Give-Me-A-Hand: The Effect of Partner's Gender on Collaboration Quality in Virtual Reality

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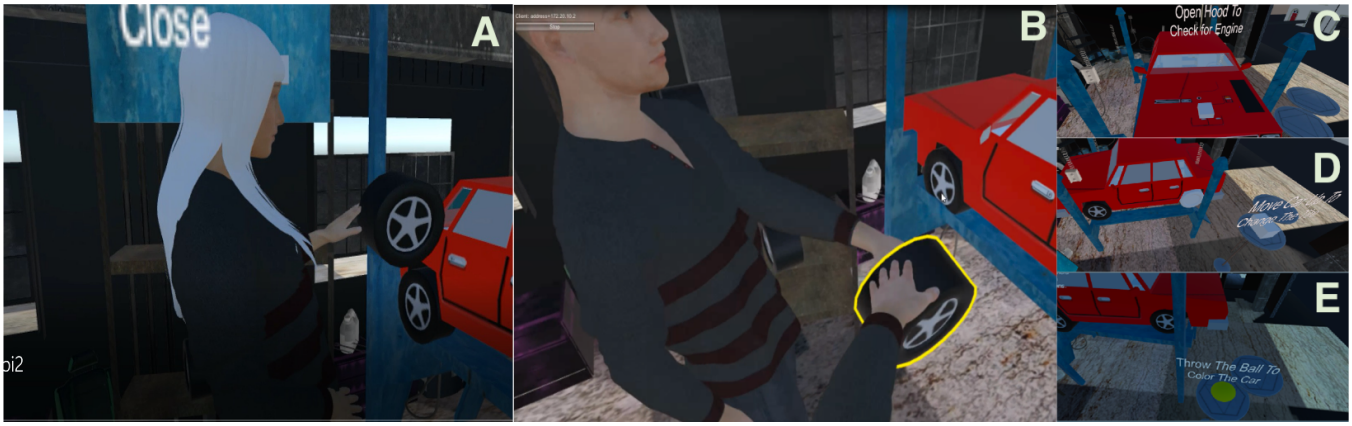

Figure 1: Users collaborating on fixing a car in a virtual garage. Figure A shows a player holding a tire. Figure B illustrates users' collaboration on changing a virtual flat tire. Figures C, D, and E show the car garage meanwhile changing the battery, tire, and color of a virtual car respectively.

ABSTRACT

Avatar appearance, especially *gender*, influences user behavior in virtual environments (VE). However the effect is often examined only as a co-variant. In this paper, we use technology to empower individuals beyond traditional societal gender roles to effectively collaborate in virtual environments. We specifically investigate the impact of the *partner's avatar gender* on the quality of collaboration in the VE, while performing an inherently male-dominated task. We designed a virtual garage, where pairs of same (C1) and mixed (C2) gender repair cars collaboratively. We evaluated the interaction using a collaboration questionnaire adopted from Team Effective Questionnaire (TEQ). Our results show that same-gender pairs were perceived as more productive and supportive. We envision that our work aids developers and researchers in enhancing the collaboration quality by supporting group cohesion and positive interactions.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; **Collaborative interaction**; • **Social and professional topics** → **Gender**.

KEYWORDS

Social VR, Collaboration, Gender, Communication, Avatar's Gender

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1 INTRODUCTION

Virtual Reality (VR) is a promising medium for collaboration, as it supports presence and social presence similar to face-to-face interactions [24], and provides a medium for performing unrealistic tasks in real life. Users behavior in the virtual environments (VE) conforms to the social norms associated with their avatar appearance (e.g. gender) regardless of their actual appearance. For example, female avatars expressed more emotions through their texts independent of the participant's physical gender [16]. Similarly, users embodying taller avatars show more confidence and assertiveness in their behavior [16]. Moreover, Lehdonvirta et al. supported nonverbal cues in collaborative environments to encourage men to seek help [11]. Gender Role Theory also confirms that gender influences an individual's behavior within a community [6]. However, the effect of gender on the user experience in VR platforms is often analyzed only as a co-variant (see literature review [15]). The behavioral changes associated with the avatar's gender is a design opportunity to enrich the collaborative experience and lift gender stereotypes. Therefore, **we examine** the effect of the *avatar's gender* on the quality of collaborative interactions while performing social nonverbal tasks in immersive VEs. Our work specifically evaluates the impact of a *partner's avatar gender* on the collaboration quality in a gendered environment. To attain this goal, we (1) designed a male-dominant collaborative environment, virtual car garage, where two participants collaborate on repairing a car, and (2) conducted a within-subject user study (N=16, 8 pairs) to measure the impact of the partner's gender on the collaborative behavior in the virtual environment (VE). We investigated two conditions by changing the partner's avatar's gender to match the participant's self-reported gender (*C1*), or mismatch it (*C2*) while performing five nonverbal tasks in a virtual garage. Since female interviewees in prior work reported gender biases while applying for positions in the automotive field [12], we chose the theme of virtual car workshops to properly gauge the effect of the partner's avatar gender in collaborative virtual environments, especially ones with a gendered nature. We ensured that pairs did not meet physically before the experiment. Each participant saw their own avatar matching their self-reported gender while performing the task in both conditions *C1* and *C2*. Our results reveal that participants perceived the interactions to be more productive and supportive when their partner's avatar gender matched theirs. Since the pairs did not meet in real life, they perceive their partner's gender from the partner's avatar gender. Therefore, these results are held independently from the physical gender of the partner. We believe that our work could aid designers in maximizing throughput and collaboration in virtual environments focused on building and repairing tasks. It could also inspire other researchers to investigate the impact and the ethical implications of gender alteration in VR within different tasks (e.g. content creation VS. practical tasks) and contexts, especially gendered ones.

2 BACKGROUND AND RELATED WORK

Gender differences were proven to influence social interactions and behaviors [3]. Therefore, researchers explored the influence of these gender differences on general social behavior in various mediums and setups (e.g. real world and virtual world). Consequently, we targeted the social psychology and virtual reality literature to (1) shed the light on the Gender Role theory in order to properly gauge the effect of gender in different social VR setups, (2) examine the effect of avatar gender on social behavior in virtual communities, (3) identify the research gap which our study adds to, (4) state our research question to fill the identified research gap, and (5) state the definition of the study terms used through our study design.

2.1 Study Terms

Within this manuscript, we use the term *real gender* to refer to the self-reported gender of the participant prior to starting the study. In contrast, we use the term *virtual gender* to refer to the avatar gender of the participant. Following the convention adopted in related work, we use *male* to denote the features of a man that conforms to the cultural norms of the study place, meanwhile, we use *female* to refer that of a woman.

2.2 Gender Role Theory

As a term, gender is used to denote the non biological differences between the sexes [6]. Theorists believe that such differences vary according to societal norms and expectations [6]. Therefore, gender differences are socially constructed [29]. Psychologists state that gender roles are formed at a young age according to social structure and expectations [6]. For instance, women are believed to act as care takers, meanwhile men act as providers [29]. These roles are believed to influence an individual's behavior within a community [4, 6] and their career choices [7]. For instance, Mckinsey Global Institute conducted a study in 2017 across 10 countries, covering 4 continent, that investigated gender differences in current work occupations and sectors [13]. Their work revealed that the fields of manufacturing, especially the machine operator and craft worker sector, are considered as male-dominated fields. Following the same pattern, Leonard et al. [12] investigated the career making factors that influenced females to choose automotive career. In their study, female participants reported difficulties and gender biases during job interviews for automotive related positions, as automotive field is a male-dominant one. These reports are in accord with Eagly et al.'s findings [7], as their work showed women leaned toward communal career choices(e.g. social worker, nurse), while men preferred more agentic choices (e.g. construction, engineering). On another note, Diekman et al. [4] examined the gender differences' influence on prosocial behavior. Their work concludes that the gender-related differences observed in giving and receiving help stem from the social expectations. For instance, females are expected to be caregivers. Therefore, they provide help in activities that require long-term care, such as teaching or nursing. However, males are expected to be providers. Therefore, they give help in activities involving physical risk and chivalry. Following the same line, Diekman et al. [5] predicted that social roles change with respect to time and several societal factors. For instance, when women joined the labor force, they started to acquire more masculine qualities, such as independence. Similarly, men gained more feminine qualities upon providing more help in the household, which leads to the emergence of gender sub-groups. Athenstaedt et al. [1] examined the effect of self-categorizing to gender groups on the gender role self-concept. Their findings reveal that categorizing self to a gender

sub-group highly influences the self behavior, the characteristics, as well as their gender role self-concept. For instance, women who categorize themselves to the class of "House Wife" perceive themselves more feminine than women that belong to "Business Woman" class. Moreover, people conform to the characteristics of a role, once categorized to it. For instance, "Business Women" conform to the characteristics of their role through exhibiting more independence and intellect than women in other female-subgroups. Consequently, gender is often perceived as the spectrum that encompass femininity and masculinity aspects of the human personality [18]. In conclusion, gender roles, stereotypes, and social expectations elicit gender-based behavioral differences that are observed in various contexts, such as communication [8] and collaboration [27]. Consequently, in the following subsections, we will highlight the gender differences in each of the aforementioned contexts.

2.3 Impact of Avatar Gender in Virtual Environments

Although gender equivocation is exhibited more commonly with women than men [16], women are more inclined to choose gender matching avatars than men in virtual environments, namely League of Legends [19]. Moreover, avatar gender is believed to highly influence the language adopted in text-based virtual environments. For instance, users represented by female avatars expressed more emotions through their texts regardless of their real gender [16]. This implies that participants conform to the norms of their virtual identity, regardless of their normal one. Along the same line, Ratan et al. [18] conducted a study to examine the effect of avatar appearance on group satisfaction. They show that avatars positively expressing one's identity correlate to group satisfaction. Lehdonvirta et al. investigated the effect of avatar gender on giving and receiving help in virtual environments [11]. They reported that men are less likely to seek help than women, as they are perceived as problem solvers. As a result, men prefer indirect help-seeking methods (e.g. nonverbal cues). Moreover, when men were represented with female avatars, they overcame their help-seeking inhibitions. Consequently, designers are advised to either support non-verbal cues or swap the avatar gender of men in order to enhance the quality of collaborative platforms [11]. Following the same pattern, Zhang et al. [28] examined the effect of avatar gender and age on help-seeking behavior in Second Life, a virtual platform. They concluded that no differences were observed in the help-seeking pattern between male and female avatars. However, interactions within same gender groups (male-male, female-female) exhibited more centrality than that exhibited in mixed gender groups (female-male), which implies that some members had more authority over the others in same gender groups. In conclusion, users behavior in the VE conforms to the norms mandated by the avatar appearance, especially gender.

2.4 Impact of Avatar Gender Body-Swap Illusion on Behavior in Virtual Environments

Avatar appearance alters the behavior of participants in virtual environments. For instance, users embodying taller avatars show more confidence and assertiveness in their behavior [16]. Moreover, participants represented by different race avatar (e.g. light-skinned participant inhabiting dark-skinned avatar) reduced racial bias [2]. Avatar gender also alters behavior and lift gender stereotypes [17]. For example, Lee et al. examined the effect of avatar gender on users' performance in solving arithmetic tasks in a cooperative and competitive setting [10]. Their findings reveal that male avatar showed the strongest performance, regardless of their real gender, even when outnumbered by two female avatars in both settings. Moreover, they conclude that gender related stereotype threats were absent in the study [10], as the performance of female avatar remained unaffected throughout the experiment and was not significantly worse than the male avatar performance. Kaye et al. [9] confirmed this notion by investigating the effect of negative stereotypes on females performance in casual gaming activities. Peck et al. [17] investigated the effect of avatar gender swap illusion on gender stereotype threat within an immersive VR setting. They conducted a between-subject study with 2 independent variables, avatar gender (male, female) and stereotype threat (present, not present). They concluded that females that embody same gender avatar exhibit working memory load in the stereotype threat condition. On the other hand, females that embodied a male avatar during the threat condition showed no working memory load. This implies that avatar gender swapping establish stereotype lift. Similarly, Martey et al. [14] examined the effect of avatar gender switching and gender role on user chat, movement, and appearance within online gaming platforms. They concluded that avatar attractiveness and appearance is associated more with the avatar gender than the real gender. Moreover, they reported that gender role had no influence on avatar appearance. On the other hand, participants reported significantly high eeriness rates and negative feelings (e.g. disgust, discomfort) while embodying a different gender hand (e.g. female participant embodying a masculine hand)[23]. These findings imply that the effect of virtual identity surpassed that of the real one, especially in embodied virtual environments. Moreover, explicit avatar gender swap is beneficial in case of stereotype threat is salient to the participants.

2.5 Research Gap and Question

Prior work (1) observed the effect of embodying an avatar with a different gender than that of the participant on presence within VR (e.g. [23]) and help-seeking behavior within non-immersive platforms (e.g. [28]), and (2) examined the effect of team's gender composition on overall team satisfaction and performance in virtual environments (e.g. [20, 22]). However, our work observes the effect of changing the *partner's virtual gender* in the VE on *collaboration quality in a gendered immersive virtual environment*. Therefore, we conducted a within-subject study to answer our research question: How does the partner's virtual gender influence uniting efforts to solve a collaborative task?

3 STUDY DESIGN

The *aim* of our study is to investigate the impact of the partner's avatar representation, specifically gender, on the collaboration quality in virtual environments. To achieve this goal, we designed a *within-subject* study where we invited pairs to collaborate on non-verbal tasks regarding fixing cars in a virtual garage. We changed

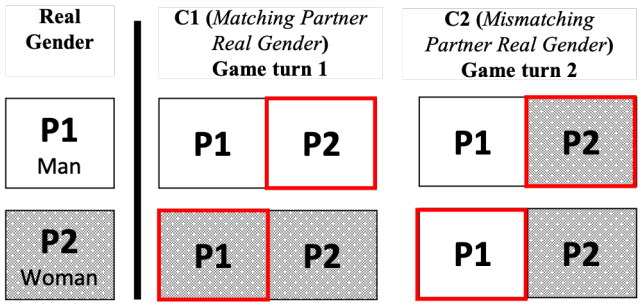

Figure 2: An exemplary depiction of the avatar pair gender composition from the perspective of both participants, P1 (gender= male) and P2 (gender= female). Solid white represents the male gender while grey dots represent the female gender. Within the same game turn during the matching gender condition (C1), P1 would see P2 as a male avatar (swapped gender) while P2 would see P1 as a female avatar (swapped gender). In the mismatching condition (C2), the partner's avatar gender would not match that of the participant's, resulting in a male-female avatar pairing. Each pair performed the task in both conditions (C1) and (C2). The two game turns along with filling the proper surveys and questionnaires took 17-25 minutes.

the *partner's virtual gender* while performing the tasks. We had two conditions:

Matching-gender (C1) the partner's virtual gender *matched* the real gender of the participant. For example, a female participant would see a female virtual partner regardless the real gender of the virtual partner.

Mismatching-gender (C2) the partner's virtual gender *mismatched* the real gender of the participant. For example, a female participant would see a male virtual partner regardless the real gender of the virtual partner.

After obtaining the institution's approval to conduct the study, we prepared two separate rooms to ensure that both pairs did not physically meet. Thus, each participant believes they had a different partner for every condition (C1 and C2). The participant always virtually viewed themselves from a first person perspective. Therefore, each participant saw their own avatar matching their self-reported gender while performing the task in both conditions *C1* and *C2*. Consequently, each participant within the environment perceived the pair gender composition differently, as shown in Figure 2. All the avatar pairs were perceived as male-female pairs in the mismatching gender condition (C2). We also randomized and balanced the order of the conditions. Verbal communication was not supported in our design and participants communicated via gestures to avoid mismatch in voice and avatar appearance.

3.1 Procedure

We recruited 16 university students (8 females and 8 males) through university mailing list and word-of-mouth. They were paired as follows: 2 male-male pairs, 2 female-female pairs, and 4 female-male pairs. The gender pairings stated are the self-reported gender by the participant him(her)self (i.e. the real gender). Their ages lie between 18 and 28 years old (mean = 21.17 years, SD = 2.33). They were compensated with snacks and chocolates. It was a prerequisite that participants would not physically meet before the study to minimize the bias. Each participant was greeted individually and was shown to a separate room once they arrived. Thus, pairs did not physically meet. Afterwards, the participants were handed a consent form that discussed (1) the nature of the study, (2) the type of data that will be collected, and (3) the acquisition of video and image footage of the experiment session. Moreover, participants had the freedom to withdraw from the experiment. However, no such case occurred. Afterwards, participants were individually given an ethnographic survey, in which they were asked to specify where they identified themselves on the spectrum of gender and sexuality. The survey was designed under the HCI Guidelines for Gender Equity and Inclusion [21]. The participants were asked to fill the form in an environment they felt safe in. Thereafter, participants were introduced to the apparatus and shown how to interact with it and the device was calibrated to the participant's height. The gender of the participant's avatar was selected based on self-reports in the earlier ethnographic survey. Afterwards, each pair performed the five nonverbal tasks, (1) changing tires twice , (2) replacing batteries once, and (3) changing the car's color twice, in each condition C1 and C2 (2 rounds), where the order of the conditions was randomized and balanced. After each round, participants filled the collaboration questionnaire. The whole session lasted between 17-25 minutes.

3.2 Apparatus

To investigate our research question, we built "Rolling My Ride", a multiplayer VR simulation game of a car workshop, where two players collaborate on repairing cars. The game starts with the players getting familiar with the workshop space. On one side of the workshop, there is an interactive shelf that would change its content based on the needs of the players. The player changes the content within the shelf by pressing on buttons next to the shelf. Each button corresponds to specific spare parts for the car. On the other side of the workshop, there is the Color Sphere, which is a small ball that changes its color based on the car owner's preferences. Players can grab the ball and throw it at the car to change its color. Finally, there is a button to get in the next car once both players are done with the current car. The game starts with a car entering the garage. Each car has an indication of what needs to be changed. The changes could be: (1) changing tires which is done by marking the flat tires with a white material, (2) replacing batteries, or (3) changing the car's color. The players were asked to do all the above mentioned tasks together. The space is designed in a way that encourages collaboration between players. For instance, in the tire change task, one player would be close to the shelf of the new tires, meanwhile the other player would be closer to the flat tire that requires replacement. Therefore, the player closest to the shelf is encouraged to pass the new tire to the player standing near the flat one.

3.3 Implementation

In our setup three aspects were considered: (1) the game implementation, (2) scene rendering for both players, (3) tracking the user's

gestures and posture. The first aspect, the game, was implemented using Unity engine. HTC Vive headsets were used as the scene rendering tool for the participants. The participants were represented via fullbody avatars (first person perspective) and interacted with the virtual environment using the Vive controllers to grab different objects placed inside the car garage. As for the body tracking, Microsoft Kinect version 2.0 was utilized. Players' movements were streamed to the unity engine and rendered accordingly to the participant in real time. Since the game is collaborative, Mirror[1] was used to relay the scene changes data over the network in order to be rendered for the other participants. Therefore, our experiment setup consisted of 2 Windows 10 PCs, 2 Microsoft Kinect version 2.0, and 2 HTC Vive sets and 4 Vive controllers. Each set of devices was in a separate room connected over a local network. We observed technological limitations while utilizing the Kinect version 2. The tracking quality deteriorates when the users are not facing the Kinect. Therefore, we mandated that users have to always face the Kinect to avoid disrupting the tracking.

4 ANALYSIS AND RESULTS

We used the **Collaboration Questionnaire** to answer our research question. The questionnaire questions (5-point likert scale) are part of the Team Effectiveness Questionnaire (TEQ) [25] and was answered after each round. Afterwards, Wilcoxon test was conducted to analyze the questionnaire results shown in Figure 3.

How does the partner's virtual gender influence uniting efforts to solve a collaborative task? The results show that displaying high levels of cooperation and mutual support was significantly higher in that matching condition ($C1$) ($M = 4.63, SD = 0.62$), than the mismatching condition ($M = 4, SD = 1.09$), $Z = 1.72, W = 14, r = 0.52, f = 0.79, p < 0.05$. Similarly, the collaboration was perceived more productive, worthwhile, and yielding good results in the matching condition ($C1$) ($M = 4.5, SD = 0.52$) than the mismatching condition ($C2$) ($M = 3.69, SD = 1.25$), $Z = 2.35, W = 42.5, r = 0.78, f = 0.94, p < 0.05$. However, no significance was observed between the matching ($C1$) and mismatching ($C2$) conditions regarding (1) participants' understanding their roles, ($Z = 1.43, W = 28, r = 0.51, f = 0.78, p = 0.08$), (2) reporting that issues were addressed and resolved quickly, ($Z = -0.42, W = 28, r = 0.13, f = 0.42, p = 0.33$), (3) participant sense of accomplishment towards the task, ($Z = 1.04, W = 20, r = 0.39, f = 0.71, p = 0.14$), (4) participants' understanding their partners' roles, ($Z = 0.92, W = 30.5, r = 0.31, f = 0.68, p = 0.17$), and (5) taking initiative, ($Z = 0.52, W = 33, r = 0.17, f = 0.6, p = 0.3$). These results imply that matching virtual gender groups perceived their collaboration to be more productive and supportive.

5 DISCUSSION

5.1 Same virtual gender teams were more *productive* and *supportive*

In contrast to prior work [20, 26], participants reported that interactions with the same virtual gender were significantly more *productive*, *supportive* and their overall collaboration *yielded good results*. However, we hypothesize that the difference in findings is

[1] A package for networking in Unity.

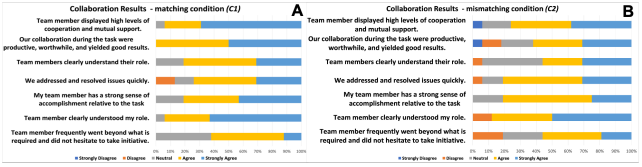

Figure 3: Collaboration Questionnaire Results. Wilcoxon Test was administered on these results to detect the differences between matching gender condition *(C1)* and mismatching gender condition *(C2)*. A and B: show the results of the collaboration questionnaire for both conditions, (*C1*) and (*C2*) respectively.

related to the medium utilized, as Richert et al. utilized tabletop in real world, meanwhile, Vasilescu et al. conducted the study on online collaborative coding platform (Github). Furthermore, prior work reported that gender influences the collaboration style. For example, males tend to demonstrate their ideas and then consult with their peers [27] or work individually [20]. On the other hand, females have stronger sense of collaboration [27]. Our task in the study was a practical and a male-dominated task, fixing a car in a virtual garage, meanwhile tasks in prior work required content creation, interior design [20] and story creation [27], which are not perceived as naturally gendered tasks. Accordingly, matching avatar gender elicit effective and supportive collaborations in environments that entail practical work or perceived as an inherently gendered environment. This requires further investigation, especially the ethical implications pertaining this finding.

5.2 Virtual gender surpasses the impact of the real gender on collaboration quality

Participants were neither aware of the real gender of their partner, nor that it was the same partner, as they were in separate locations. However, their interactions were natural in the virtual environment, even with the swapped virtual gender. This finding is in accord with that reported by Buck et al. and Lehdonvirta et al. [3, 11], as the avatar's gender did not always match that of the partner in some of their configurations. This suggests that we can decouple the virtual and the real gender of the partner to maximize the collaboration quality within virtual environments. It is also possible to explore using this design decision, along with its ethical implications, to elicit particular collaboration patterns or overcome existing gender biases.

6 CONCLUSION

Since gender influences user's behavior in collaborative virtual environments [15], we investigate the effect of the partner's avatar gender on collaboration quality while performing a male-dominated task. Consequently, we conducted a within-subject user study (N = 16) to observe the effect of the partner's avatar gender on collaboration quality. Our findings show that matching virtual gender teams (C1) were significantly perceived as more productive and supportive. Moreover, we observed a dominant effect of the virtual (avatar) gender over that of the real gender in collaborative VEs. We believe that our work could be used in team building activities and

training, as productivity is affected by not only the team gender composition, but also the nature of the activity. We envision that our work will aid designers in creating higher quality collaborative virtual experiences that maximizes throughput and group cohesion.

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