Effects of Virtual Agent Gender on User Performance and Preference in a VR Training Program

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Abstract. This paper presents findings of a small-scale exploratory study that investigated effects of virtual agent gender on user performance and preference in a virtual reality (VR) training program. During the study, twelve participants, predominantly young male adults (10 males, average age 24 years), took part in a customized Box and Blocks Test (BBT), where virtual female and male agents instructed them to quickly move specific color cubes from one side of the table to the other side of the table. Although, on average, the male-dominated sample performed better with the male agent than the female agent, with respect to task completion time, error rate, and error correction time, no significant difference was identified. There was also no significant effect of agent gender on preference, perceived helpfulness, and perceived professionalism. However, interestingly, significantly more participants found the female agent more attractive than the male agent, presumably due to the male-dominated sample.

Keywords: Gender · Virtual agent · Avatar · Training system Virtual character · Box and Block · Virtual reality (VR) · Head-Mounted Display (HMD)

1 Introduction

Because virtual reality (VR) can give people a sense of presence in virtual worlds, it is becoming popular in various fields, including entertainment, education, engineering training, and rehabilitation. Virtual human-like characters are common in virtual worlds, which enable social interaction with other users or a computer system. Two different types of characters are commonly used, virtual *avatars* and virtual *agents*. An avatar is a virtual character that is controlled by an actual user [18]. Avatars are very popular in video games, including social platforms such as High Fidelity [12], AltspaceVR [1], and Sansar [28]. Agents, on the other hand, are virtual characters that are controlled by computer programs [18]. 2D and 3D virtual agents have already been a powerful strategy in online enterprises, such as in advertising [7], shopping [2],

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education [17], and persuasion [31]. However, not many studies have investigated virtual agents in the context of Virtual Reality Environments (VRE).

This work explores social interactions among users and virtual agents in a virtual reality training scenario, where users enter the virtual world through a Head-Mounted Display (HMD). Particularly, it investigates whether virtual agent gender affects user performance and preference in a training program, where they have to take instructions from a virtual agent.

2 Related Work

2.1 Virtual Avatar

Numerous social video games enable users to customize their own avatar appearance and interact with other users' avatars. Hence, many have studied the impact of avatar appearance on users' social behavior and social success in virtual worlds [6, 15, 19]. In such an investigation, Banakou and Chorianopoulos found out that users with more elaborate avatars have a better chance at social encounters than users with the default avatars [6]. Some found out that male users tend to speak more frequently with female avatars, while female prefers male avatars [6, 15, 19]. Also, female users with attractive avatars interact with male avatars more frequently, which suggests *"a self-confidence effect induced by the appearance of the personal avatar"* [6].

Another work [13] reported that avatars that mimic the outfits of the users give them the highest sense of body ownership and presence, even when the avatars are cartoon-like characters. A study exploring effects of gender on the perception of different hands reported that women dislike and feel lower levels of presence with male avatar hands, while men accept and feel presence with avatar hands of both genders [29]. A different work explored the interpersonal distance in virtual worlds with both avatars and agents [5]. Although in real-world men tend to give more interpersonal space to each other, while women usually stay closer together [8], such patterns are not prevalent in virtual worlds.

2.2 Virtual Agent

Several studies reported that agent appearance, particularly facial expression [27], gaze [3], voice [20], and body language [26] affect user performance in training scenarios. Guadagno et al. [9] studied impacts of agent gender on persuasion, where they asked users to listen to persuasive communications from both female and male agents. They found out that users were more persuaded by same gender agents than opposite gender agents. Similar results were found with virtual agents in 3D screen environments [31]. A different study reviewed visual stereotypes in agents and cautioned about the risks of applying visual stereotypes to pedagogical agents [10].

Some studies reported that the effect of social agent gender varies in different age groups. For instance, female undergraduate students tend to find young, attractive, and cool female agent most effective since it can enhance their self-efficacy towards being successful as engineers [16, 25, 30]. Middle school students also find female agents more effective than male agents [23].

3 Motivation

While many have explored effects of *avatar* gender and appearance on performance and preference in different systems, not much work has investigated *agents*. Besides, most existing works exploring agents are conducted either in 2D or 3D environments, where only a part of the agent is visible. Therefore, the findings of these works may not be generalizable to systems that enable a full visual perception of the agents. In addition, to our knowledge, no prior work has investigated agent gender effect in a VR interactive training scenario. An understanding of how users react to agents of different gender can facilitate the design and development of more effective and useful pedagogical agents, as well as give us an insight into human psyche.

4 An Experiment

The goal of this study was to explore whether agent gender impacts user performance and preference in a VR training program.

4.1 Agent Selection

We conducted an informal study to decide on female and male agent appearance for the study. For this, we created six female and six male characters using the Autodesk Character Generator [4]. Since *race* and *clothing* are outside the scope of this work, we used similar hair color, skin tone, and cloths for all characters. However, different facial features and body types were used for different characters (Fig. 1).

Participants. Thirteen volunteers, aged from 20 to 22 years, average 21.2 (SD = 0.8), participated in the informal study. Twelve of them were male and one was female. Nine of them had used an HMD prior to participating in the study, while the remaining four had no prior experiences.

Procedure. During the informal study, participants completed a questionnaire that asked them to rank the six female and six male characters (Fig. 1) based on their femininity and muscularity, respectively. The questionnaire included headshots and full-body pictures of all characters. A scale of six was used, where *1* represented the *least* feminine or masculine and *6* represented the *most* feminine or masculine characters.

Results. Figure 1 presents results of the informal study, where one can see that *Female 4* and *Male 6* yielded the highest median compared to the other characters. Hence, these two were selected for the final study.

4.2 Apparatus

The VR system used in the final study consisted of one desktop computer, 4.20 GHz, 32.0 GB RAM, Windows 10, one Oculus Rift Headset, two Oculus Touch Controllers, and three Oculus Constellation Sensors [21]. The three sensors were positioned at the

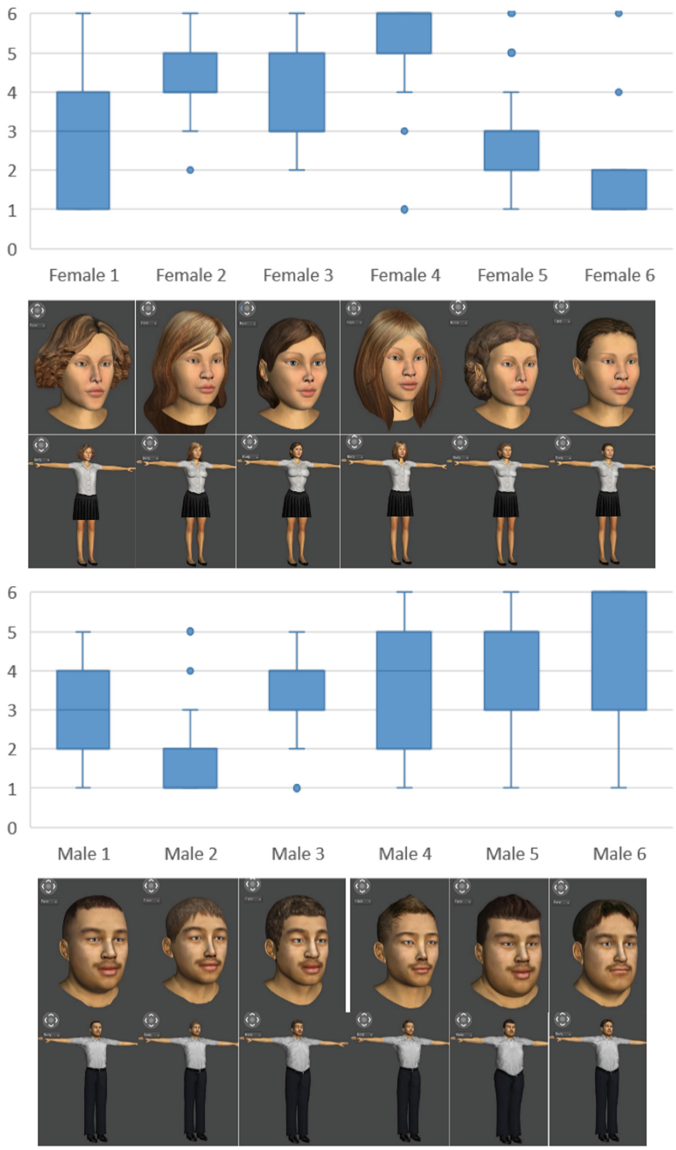

Fig. 1. Results of the informal study, together with the pictures used in the questionnaire. Error bars represent interquartile range (IQR)

same height (248 cm), two facing the user and another behind the user. The distance between the front sensors was 217 cm, and the distance between the front and back sensors was 455 cm (Fig. 2). All sensors were tilted at a 30° angle. This setup was used as it yielded a relatively better performance than several other settings tested in a pilot.

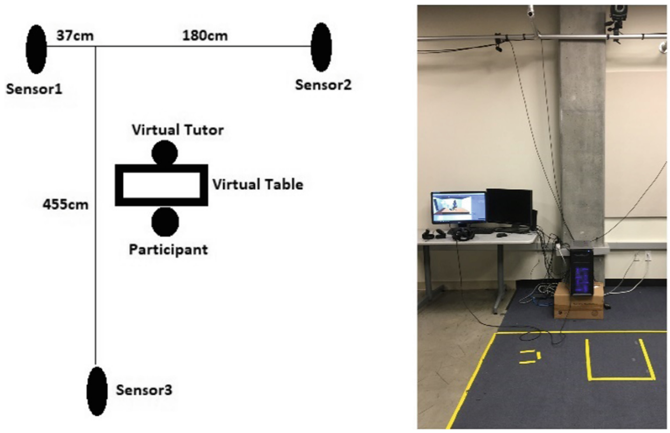

Fig. 2. The Oculus Constellation Sensor (left) and the VR system setup (right) in the study

We used a Perception Neuron full-body motion capture suit [24], 60 fps, 32 Neurons, for capturing real human motion and gestures in a pseudo training scenario (Fig. 3). This was to make the virtual agents more human-like. We tested all recorded postures, movements, and gestures in multiple trials before using them in the final study.

Fig. 3. Perception Neuron full-body motion capture suit setup

We also tried to make the study environment as welcoming as possible by adding a rug, a water dispenser, and some house plants and wall paintings to the room (Fig. 4). The study software was written in Unity.

Fig. 4. The virtual training environment used in the study

4.3 Participants

Twelve volunteers, aged from 21 to 31 years, average 23.55 (SD = 2.62) participated in the study. None of them participated in the informal study. Two of them were female and ten were male. Only two participants had prior experience with HMDs, while the remaining ten had never used an HMD before. All of them were right-handed. They all received a small compensation for participating in the study.

4.4 Design

The study used a within-subjects design, where the independent variable was the agent gender and the dependent variables were the performance metrics. There were two levels in the independent variable (conditions): female agent and male agent. Each condition included six tasks. The conditions were counterbalanced to eliminate the effect of order. In each task, participants moved four different color cubes. Each agent used two audio-instructions per gender (in total, four instructions), which were also counterbalanced to reduce the effect of instruction. In summary, the within-subjects design was:

12 participants ×
2 conditions (counterbalanced) ×
6 tasks (with 2 audio instructions, randomized) ×
3–4 cubes = 432–576 cubes, in total.

4.5 Procedure

In the study, all participants took part in a customized Box and Blocks Test (BBT), where female and male agents instructed them to quickly move specific color cubes from one side of the table to the other side of the table (Fig. 4). BBT is a functional test, commonly used in upper limb rehabilitation to measure the gross manual dexterity of a patient or a person using an upper limb prosthetic device [11]. Participants picked up the cubes by gripping the Oculus Touch Controller (which triggered the “Grip” button) when it is in close proximity to the target item, then dropped it by releasing the button. For proximity detection, we added a sphere collider to the controller (1.0 cm) and a box collider to the cubes (7.0 cm). The system enabled grasping a cube only when the cube and controller colliders collided. Inside the virtual training system, an agent first greeted the participant, then described the study, e.g., *“Hello! Welcome to the test. In this test, you have to complete three tasks. In each task, you will be asked to pick up four cubes of specific colors, as instructed, and place them on the other side of the table”*. The agent then started giving instructions on moving the cubes, e.g., *“Please pick up all red cubes one by one and put them on the other side of the table”*. The agent alerted the participant on all mistakes, e.g., *“This is not a red cube. Please put it back; and pick the right one”* and concluded each *session by thanking the participant, e.g., “Well done! You have completed all tasks. Thanks for supporting our work. Have a nice day!”*. Both virtual agents used appropriate posture and hand gestures, recorded through the full-body motion capture suit with actual human subjects.

The study took place in an academic research lab. Participants arrived individually to take part in the study. First, we explained the study procedure to all participants and collected their consents. They all filled out a short demography questionnaire. Then, we demonstrated the system, starting with the Oculus Rift. We showed them how to adjust it for a perfect fit and use the controllers. Since all our participants were right-handed, we only used the right-hand controller in the study. We then allowed the participants to practice and get comfortable with the system in a practice block, where they played the Oculus Sample Framework [22] for about five minutes. We used this game since, like the study, it involves picking up objects using the controllers. Finally, we started the study. The study software recorded all user actions with timestamps. In addition, we video recorded all sessions for post-hoc analysis. Figure 5 illustrates the study setup.

Upon completion of the study, all participants completed the Simulator Sickness Questionnaire (SSQ) [14]. They were also asked to fill out a custom questionnaire that asked them about their preference, and perceived helpfulness, professionalism, and attractiveness of the agents on 7-point Likert scales. Each session lasted for about 30 min, including demonstration, practice, breaks, and post-study questionnaires.

4.6 Performance Metrics

The system automatically calculated and recorded the following metrics.

- **Task Completion Time (Seconds)** signifies the average time the user took to complete a task.
- **Error Rate (%)** represents the average percentage of errors committed by the user per task.
- **Error Correction Time (Seconds)** represents the average time the user took to correct mistakes in each task.

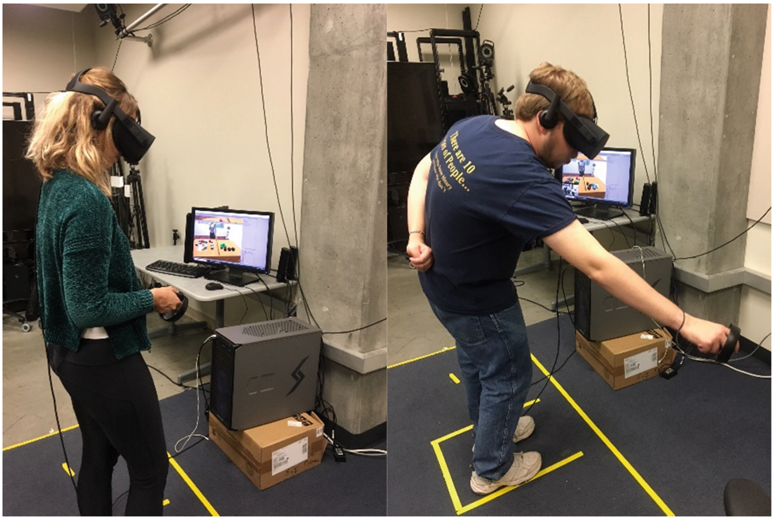

Fig. 5. Two volunteers participating in the user study. The computer monitor in the background is displaying the participants' point of view (POV)

5 Results

We used a repeated-measures ANOVA on the quantitative data.

5.1 Task Completion Time

Data revealed that participants were 11% faster with the male agent than the female agent (Table 1). However, an ANOVA failed to identify a significant effect of agent gender on task completion time ($F_{1,\ 11} = 3.33$, $p = .09$). On average task completion time with female and male agents were 15.59 (SD = 4.08) seconds and 17.61 (SD = 11.30) seconds, respectively.

Table 1. Results of the user study. All times are in seconds. SD signifies standard deviation

Metrics	Female agent		Male agent		*p*
	Mean	SD	Mean	SD	
Task completion time	15.59	4.08	17.61	11.30	.09
Error rate	3.01	2.10	2.89	2.10	.95
Error correction time	1.32	6.46	0.73	1.73	.50

5.2 Error Rate

Participants were 4% more accurate with the male agent than the female agent (Table 1). Yet, an ANOVA failed to identify a significant effect of agent gender on error rate ($F_{1,\,11} = 0.01$, $p = .95$). On average operations per task with female and male agents were 3.01% (SD = 2.1) and 2.89% (SD = 2.1), respectively.

5.3 Error Correction Time

Participants were 45% faster with error correction with the male agent than the female agent (Table 1). However, an ANOVA failed to identify a significant effect of agent gender on error correction time ($F_{1,\,11} = 0.46$, $p = .50$). On average operations per task with female and male agents were 1.32 s (SD = 6.46) and 1.73 s (SD = 1.73), respectively.

6 Qualitative Results

We collected simulator sickness data using the SSQ inventory [14]. Individual and total severity scores were calculated using the convention established by Kennedy et al. [14]. We used a Wilcoxon Signed-Rank Test on the custom questionnaire data.

6.1 Simulator Sickness

The average total simulated sickness score for the system was 10.52 (SD = 7.50). The average nausea score was 23.85 (SD = 15.46), while the average oculomotor score was 2.37 (SD = 4.42). None of the participants reported any disorientating symptoms. Table 2 presents the complete SSQ scale means for the system.

6.2 Helpfulness

About 83% participants ($N = 10$) rated the two agents equally in terms of helpfulness. The remaining 17% ($N = 2$, 1 *female*, 1 *male*) found the male agent more helpful. Figure 6 displays all user responses. However, a Wilcoxon Signed-Rank Test failed to find a significant effect of agent gender on helpfulness ($z = 1.41$, $df = 11$, $p = .18$). The median helpfulness ratings for both agents were 4.0.

6.3 Professionalism

About 67% participants ($N = 8$) rated the two agents equally in terms of professionalism, while 25% found the male ($N = 3$, 1 *female*, 2 *male*) and 8% ($N = 1$, 1 *male*) found the female agent more professional. Figure 7 shows all user responses. However, a Wilcoxon Signed-Rank Test failed to find a significant effect of agent gender on professionalism ($z = 0.06$, $df = 11$, $p = .95$). The median professionalism ratings for both agents were 4.0.

Table 2. Simulator Sickness Questionnaire (SSQ) scale means for the experiment system

SSQ symptoms	Nausea	Oculomotor	Disorientation	*Total score*
General discomfort	28.62	0	0	11.22
Fatigue	28.62	0	0	11.22
Headache	38.16	7.58	0	18.7
Eye strain	57.24	15.16	0	29.92
Difficulty focusing	19.08	7.58	0	11.22
Salivation increasing	9.54	0	0	3.74
Sweating	28.62	7.58	0	14.96
Nausea	9.54	0	0	3.74
Difficulty concentrating	19.08	0	0	7.48
Fullness of the Head	47.7	0	0	18.7
Blurred vision	28.62	0	0	11.22
Dizziness with eyes open	28.62	0	0	11.22
Dizziness with eyes closed	9.54	0	0	3.74
Vertigo	0	0	0	0
Stomach awareness	28.62	0	0	11.22
Burping	0	0	0	0
Mean	*23.85*	*2.37*	*0*	*10.52*
SD	*15.46*	*4.42*	*0*	*7.50*

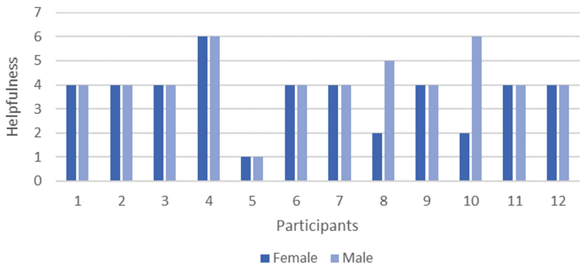

Fig. 6. User ratings of the two agents with regard to "helpfulness" on 7-point Likert scale, where *1* represents the *least* and *7* represents the *most* helpful

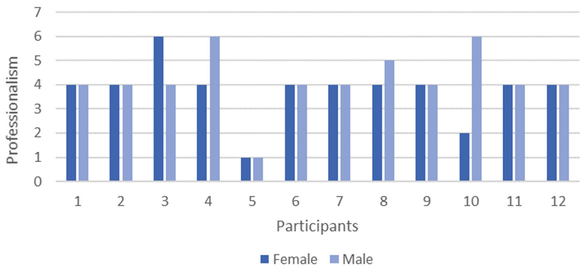

Fig. 7. User ratings of the two agents with regard to "professionalism" on 7-point Likert scale, where *1* represents the *least* and *7* represents the *most* professional

6.4 Attractiveness

About 50% participants rated the two agents equally with regard to attractiveness. The remaining 50% (*N* = 6, 1 *female*, 5 *male*) found the female agent more attractive. Figure 8 shows all user responses. A Wilcoxon Signed-Rank Test found this to be statistically significant (z = 2.42, *df* = 11, p = .01). The median attractiveness ratings for the female and the male agents were 4.0 and 3.5, respectively

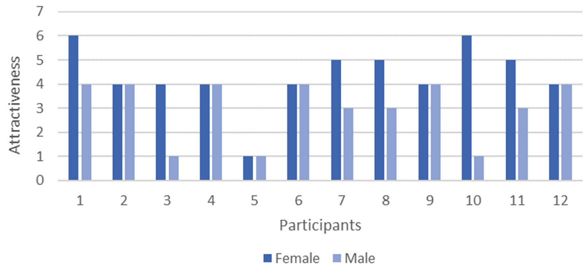

Fig. 8. User ratings of the two agents with regard to "attractiveness" on 7-point Likert scale, where *1* represents the *least* and *7* represents the *most* attractive

6.5 Preference

About 67% participants (*N* = 8) preferred both agents, while 17% (*N* = 2, 2 *male*) preferred the female and 17% (*N* = 2, 1 *female*, 1 *male*) preferred the male agent. Figure 9 illustrates all user responses. A Wilcoxon Signed-Rank Test failed to identify a significant effect of agent gender on preference (z = 0.06, *df* = 11, p = .95). The median professionalism ratings for both agents were 4.0.

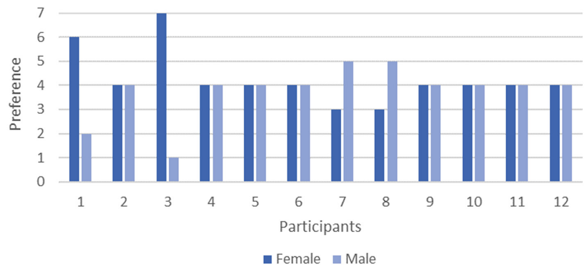

Fig. 9. User ratings of the two agents with regard to "preference" on 7-point Likert scale, where *1* represents the *least* and *7* represents the *most* preferred

7 Discussion

Some participants reported slight discomfort with the experiment system, but none of the symptoms exceeded the nausea and oculomotor severity levels (Table 2). The total SSQ score for the system was 10.52, which is negligible (the maximum score possible on the SSQ is 300). Hence, it can be said that the experiment system was appropriate for the study since its side effects were not severe enough to impact user performance or preference. However, some participants criticized the reliability of the system. For example, one female participant remarked, *"The agents did not respond well […] when I was [being] impatient"*. One male participant (22 years) commented, *"[the system must] display the actual distance between the hand and the cubes because sometimes I thought I [could] grab a cube but it turned out that my hand was too far"*. Further, we made some interesting observations during the study. We noticed that some users were rubbing their feet across the carpet to find out whether it felt real. We also noticed that users were making eye contact when the instruction started, then focused on the task. They made eye contact again, when the agent warned them about a mistake.

Participants yielded a relatively better performance with the male agent than the female agent. On average, they were 11% faster and 4% more accurate with the male agent (Table 1). They were also 45% faster in correcting errors. Nevertheless, statistical tests failed to identify a significant effect of agent gender on performance. Interestingly, effect of agent gender on task completion time almost reached significance ($p = .09$). Hence, it is possible that this effect will reach significance with an increased number of participants, which would conform to results from older studies [9, 31] that showed that users are more persuaded by same gender agents than opposite gender agents, as most of our participants were male.

Statistical tests also failed to identify significant effects of agent gender on user preference (Fig. 9), perceived helpfulness (Fig. 6), and perceived professionalism (Fig. 7). Both agents yielded comparable ratings from the users, which suggests that participants were comfortable with taking instructions and working with both agents. One female participant commented, *"female agent [was] as helpful as male and [vice versa]. Both seemed very professional"*. Interestingly, significantly more users found the female agent more attractive than the male agent. This is most likely due to our male dominated sample, as a similar trend was reported with virtual avatars, where male users preferred speaking with female avatars than male avatars [6, 15, 19]. Further investigation is needed to fully explore this behavior.

7.1 Limitations

We acknowledge several limitations of the study. First, it failed to recruit adequate female participants to investigate any potential effects of user gender on performance and preference for different gender agents. Ten of our twelve participants (83%) were young male adults. Hence, we recommend caution in interpreting the results since it may not be generalizable to a larger population. Second, the study used a binary gender classification, mainly for simplicity, while both users and agents could have a range of gender identities and expressions, not just male and female.

8 Conclusion

This paper presented results of a small-scale exploratory study that studied effects of virtual agent gender on user performance and preference in a VR training program. In the study, twelve participants (10 *male*, average age 24 years) participated in a custom Box and Blocks Test (BBT) under the guidance of a female and a male agent. On average, participants performed better with the male agent than the female agent, with respect to task completion time, error rate, and error correction time. However, no significant different was identified. The study also failed to find a significant effect of agent gender on preference, perceived helpfulness, and perceived professionalism. But interestingly, significantly more participants found the female agent more attractive than the male agent, presumably due to the study's male-dominated sample.

This work merely scratches the surface of the topic. We hope the findings of this work will inspire others to fully explore any potential effects of agent gender on performance and preference of a diverse group of users, including users of different age, gender, education, culture, technological experience, and socio-economic background. Among other applications, advances in this area will inform the automatic selection of virtual trainers in order to improve interactions in VR systems.

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