The Impact of Gender and Nonverbal Behavior on Perception of Virtual Audiences in VR

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The development of increasingly realistic virtual avatars has transformed human–machine interactions. Through their human appearance and behavior, they enable realistic human-centered simulations in various domains, encompassing tourism (Choi *et al.*, 2020), healthcare (Sestino & D'Angelo, 2023), and training (Lugrin *et al.*, 2016).

Public Speaking Training (PST) environments have particularly benefited from the development of avatars. By simulating human presence, such environments allow individuals to practice their communication skills, which are essential in many management contexts, through one-to-one interactions with avatars (Stanica *et al.*, 2018) or before virtual audiences (Batrinca *et al.*, 2013). When combined with the immersive capabilities of Virtual Reality (VR), these environments provide promising training experiences in terms of effectiveness and acceptance (Palmas *et al.*, 2019). However, to design scenarios that effectively foster skills acquisition, believable and challenging audiences are needed. In this context, a growing body of research has underscored the critical role of avatars' design, emphasizing the multimodal characteristics that influence their perception (Etienne *et al.*, 2024).

PST environments typically rely on avatars' nonverbal behavior to shape their attitudes toward the user (Batrinca *et al.*, 2013; Chollet *et al.*, 2017), thereby reflecting different levels of sympathy, interest, or even dominance (Kang *et al.*, 2016). Users can indeed perceive variations in avatars' attitudes (Chollet *et al.*, 2017; Etienne *et al.*, 2023; Glémarec *et al.*, 2021) and interpret cues that reflect mood states and personality traits (Kang *et al.*, 2016). Studies have also considered the avatars' *valence* (*i.e.*, positive or negative emotions evoked by the avatar) and *arousal* (*i.e.*, alertness) to design their behavior (Chollet *et al.*, 2017). Etienne *et al.* (2023) evaluated combinations of posture, head movements, and facial expressions in VR, assessing them along these dimensions using individual avatars. This study resulted in the classification of 40 behavioral combinations according to their perceived levels of valence and arousal. Similar behavioral patterns had previously been investigated by Chollet *et al.* (2017) using a 2D-based system, and comparable results were obtained. However, although audiences are common in public speaking contexts, the perception of groups of avatars has been less explored than that of individual avatars. Moreover, despite its immersive capabilities, VR has been less used than PC-based systems in perceptive studies (Etienne *et al.*, 2024).

The gender of virtual avatars influences perception as well. Armando *et al.* (2022) highlighted the persistence of gender stereotypes in human-avatar interactions. The presence of gender biases was further confirmed by Ristorcelli *et al.* (2023), who showed that female agents were perceived more positively than male agents for the same attitude. In another application context, male avatars were considered more competent than female ones (Choi *et al.*, 2020). However, research investigating gender-related aspects and their mediating effect on the perception of avatars' behavior remain scarce. In particular, the gender distribution within audiences has not, to the authors' knowledge, been considered.

In this context, the present study will aim to fill the abovementioned gaps by examining how nonverbal behavior and gender influence attitude perception in medium-sized virtual audiences using VR.

Virtual audiences varying in both their nonverbal behavior and gender representation have been created. Combinations of postures, head movements, and facial expressions were assigned to each avatar within the audience to create seven distinct attitude conditions, each designed to elicit different levels of valence and arousal (see Table 1). These combinations were retrieved from the classification proposed by Etienne *et al*. (2023), such that avatars adopt appropriate behaviors associated with the desired levels of valence (*i.e*., positive, neutral, or negative) and arousal (*i.e*., low, neutral, or high). Given the importance of avatars' gaze in arousal ratings (Chollet *et al.*, 2017), this aspect was also incorporated. Each condition is associated with different percentages of time the avatars spend looking at the user (see Table 1). During the remaining time, they either look down or ahead.

Table 1. Attitude conditions

Attitude conditions	Valence level	Arousal level	Eye contact percentage
A1	Neutral	Low	20%
A2	Negative	Neutral	50%
A3	Neutral	Neutral	50%
A4	Positive	Neutral	50%
A5	Negative	High	80%
A6	Neutral	High	80%
A7	Positive	High	80%

When few combinations were available for a specific attitude condition in Etienne *et al.* (2023), these were alternated between agents to maintain realism. In addition, the closer an avatar was positioned to the user, the more distinctive the assigned combination was, based on the valence and arousal rankings established (Etienne *et al.*, 2023).

This study also investigates the influence of gender on attitude perception. To that end, five gender conditions have been created, each associated with a specific distribution of male and female avatars within the audience (see Table 2).

Table 2. Gender conditions

Gender conditions	Number of female avatars	Number of male avatars
G1	0	20
G2	5	15
G3	10	10
G4	15	5
G5	20	0

The resulting VR environment used in this study then simulates 35 audience conditions (*i.e.*, 7 attitude x 5 gender conditions), each composed of 20 seated avatars of different ethnicities (see Figure 1).

Figure 1. Screenshot of the virtual environment

The study involved the participation of 70 gender-balanced participants to mitigate potential biases related to gender perception. Indeed, aspects such as cultural background, gender, or age of the users may influence the perception of avatars as well (Etienne *et al.*, 2024). They observed 10 different, randomly assigned audiences that vary in their nonverbal behavior and gender distribution using Meta Quest 3 headsets. For each observed audience, participants rated on 7-point Likert scales the perceived valence and arousal, along with their confidence in these two ratings. Demographic information was collected, and a presence questionnaire was also completed (Bouchard & Robillard, 2019; Witmer & Singer, 1998). Finally, they were allowed to provide comments on the environment and the experience.

This work, which is part of an ongoing doctoral thesis, is part of a larger project dedicated to the development of a PST application in VR. The project aims to simulate common public speaking situations (e.g., meetings, business presentations, courtroom pleadings…) to help people improve their communication skills. Moreover, the creation of AI-driven audiences that react to speaker performance is considered to provide users with challenging and realistic training experiences. Understanding how virtual audiences are perceived is crucial to making them behave appropriately. The analysis is ongoing, and results will be presented during the conference. Overall, this study will inform the design of virtual audiences, enabling them to be tailored to the context of the application and to elicit the intended levels of perceived arousal and valence.

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