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Uncanny Valley, Neurodiversity and Virtual Avatars

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Abstract. This paper examines the intersection of neurodivergence and the uncanny valley effect in virtual reality (VR) environments, focusing on emotional recognition and avatar realism. Three studies employing high-fidelity MetaHuman avatars explored how neurodivergent (ND) and neurotypical (NT) individuals perceive uncanniness and emotional expressions in VR. Across 126 trials per participant, avatars depicted Ekman's seven universal emotions, with participants rating realism, emotional accuracy, and uncanniness. Findings revealed ND individuals rated avatars as significantly uncannier and displayed lower emotional recognition accuracy than NT participants. Negative emotions, particularly contempt and disgust, were perceived as uncannier and challenging to recognize. Strong correlations emerged between uncanny ratings and animation quality. These results highlight the nuanced differences in perception between ND and NT individuals and underscore the importance of inclusive design in VR environments for improved accessibility and usability.

Keywords: Virtual Reality (VR), Avatars, Neurodiversity/Neurodivergence.

1 Introduction

Virtual reality (VR) has emerged as a transformative technology, enabling immersive experiences for education, training, and research. With advancements in avatar realism, VR can simulate complex social interactions, bridging gaps for diverse users, including neurodivergent individuals. However, the uncanny valley (UV)—a phenomenon where entities appear almost human but evoke discomfort—poses a significant barrier to seamless user experiences [1]. This paper explores the UV's impact on neurodivergent populations, focusing on emotional perception and its implications for inclusive VR design.

The uncanny valley effect is attributed to a mismatch between user expectations and avatar behavior, often leading to heightened discomfort [2]. Neurodivergent individuals, such as those with autism or ADHD, may experience unique challenges in such environments due to differences in sensory processing and emotional recognition [3]. While VR offers opportunities for personalized and controlled learning environments, it also necessitates careful consideration of avatar design to avoid exacerbating these challenges.

Three independent studies investigated the intersection of neurodivergence and UV effects using high-fidelity MetaHuman avatars. These avatars, known for their advanced facial animations and realism, allowed for detailed assessments of emotional recognition and uncanniness. By analyzing the reactions of ND and NT participants across various avatars and emotions, this research provides critical insights into optimizing VR environments for diverse users

2 Introduction

2.1 Participants

A total of 35 participants (22 female, 13 male) aged 18–50 years (M = 22.7, SD = 6.6) were recruited via socialmedia and university channels. Seven participants self-reported neurodivergence (e.g., autism, ADHD). Ethical approval was obtained from the University of Glasgow Ethics Committee.

2.2 Materials

The study utilized high-fidelity MetaHuman avatars created using Unreal Engine. These avatars represented three racial categories (Caucasian, Asian, and Black), with male and female counterparts (Fig 1). Each avatar expressed Ekman's seven universal emotions (happiness, sadness, fear, disgust, anger, surprise, contempt) through advanced facial animations. Participants wore Oculus Quest 2 headsets connected to an Alienware m18 R1 gaming laptop. A VR environment resembling a café was designed to provide consistent visual and auditory stimuli across trials. The ALIVE software was used to record data on participants' emotion recognition accuracy, uncanny valley ratings (0–1 scale), and animation quality ratings (0–10 scale).

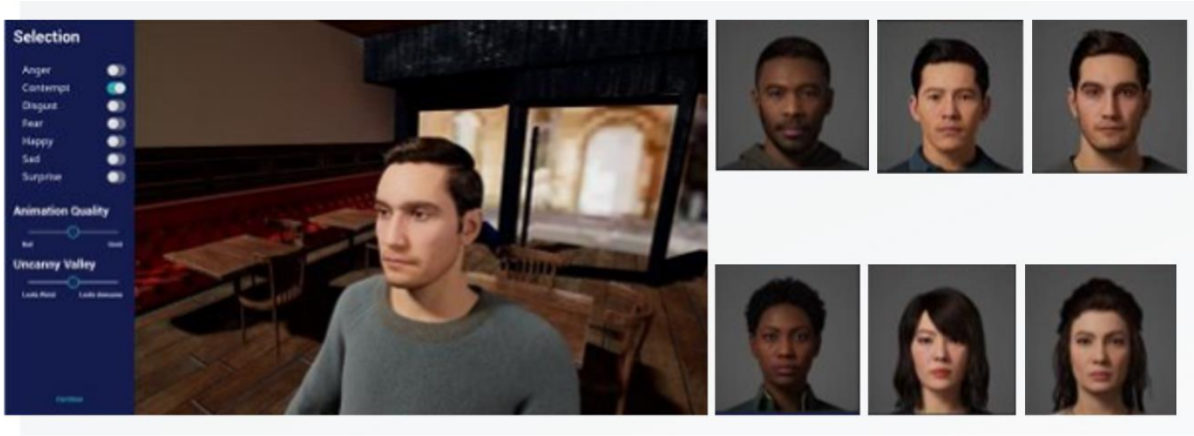

Fig. 1. Experimental set up demonstrating virtual environment (ALIVE) and the selected MetaHuman avatars (the environment was created by Edify.ac as part of a collaborative Innovate UK grant).

3 Results

Neurodivergent participants rated avatars as significantly more uncanny than neurotypical participants ($W = 12$, $p < 0.001$). The mean uncanny rating for ND participants was 0.41, compared to 0.44 for NT participants (Fig 2). Differences were particularly pronounced for negative emotions like contempt ($W = 197$, $p < 0.001$) and fear ($W = 180.5$, $p < 0.001$), where ND participants rated avatars as significantly more uncanny.

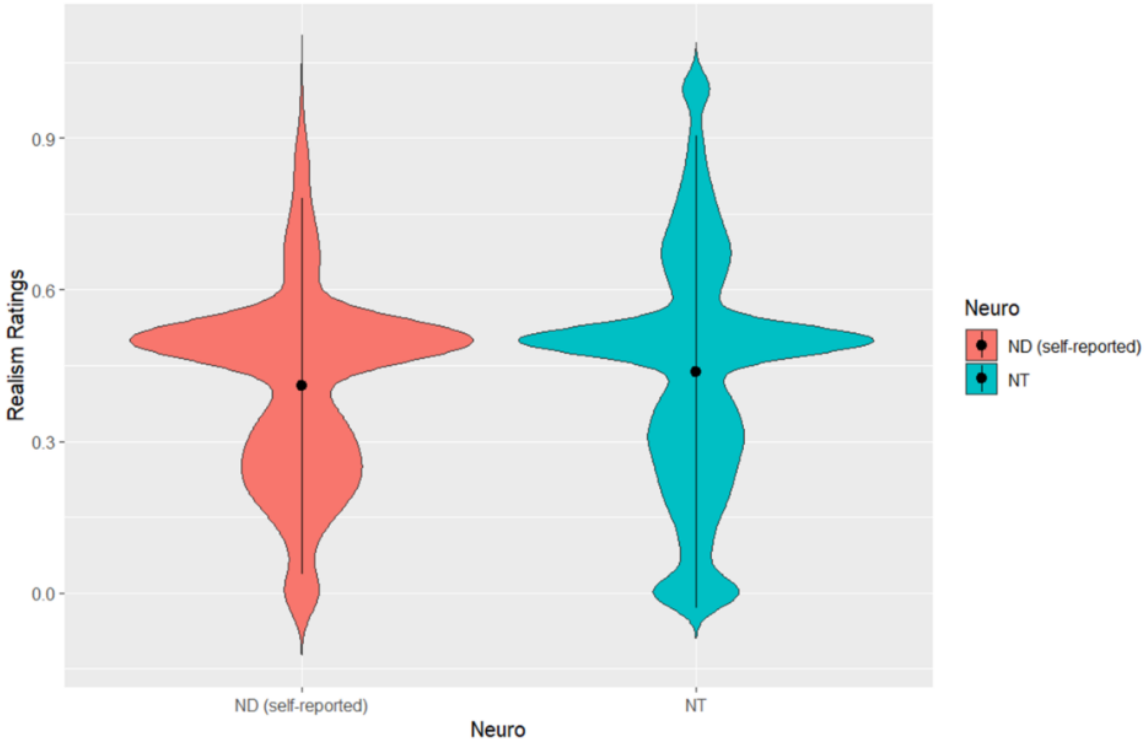

Fig. 2. Figure depicts Neurodivergent (ND) Individuals perceived Avatars as more Uncanny.

Chi-square tests revealed significant differences in emotion recognition accuracy between ND and NT participants ($X^2 = 6.48$, df = 1, $p = 0.01$). NT participants had higher mean accuracy (72.7%) than ND participants (68.1%) (Fig 3). Negative emotions such as disgust ($X^2 = 17.6$, df = 1, $p < 0.001$) and anger ($X^2 = 19.9$, df = 1, $p < 0.001$) were particularly challenging for ND participants.

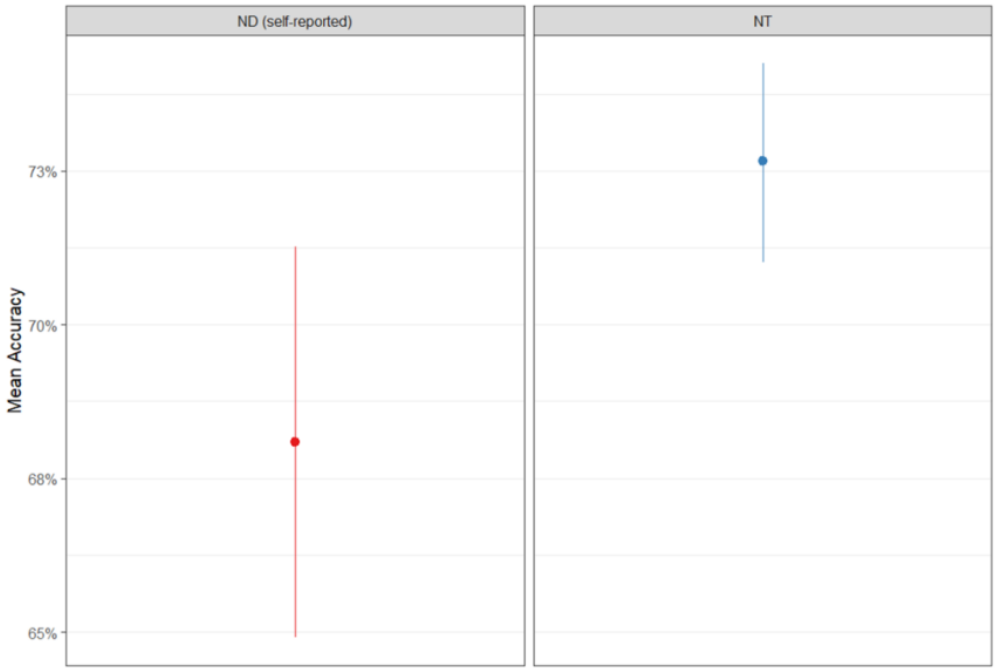

Fig. 3. Figure depicts how Neurotypical (NT) Individuals performed more accurate.

One-way ANOVA revealed significant differences in uncanny ratings across emotions ($F(6, 4026) = 35.6$, $p < 0.001$). Emotions like contempt and disgust received the highest uncanny ratings, correlating strongly with lower animation quality ratings ($r = 0.66$, $p < 0.001$).

4 Discussion

The findings indicate that neurodivergent participants experience greater discomfort with VR avatars, particularly when negative emotions are expressed. This aligns with prior research suggesting that ND individuals are more sensitive to perceptual mismatches, such as those triggering the uncanny valley effect [1]. Lower emotion recognition accuracy among ND participants further underscores the challenges they face in interpreting subtle social cues in VR.

Negative emotions like contempt and disgust were rated as more uncanny and harder to recognize, particularly by ND participants. This suggests that these emotions may be more challenging to animate convincingly, highlighting a need for improved rendering techniques and animation pipelines in avatar design. Such refinements could reduce the uncanny valley effect and improve user comfort and engagement.

The strong correlation between animation quality and uncanny ratings highlights the importance of high-fidelity animations in minimizing discomfort. For ND users, VR environments must incorporate customizable avatars and adaptive features to cater to diverse perceptual needs. Educational and therapeutic applications of VR could benefit significantly from these modifications, providing neurodivergent individuals with more accessible and inclusive tools for learning and social interaction.

Designers and Instructors should be aware of these individual differences when designing learning content. However, more nuanced investigation of these individuals differences might be required, potentially employing qualitative or mixed methods.

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