$; age range: $18-36$) through announcements and emails sent to students' listservs. Our participants comprised 12 males (age: $M = 23.67$, $SD = 4.89$) and 16 females (age: $M = 21.63$, $SD = 3.85$). All participants were undergraduate or graduate students from our university, and 21 reported having prior experience with virtual reality applications.

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3.2 Implementation

To implement the jigsaw puzzle co-solving experiences with virtual characters, we developed a virtual reality application using the Unity game engine (version 2020.3.20) and the Oculus Integration Toolkit. For our implementation and study, we used a Dell Alienware computer (Intel i7, 32GB RAM, and NVIDIA GeForce RTX 2080) and the Meta Quest 2 head-mounted display (HMD).

3.2.1 Virtual Characters

In our virtual reality application, the virtual characters could solve a jigsaw puzzle and exhibit their personality. To do so, we developed a brain (see Algorithm 1) and personality (see Algorithm 2) algorithm, and an animation system to allow the virtual character to interact with the puzzle pieces and puzzle board. Specifically, the brain system determines the virtual character's behaviors, and the animation system drives the virtual character based on the decisions made by the brain system. For our study, we used the same set of female virtual characters for all participants, regardless of gender, to standardize the experimental conditions and stimuli. We did so due to prior research, which demonstrated that female virtual characters enhance participants' engagement [70] and social presence [63].

Brain System. The brain system has seven input variables: U, A, T, P, V, H, and S (see Algorithm 1). U is a list of the unsolved puzzle pieces, A is a list of pairs of a puzzle piece and their target spots, T is the assigned virtual character's personality, P is the probability of exhibiting the personality, V is the puzzle piece interacted by the virtual character, H is the puzzle piece grabbed by the participant's hand, and S is the current state of the brain system. The brain system has three states: $PickUp$, $ForceToPickUp$, and $Place$. The $PickUp$ state of the brain system determines whether the virtual character should exhibit its personality. If the brain system decided not to exhibit the virtual character's personality, the virtual character would pick up a puzzle piece from the list of unsolved puzzle pieces. Then, the brain system makes a transition to the $Place$ state. Otherwise, to exhibit the virtual character's personality, the brain system checks whether the participant grabs a puzzle piece. If the participant did not grab a puzzle piece, the brain system would wait until the participant grabbed one. When the participant picks up a puzzle piece, the brain system lets the virtual character exhibit its personality. In the $ForceToPickUp$ state, the brain system forces the virtual character to pick up a puzzle piece from the list of unsolved puzzle pieces and updates its state to $Place$. In the $Place$ state of the brain system, the virtual character places the grabbed puzzle piece in the right spot, and the brain system's state moves to the $PickUp$ state. The brain system keeps this routine until the participant and the virtual character solve all the puzzle pieces.

Personality. To implement the personality markers of the virtual character, we simulated behaviors and developed monologues customized for each personality, which we assigned to a function called `Personality`. The `Personality` function has four input variables: A, T, H, and S (see Algorithm 2). This function makes the virtual character exhibit its personality through corresponding behaviors and monologues. Specifically, when the virtual character's personality is egotistic, it seizes the puzzle piece from the participant's hand (see Fig. 2a). Then, the `Personality` function returns $Place$ as the updated state of the brain system and puzzle piece interacted with by the virtual character.

In contrast, when the virtual character's personality is altruistic, it points to the right spot of the participant's grabbed puzzle piece with its finger (see Fig. 2b). After the virtual character helps the participant, the `Personality` function returns $ForceToPickUp$ as the updated state of the brain system to prevent repeated altruistic behaviors of the virtual character. Additionally, we designed three distinct monologues for each personality (see Table 1) and generated audio files using TTS services. When the virtual character exhibited the assigned behaviors, it said a randomly chosen monologue/phrase corresponding to its personality to deliver its simulated personality more clearly.

To optimize the frequency of personality exhibitions, during the development process, we tested different probabilities to determine

Algorithm 1 Brain System Behavior Decision Algorithm

Input:
U ▷ U is a list of unsolved puzzle pieces
A ▷ A is a list of pairs of a puzzle piece and its target spot
T ▷ T is the virtual character's personality
P ▷ P is the probability of exhibiting the personality
H ▷ H is the puzzle piece grabbed by the participant's hand
S ▷ S is the current state of the brain system
Output:
V_n ▷ V_n is the next puzzle piece interacted by the virtual character
S_n ▷ S_n is the next state of the brain system

function BRAINSYSTEM(U, A, T, P, V, H, S)
  switch S **do**
    case $PickUp$
      Choose D from 0% to 100%
      if $D \leq P$ **then**
        if $H = null$ **then**
          Wait for the user to pick up a puzzle piece
        end if
        V_n, $S_n \leftarrow$ Personality(T, H, P, S)
      else
        Pick up a puzzle piece from U
        $V_n \leftarrow$ the picked puzzle piece
        $S_n \leftarrow Place$
      end if
    case $ForceToPickUp$
      Pick up a puzzle piece from U
      $V_n \leftarrow$ the picked puzzle piece
      $S_n \leftarrow Place$
    case $Place$
      Place the puzzle piece in the right spot
      $V_n \leftarrow null$
      $S_n \leftarrow PickUp$
  return V_n, S_n
end function

the appropriate value. This preliminary testing revealed a critical balance: probabilities that were too low (i.e., below 50%) failed to provide participants with sufficient exposure to the virtual character's personality traits; conversely, excessively high probabilities (i.e., approaching 100%) resulted in overly repetitive behaviors that participants perceived as robotic and unnatural. Based on these findings, we established a 75% probability for personality exhibition, providing adequate personality expression while maintaining behavioral naturalness.

(a) (b)

Fig. 2: (a) The egoistic child virtual character exhibits its personality by seizing the puzzle piece from a user's hand. (b) The altruistic child virtual character exhibits its personality by pointing to the user where to place the puzzle piece on the puzzle board.

Age. We integrated virtual characters from the RocketBox Avatar Library [27]. We used the Female_Child_01 for the child virtual character and the Female_Adult_01 for the adult virtual character (see Fig. 3). We designed the virtual character's voice and appearance based on the assigned age. To synthesize the voice of the virtual character, we

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Algorithm 2 Personality Exhibition Algorithm

```
Input:
A    ▷ A is a list of pairs of a puzzle piece and its target spot
T    ▷ T is the virtual character's personality
H    ▷ H is the puzzle piece grabbed by the participant's hand
S    ▷ S is the current state of the brain system
Output:
V_n  ▷ V_n is the next puzzle piece interacted by the virtual character
S_n  ▷ S_n is the next state of the brain system

function PERSONALITY(A, T, H, S)
    switch T do
        case Egoism
            Seize H from the participant
            V_n ← H
            S_n ← Place
        case Altruism
            Point the answer of H based on A
            S_n ← ForceToPickUp
    return V_n, S_n
end function
```

used TTS services. Specifically, we used Kelly's voice model from ElevenLabs[1] for the child virtual character and Evelyn's voice model from PlayHT[2] for the adult virtual character. Before we chose which voice models and virtual characters to use for our study, we evaluated the combination of voice and appearance by conducting a sanity check.

For the sanity check, we recruited four experts (two male [age: $M = 29.00$, $SD = 4.24$] and two female [age: $M = 27.00$, $SD = 1.41$]) who had enough experience in computer graphics and character modeling/animation (years of experience: $M = 7.75$, $SD = 6.24$). We asked the experts to evaluate the match between the virtual character's voice and appearance on a 7-point scale by asking them, "*How well does the virtual character's voice match their appearance?* in which 1 = Not well at all and 7 = Very well." Until all experts agreed that the virtual character's voice and appearance matched and their combination was convincing, we tested different virtual character models from the RocketBox Avatar Library and voice models from PlayHT and Eleven Labs. The combination of virtual characters and voice models we used for our study received high scores from the experts: adult ($M = 6.00$, $SD = .82$) and child ($M = 6.00$, $SD = 1.15$).

(a) (b)

Fig. 3: We used two virtual characters of different ages: (a) a child and (b) an adult.

Animation System. The animation system drives the virtual character based on the decisions of the brain system. To allow the virtual character to solve the jigsaw puzzle and display a specific behavior based on the assigned personality, we implemented the full-body forward and backward reaching inverse kinematic (FABRIK) solver [4]. The inverse kinematics system allowed the virtual character to interact with a puzzle piece or a spot on the puzzle board. For instance, the virtual character could pick up an unsolved puzzle piece wherever it was, even if it was held by the participant's hand. Furthermore, to provide a more realistic experience to our participants, we implemented common facial expressions, such as blinking and gaze movement, and lip-sync animations through SALSA LipSync Suite.[3]

Table 1: We designed monologues to exhibit the virtual character's personality. When the virtual character displayed altruistic or egoistic behaviors, it delivered one of these monologues that matched its personality.

Personality	Monologues
Altruistic	- Place your piece there. - The edge of your piece matches the pattern of this empty spot. - That piece fits into this empty space.
Egoistic	- I'm sure I can do it faster. - Let's do it my way. - I know exactly where that piece goes.

3.2.2 Virtual Environment

To provide an immersive experience to our participants, we placed them in a virtual living room. The living room 3D model included various furniture. In this living room, we placed the participant and virtual character on chairs near a table. We applied L-shaped formation [18] to the placement of the participants and the virtual character to enhance cooperative interactions [68]. Specifically, from the participant's perspective, the virtual character sat on a chair on the right side, and the participant could see the puzzle pieces, puzzle board, and puzzle goal on the table. Our jigsaw puzzle consisted of 25 puzzle pieces, which we placed on the table in front of the participant and the virtual character. The size of each puzzle piece was 4×4 cm. For the puzzle board, we used a semi-transparent texture to indicate where the participant needed to place the puzzle piece. When the participant brought the grabbed puzzle piece close to its correct target spot on the puzzle board, it snapped automatically to the target spot. Note that we used the same puzzle pieces, puzzle board, and puzzle goal across all experimental conditions. We did so to standardize the experimental conditions.

3.2.3 User Interaction Tools

Our virtual reality application supported interaction tools for participants to communicate and co-solve the jigsaw puzzle with the virtual character. When our virtual reality application started, the virtual character greeted our participants and started a small talk based on pre-defined dialogues. Note that our virtual reality applications provided two small talks before and after co-solving the jigsaw puzzle with the virtual character (see Table 2). After each dialogue, our system rendered options for answers in a graphical user interface (GUI). Our participants could answer them by selecting the appropriate answer using the Oculus controller. For the answer selection process, we implemented a ray casting method that originates a ray from an Oculus controller to visualize where our participants pointed and allowed them to click one of the answers through the controller. After the small talk, our participants started co-solving the jigsaw puzzle with the virtual character. Our participants could grab and place the puzzle pieces through Oculus controllers. Specifically, we implemented virtual hands driven by signals from Oculus controllers to provide intuitive interactions to our participants. Through these virtual hands, our participants could interact with puzzle pieces using semi-natural hand gestures.

3.3 Survey

In the experiment, we provided a survey to our participants to investigate their perception of the virtual character and user experiences. The survey consisted of nine variables totaling 32 items. Specifically,

[1] https://elevenlabs.io/
[2] https://play.ht/
[3] https://assetstore.unity.com/packages/tools/animation/salsa-lipsync-suite-148442

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Table 2: We designed dialogues between the virtual character and our participants to provide engaging and realistic experiences. The dialogues consisted of two parts: before and after co-solving the jigsaw puzzle. Note that participants' answers did not affect the progress of our application.

Time	Virtual Character's Dialogue	Options for Participant's Answers
Before co-solving the jigsaw puzzle.	- Hi, I am happy to meet you. How was your day?	1. It was good! 2. A little bit bored.
	- Okay, let's solve this puzzle together!	1. Good, let's do it! 2. No, I don't want to play.
After co-solving the jigsaw puzzle.	- Good job! We did it.	1. Good job! 2. Bye.

inspired by previously published work [61], we created a scale composed of four items to measure the virtual character's altruism. Also, the survey included three items for uncanny valley from Ho and MacDorman [32], five items for anthropomorphism, five items for likability, and three items for perceived safety from Bartneck et al. [5], six items for perceived collaboration from Liu et al. [44], three items for rapport from Gratch et al. [28], and two items for emotional reactivity from Mousas et al. [52]. Last, we created and included one item to measure our participants' desire for future interaction. Note that we used a 7-point Likert scale for all items in the survey (see supplementary material document). We also asked our participants to provide written feedback after experiencing all four study conditions. We collected all data and feedback using the Qualtrics online survey tool.

3.4 Procedure

When participants visited our lab, we guided them through the process, introduced the details of the experiment, and provided them with the consent form, which our university's IRB approved. Once the participants signed the consent form, we asked them to enter their demographic information. After submitting the information, we helped them wear the virtual reality HMD and adjusted its setup. During the experiment, the participants experienced four conditions in a balanced order. Specifically, we used the Latin squares method [82] to balance the sequence of our conditions to eliminate the first-order carry-over (residual) effects. During the experiment, our participants were seated in a comfortable chair in our lab space. They were not surrounded by furniture or other obstacles, allowing them to move their hands freely. After completing each condition, we asked them to answer the survey we developed. Also, we provided breaks between conditions and checked whether they were ready to resume the experiment. When the participants completed all experimental conditions, we requested them to leave comments about their experiences. Our participants completed the study in less than an hour.

4 Results

4.1 Self-reported Ratings

In our statistical analyses, we used the personality and age factors as independent variables and the self-reported ratings as dependent variables. We assessed the normality of our data graphically using Q-Q plots of the residuals and conducted the Shapiro-Wilk test at the 5% significance level. Our data fulfilled the normality criteria. Thus, we performed a two-way repeated measures analysis of variance (RM-ANOVA) for each variable. We performed multiple comparisons with Bonferroni-corrected estimates. We provide detailed results in Table 3.

4.1.1 Perceptions of the Virtual Characters

Virtual Character's Altruism. Our simple main effect analysis on the personality factor indicated that our participants rated the virtual character's altruism higher when we exposed them to altruism ($M = 5.42$, $SE = .19$) than egoism ($M = 2.49$, $SE = .17$) conditions (Wilk's $\Lambda = .183$, $F[1,27] = 120.942$, $p = .000$, $\eta_p^2 = .817$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .965$, $F[1,27] = .969$, $p = .334$, $\eta_p^2 = .035$) or for the personality $\times$ age interaction effect (Wilk's $\Lambda = .998$, $F[1,27] = .042$, $p = .839$, $\eta_p^2 = .002$).

Uncanny Valley. We did not find a statistically significant result on our participants' rating on the uncanny valley for the personality factor (Wilk's $\Lambda = .990$, $F[1,27] = .281$, $p = .600$, $\eta_p^2 = .010$). However, our simple main effect analysis on the age factor indicated that our participants rated the uncanny valley higher when we exposed them to the adult ($M = 2.96$, $SE = .11$) than the child ($M = 2.69$, $SE = .15$) conditions (Wilk's $\Lambda = .846$, $F[1,27] = 4.923$, $p = .035$, $\eta_p^2 = .154$).[4] Nevertheless, we did not find a statistically significant result for the personality $\times$ age interaction effect (Wilk's $\Lambda = .973$, $F[1,27] = .761$, $p = .391$, $\eta_p^2 = .027$).

Anthropomorphism. Our simple main effect analysis on the personality factor indicated that our participants rated the anthropomorphism higher when we exposed them to altruism ($M = 3.66$, $SE = .19$) than egoism ($M = 3.23$, $SE = .24$) conditions (Wilk's $\Lambda = .805$, $F[1,27] = 6.524$, $p = .017$, $\eta_p^2 = .195$). However, we did not find a statistically significant result for the age factor (Wilk's $\Lambda = .933$, $F[1,27] = 1.946$, $p = .174$, $\eta_p^2 = .067$). In contrast, we found a statistically significant personality $\times$ age interaction effect (Wilk's $\Lambda = .661$, $F[1,26] = 13.854$, $p = .001$, $\eta_p^2 = .339$). To further examine this interaction effect, we conducted post-hoc pairwise comparisons using t-tests. With the adult condition, there was not a significant difference ($t[27] = -.217$, $p = 0.830$, $d = -.041$) in the ratings of the anthropomorphism between the altruism ($M = 3.33$, $SD = 1.25$) and egoism ($M = 3.37$, $SD = 1.30$) conditions. However, with the child condition, we found a significant result ($t[27] = 4.023$, $p < 0.001$, $d = .760$) indicating that our participants rated the anthropomorphism in the altruism ($M = 4.00$, $SD = .90$) condition higher than in the egoism ($M = 3.09$, $SD = 1.43$) condition.

Likability. Our simple main effect analysis on the personality factor indicated that our participants rated their likability higher when we exposed them to altruism ($M = 4.97$, $SE = .19$) than egoism ($M = 1.88$, $SE = .12$) conditions (Wilk's $\Lambda = .099$, $F[1,27] = 246.189$, $p = .000$, $\eta_p^2 = .901$). Also, our simple main effect analysis on the age factor indicated that our participants rated the likability higher when we exposed them to the adult ($M = 3.61$, $SE = .16$) than the child ($M = 3.23$, $SE = .16$) conditions (Wilk's $\Lambda = .862$, $F[1,27] = 4.326$, $p = .047$, $\eta_p^2 = .138$). However, we did not find a statistically significant result for the personality $\times$ age interaction effect (Wilk's $\Lambda = 1.000$, $F[1,27] = .001$, $p = .970$, $\eta_p^2 = .000$).

Perceived Safety. Our simple main effect analysis on the personality factor indicated that our participants rated the perceived safety higher when we exposed them to altruism ($M = 4.58$, $SE = .17$) than egoism ($M = 3.30$, $SE = .11$) conditions (Wilk's $\Lambda = .349$, $F[1,27] = 50.464$, $p = .000$, $\eta_p^2 = .651$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .999$, $F[1,27] = .024$, $p = .879$, $\eta_p^2 = .001$) or for the personality $\times$ age interaction effect (Wilk's $\Lambda = .964$, $F[1,27] = .996$, $p = .327$, $\eta_p^2 = .036$).

4.1.2 User Experiences

Perceived Collaboration. Our simple main effect analysis on the personality factor indicated that our participants rated the perceived

[4] Note that higher mean values of uncanny valley ratings indicate a lower uncanny valley effect (i.e., the scale has not been reversed).

Table 3: Detailed results of our study for the self-reported ratings (we present significant results with bold font).

	ALT		**UNC**		**ANTH**		**LIK**		**SAF**		**COLL**		**RAP**		**EMO**		**FINT**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
EC	2.44	1.09	2.61	.88	3.09	1.43	1.69	.70	3.37	.60	2.54	1.12	1.52	.52	4.57	1.73	1.43	.69
EA	2.54	1.01	2.96	.77	3.37	1.30	2.07	.96	3.23	.87	2.58	1.05	1.82	.90	4.43	1.66	1.54	.79
AC	5.33	1.17	2.78	.99	4.00	.90	4.78	1.32	4.49	1.15	5.65	1.10	4.20	1.39	2.48	1.37	5.21	1.79
AA	5.50	1.12	2.95	.73	3.33	1.25	5.15	1.14	4.68	1.15	5.87	.85	4.51	1.25	2.36	1.30	5.89	1.45
Main Effect (Personality)																		
F		**120.942**		.281		**6.524**		**246.189**		**50.464**		**160.185**		**264.099**		**50.235**		**354.436**
p		**.000**		.600		**.017**		**.000**		**.000**		**.000**		**.000**		**.000**		**.000**
η_p^2		**.817**		.010		**.195**		**.901**		**.651**		**.856**		**.907**		**.650**		**.929**
Main Effect (Age)																		
F		.969		**4.923**		1.946		**4.326**		.024		1.080		2.504		.379		3.517
p		.334		**.035**		.174		**.047**		.879		.308		.125		.543		.072
η_p^2		.035		**.154**		.067		**.138**		.001		.038		.085		.014		.115
Interaction Effect (Personality × Age)																		
F		.042		.761		**13.854**		.001		.996		.313		.001		.001		1.428
p		.839		.391		**.001**		.970		.327		.580		.975		.974		.242
η_p^2		.002		.027		**.339**		.000		.036		.011		.000		.000		.050
Personality $df = 1$, Age $df = 1$, Interaction $df = 1$, and Error $df = 27$.																		
EC: Egoism and Child; EA: Egoism and Adult; AC: Altruism and Child; and AA: Altruism and Adult.																		
ALT: Virtual Character's Altruism; UNC: Uncanny Valley; ANTH: Anthropomorphism; LIK: Likability; SAF: Perceived Safety; COLL: Perceived Collaboration; RAP: Rapport; EMO: Emotional Reactivity; and FINT: Desire for Future Interaction.																		

collaboration higher when we exposed them to altruism ($M = 5.76$, $SE = .16$) than egoism ($M = 2.56$, $SE = .18$) conditions (Wilk's $\Lambda = .144$, $F[1,27] = 160.185$, $p = .000$, $\eta_p^2 = .856$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .962, F[1,27] = 1.080$, $p = .308$, $\eta_p^2 = .038$) or for the personality × age interaction effect (Wilk's $\Lambda = .989$, $F[1,27] = .313$, $p = .580$, $\eta_p^2 = .011$).

Rapport. Our main effect analysis on the personality factor indicated that our participants rated the rapport higher when we exposed them to altruism ($M = 4.36$, $SE = .18$) than egoism ($M = 1.67$, $SE = .12$) conditions (Wilk's $\Lambda = .093$, $F[1,27] = 264.099$, $p = .000$, $\eta_p^2 = .907$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .915$, $F[1,27] = 2.504$, $p = .125$, $\eta_p^2 = .085$) or for the personality × age interaction effect (Wilk's $\Lambda = 1.000$, $F[1,27] = .001$, $p = .975$, $\eta_p^2 = .000$).

Emotional Reactivity. Our simple main effect analysis on the personality factor indicated that our participants rated the emotional reactivity higher when we exposed them to the egoism ($M = 4.50$, $SE = .27$) than the altruism ($M = 2.42$, $SE = .18$) conditions (Wilk's $\Lambda = .350$, $F[1,27] = 50.235$, $p = .000$, $\eta_p^2 = .650$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .986$, $F[1,27] = .379$, $p = .543$, $\eta_p^2 = .014$) or for the personality × age interaction effect (Wilk's $\Lambda = 1.000$, $F[1,27] = .001$, $p = .974$, $\eta_p^2 = .000$).

Desire for Future Interaction. Our simple main effect analysis on the personality factor indicated that our participants rated the desire for future interaction higher when we exposed them to altruism ($M = 5.55$, $SE = .23$) than egoism ($M = 1.48$, $SE = .11$) conditions (Wilk's $\Lambda = .071$, $F[1,27] = 354.436$, $p = .000$, $\eta_p^2 = .929$). However, we did not find a statistically significant result for either the age factor (Wilk's $\Lambda = .885$, $F[1,27] = 3.517$, $p = .072$, $\eta_p^2 = .115$) or for the personality × age interaction effect (Wilk's $\Lambda = .950$, $F[1,27] = 1.428$, $p = .242$, $\eta_p^2 = .050$).

4.2 Qualitative Data

After completing all four study conditions, we asked our participants to leave comments about their experiences. Six participants provided positive feedback about the experiments. For example, P2 wrote, "*It went well.*" P15 stated, "*It was interesting and a fun way to access the virtual world a little.*" P21 reported, "*A very interesting experiment, and I enjoy it.*" P23 stated, "*I really enjoyed this experience.*"

Three participants reported their negative user experience when we exposed them to the egoism conditions. Specifically, P14 said, "*I got very annoyed when they would take pieces of my hand.*" P18 mentioned, "*It is agitating when the other individual takes the piece from my hand,*" and P19 stated, "*She* (the virtual character) *was annoying me as I tried to grab the puzzle piece.*"

Finally, we found three comments reporting differences between the experimental conditions. Specifically, P20 wrote, "*In a couple of the runs, I felt more at ease solving the puzzle. In the other two, I felt that I could only contribute if I rushed, or the virtual person was in the process of placing another piece,*" P26 mentioned, "*... better working with someone who will help,*" and P27 reported, "*The child seemed much more human-like as she had a warmth about her.*"

5 Discussion

5.1 Perception of Virtual Characters

We explored how the personality and age of the virtual characters affected our participants' perception of them. We found a significant result in altruism ratings (**RQ1.1**) between the two examined personality types. Specifically, our participants perceived the virtual characters as more altruistic when they helped them. This finding is consistent with Stephan's [58] observations describing human helping behaviors as an example of altruism, and we suggest that the simulated altruistic actions and carefully developed monologues effectively conveyed the characters' altruism to the participants. In contrast, when the virtual characters exhibited egoistic behaviors, our participants rated them lower in altruism. This finding aligns with the study of Riar et al. [59], which described egoism as prioritizing independent rather than cooperative goals. We think our participants perceived the virtual character as more egoistic (i.e., less altruistic) when they observed the character

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taking the puzzle piece from their hands to solve the jigsaw puzzle. Overall, our simulated personalities functioned as intended, as participants were able to distinguish between them and provide corresponding ratings. Thus, our findings supported Stephan's [58] observations and Riar et al.'s [59] results and extended them to virtual characters, indicating that the personality of a virtual character plays an essential role during human-virtual character interaction.

We also observed a significant effect related to the uncanny valley (**RQ1.2**). Interestingly, this finding showed that our participants felt more uncanny when they solved the jigsaw puzzle with the child virtual character. While the virtual character displayed realistic behaviors, its perfect task performance likely violated participants' expectations about child-level cognitive capabilities. This mismatch between the appearance and behavior of the virtual character might evoke uncanny feelings [7]. Previous research has identified various factors contributing to the uncanny valley, particularly the importance of aligning a robot's appearance with its behavior [33, 81]. Our findings extend these works by suggesting that maintaining this alignment is also a key factor in avoiding the uncanny valley in virtual character design.

We found a significant result on anthropomorphism (**RQ1.3**). Our participants rated the anthropomorphism higher when we exposed them to altruistic rather than egoistic virtual characters. This finding expands on Zhang et al. [87] who stated that a robot's response speed to the user's requests and how minimally it annoys the user can be key components comprising its anthropomorphism. Similarly, our participants might have perceived the virtual character as more anthropomorphic when it indicated where the puzzle piece should be placed during the puzzle-solving activity. Also, we found an interaction effect on anthropomorphism. Specifically, the altruistic behavior assigned to the child virtual character led our participants to provide higher anthropomorphism ratings than the adult virtual character. This finding suggests that the age factor moderated the effect of personality on the rating of anthropomorphism, aligning with prior research by Eyssel et al. [22], who found that context and social behaviors influence the perception of virtual characters. Therefore, our study supports and extends the existing literature by demonstrating that both personality and age significantly contribute to the anthropomorphism of virtual characters.

Moreover, we found significant results on likability (**RQ1.4**). Participants rated the altruistic virtual character higher in likability. This finding builds on previous studies that identified personality traits like extroversion as influencing likability [43], indicating that altruism is a crucial personality trait that enhances the likability of virtual characters. Additionally, our study revealed that participants rated the likability of the adult virtual character higher than the child. This finding aligns with Richards et al. [60], who reported that their young adult participants preferred peer-aged virtual characters. Since our participants were undergraduate and graduate students (age range: 18–36), they may have preferred the adult virtual character, perceived to be closer in age, over the child virtual character. It suggests that age also plays a significant role in shaping perceptions of likability, supporting and extending the work of Tanaka and Nakamura [74], who found that the appearance of virtual characters affected the likability ratings in social skill training contexts. Therefore, our study supports and extends the existing literature by demonstrating that both personality and age significantly contribute to the likability of virtual characters.

Last, we found a significant result in perceived safety (**RQ1.5**), showing that our participants felt less safe when interacting with the egoistic virtual characters than the altruistic ones. This finding is consistent with prior research by Akalin et al. [1], who explored factors of perceived safety in human-robot interaction and stated that a robot's personality is among many factors that could impact safety. Our findings suggest that the principle of perceived safety in human-robot interaction also applies to human-virtual character interaction, thereby extending Akalin et al.'s [1] findings. Specifically, our results agree with the notion that an egoistic personality in virtual characters can diminish the perception of safety among users, supporting the broader literature on the importance of personality in designing safe and engaging virtual agents [30].

5.2 User Experiences

We found a significant result in perceived collaboration (**RQ2.1**). Our participants rated their collaboration higher when co-solving the jigsaw puzzle with altruistic virtual characters than egoistic ones. This finding suggests that egoistic behavior in virtual agents undermines collaborative experiences by creating a conflict between individual and group interests. Egoistic behavior is recognized as inherently threatening to group collaboration [6]. Thus, when virtual characters exhibit egoism, they may trigger participants' expectations of competitive rather than cooperative dynamics, thereby disrupting the formation of shared goals and collective intentions necessary for effective collaboration. This result also aligns with Riar et al.'s [59], which found that altruistic game features formed "we-intentions" and enhanced collective performance among participants. Our results extend these findings to human-agent interaction, demonstrating that altruistic virtual characters can similarly enhance collaborative experiences.

We also found a significant result on rapport (**RQ2.2**), indicating that our participants rated the rapport with altruistic virtual characters higher than with egoistic ones. This finding aligns with Kang et al. [34], who investigated the association between participants' personalities and rapport with virtual humans. They found that participants with more agreeable personalities reported stronger rapport with the virtual character compared to those with less agreeable personalities. Our findings extend Kang et al.'s results by demonstrating that the personality of virtual characters is another factor impacting rapport ratings, suggesting that altruistic behavior in virtual characters can enhance rapport with users. The absence of age-related effects on rapport is consistent with meta-analytic findings by Oh et al. [56], who analyzed 152 studies and found that demographic factors like age have little influence on social presence, especially when compared to psychological traits such as extraversion and the need to belong.

Moreover, we found a significant result from emotional reactivity (**RQ2.3**). Our participants reported higher emotional reactivity when exposed to egoistic virtual characters than altruistic ones. This finding is consistent with Mousas et al. [52], who investigated the impacts of motion and appearance of virtual characters on emotional reactivity and reported that both properties significantly affect emotional responses. Thus, our results expand Mousas et al.'s findings by indicating that the virtual character's egoistic behaviors may provoke stronger emotional reactions than its altruistic ones.

Last, we found a significant result on the desire for future interaction (**RQ2.4**). Our participants were more willing to interact with the altruistic virtual character than the egoistic one. This result aligns with Riar et al. [59], who pointed out that people consider collaborative activities, such as helping others, more valuable in cooperative games. Based on this, we argue that our participants' higher collaboration ratings with the altruistic virtual character likely influenced their preference for future interactions with that virtual character. This supports the notion that altruistic behavior in virtual characters can enhance users' willingness to engage in future interactions, reinforcing the importance of altruistic personalities in virtual character design to promote sustained user engagement.

5.3 Implication

To investigate the impacts of a virtual character on human perceptions and experiences, researchers and practitioners strived to design virtual characters to meet their requirements. Based on our findings, we provide guidelines for researchers and practitioners interested in similar topics. If researchers and practitioners are interested in simulating altruistic and egoistic virtual characters, we recommend referring to our design of the virtual character's personality simulation and monologues. Additionally, if researchers and practitioners want a virtual character to be perceived as more anthropomorphic, we suggest that the virtual character avoid exhibiting behaviors that could be perceived as egoistic. This suggestion would be more critical, especially if the virtual character is a child, since we found that the egoistic behavior was more impactful when the virtual character was a child rather than an adult.

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According to our results, our participants provided positive feedback on perceived collaboration and higher scores for rapport on the altruistic virtual character. Therefore, we recommend integrating altruistic virtual characters rather than egoistic ones when the application requires collaboration with virtual characters. Furthermore, as developers, we must provide positive user experiences to motivate the sustained use of applications. Thus, considering the higher scores for likability, perceived safety, and desire for future interaction on the altruistic virtual character, we recommend designing interactable virtual characters to be altruistic rather than egoistic if developers implement applications supporting collaborative interactions with virtual characters. Lastly, based on our findings regarding the uncanny valley, we recommend ensuring a match between the virtual character's age and proficiency in solving tasks to prevent uncanny perceptions during the interaction.

5.4 Limitation

Although we found significant results from all research questions, it's equally important to recognize and report our study's limitations. These limitations provide insights for interpreting our findings rather than invalidating them. First, we developed a single pre-defined repeated activity to convey the personality of our characters. Although the virtual characters voiced different monologues while exhibiting altruistic or egoistic personalities, they would look more realistic if we integrated other activities reflecting their personalities. Second, the virtual character did not communicate with our participants while co-solving the jigsaw puzzle. This lack of communication limited our participants' chances of engaging with the virtual characters. If the virtual character could communicate with our participants more naturally (e.g., speech-based communication), our participants could have the chance to experience a more sophisticated interaction. Third, in our study, we used only female virtual characters to isolate the effects of personality and age. However, based on prior research, we know that the virtual character's gender influences user perception [35]. Therefore, we argue that our findings cannot be considered generalized as they may not apply to male virtual characters. Moreover, the influence of gender congruence between participants and virtual characters remains unclear and warrants further investigation, as it may significantly shape user perceptions and interactions. Last, we did not compare the altruistic and egoistic virtual characters with neutral-personality virtual characters. We argue that including an additional personality condition would have significantly increased the duration of the experiment and might have led to participant fatigue and decreased motivation. Thus, to minimize this risk and maintain the study's feasibility, we focused only on comparing the two personalities.

6 Conclusions and Future Work

In this study, we investigated the impacts of the personalities and ages of virtual characters on human perceptions and experiences. We found that the personality factor affected our participants' perceptions of the virtual character, including the virtual character's altruism, anthropomorphism, likability, and perceived safety. The virtual character's altruism also positively affected our participants' user experiences, including perceived collaboration, rapport, emotional reactivity, and desire for future interaction. Furthermore, the age factor impacted how our participants experienced the uncanny valley and the likability of the virtual character. We also found an interaction effect between the virtual character's personality and age factors on its anthropomorphism. These findings extended previous studies and provided insights for researchers interested in the impact of virtual characters on human perception and user experience. To support future work, we also developed guidelines for designing collaborative interactions with virtual characters. These are particularly useful for scenarios requiring the simulation of specific social dynamics, such as working with an uncooperative colleague.

Although we found significant results, our study still had several limitations. To resolve these limitations, we will focus on implementing realistic hand animations for interaction with puzzle pieces and implement conversational capabilities [84–86] using large language models (LLMs). In addition, we plan to explore adaptive personality modulation based on real-time user feedback and investigate the influence of cultural background on user perception and interaction with virtual characters. Lastly, we plan to incorporate participants' demographic and personality information to deepen our understanding of how age and personality factors influence user perception and interaction with virtual characters.

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