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# Understanding the Importance of Presenting Facial Expressions of an Avatar in Virtual Reality

Kyulee Kim[1], Hwayeon Joh[2], Yeojin Kim[3], Sohyeon Park[4], Uran Oh[†]

*[1,2,3,4]Master Student, Department of Computer Science and Engineering, Ewha Womans University, Seoul, Korea*
*[†]Assistant Professor, Department of Computer Science and Engineering, Ewha Womans University, Seoul, Korea*
*[1]kl.kim@ewhain.net, [2]e.jhy@ewhain.net, [3]rowenna03@ewhain.net, [4]shpark911@ewhain.net, [†]uran.oh@ewha.ac.kr*

***Abstract***

*While online social interactions have been more prevalent with the increased popularity of Metaverse platforms, little has been studied the effects of facial expressions in virtual reality (VR), which is known to play a key role in social contexts. To understand the importance of presenting facial expressions of a virtual avatar under different contexts, we conducted a user study with 24 participants where they were asked to have a conversation and play a charades game with an avatar with and without facial expressions. The results show that participants tend to gaze at the face region for the majority of the time when having a conversation or trying to guess emotion-related keywords when playing charades regardless of the presence of facial expressions. Yet, we confirmed that participants prefer to see facial expressions in virtual reality as well as in real-world scenarios as it helps them to better understand the contexts and to have more immersive and focused experiences.*

***Keywords:*** *Virtual reality, facial expressions, eye tracking, lip tracking*

## 1. INTRODUCTION

There has been a growing body of research that explores the metaverse, which is a virtual-reality space in which users can interact with a computer-generated environment and other users (see [1] for a review). To simulate avatars in the metaverse as realistically as possible, various technologies have been developed such as motion tracking [2] and facial expression data [3, 4]. However, most of the communication means still rely on textual (*e.g.,* text messages) or oral communications (*e.g.,* voice chat) without presenting facial expressions, which is known to play an essential role in a social context for understanding intentions [5, 6] and conveying information successfully [7]. To better understand the effects of facial expressions of avatars in VR, various studies were conducted [8, 9, 10, 11]. However, there were no direct comparisons to judge the effectiveness of facial expressions alone as they involved other factors (*i.e.,* dimensionality, exposed body area) in a single

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Corresponding Author: uran.oh@ewha.ac.kr
Tel: +82-2-3277-6896
Assistant Professor, Department of Computer Science and Engineering, Ewha Womans University, Seoul, Korea

scenario [9, 10, 11]. To explore the effects of facial expressions of an avatar in VR in various contexts, we conducted a user study with 24 participants where they are asked to have a conversation (Task1), and play charades (Task2) with a virtual avatar with and without facial expressions as shown in Figure 1. As a result, our gaze analysis showed that participants tend to look at the avatar's face more often when having a conversation or trying to guess emotion-related keywords than activity-related keywords when playing charades regardless of the presence of facial expressions. Still, we found that participants prefer having facial expressions because they feel like they can understand the context (*e.g.,* the opponents' feelings, intentions), and the experience is more immersive as it is more similar to interacting with an actual human. Moreover, participants reported that facial expressions help them to focus more on the task, especially during conversations as they were not sure if the opponent was listening when facial expressions were absent. The contributions of our work are: (1) empirical analysis of the importance of presenting the facial expression of a virtual avatar in different contexts, and (2) subjective assessment for designing a virtual avatar with facial expressions in a social context.

## 2. RELATED WORK

Facial expressions play an important role in communication. In fact, it is a part of communication. According to Frith *et al.* [5], ostensive gestures such as eyebrow flashing can be used as a signal for one's intent for starting a conversation. Also, expressions such as furrowing in the center of the eyebrows and relaxed eyebrows are used to inform that one feels empathy towards another [5, 12]. In addition, Ishii *et al.* [7] discovered that facial expressions are crucial for people to have successful social interactions as these serve as nonverbal cues containing important information about not only the emotion but one's identity, race, and health status. Moreover, Marian *et al.* [6] showed that dynamic changes in facial expressions in social-emotional communication are critical when capturing contextual information. The relationship between facial expression and communication can be explained by Mirror neurons discovered by Rizzolatti *et al.* [13]. These neurons which get activated when observing the movements of someone else or making certain movements are considered to be used when understanding the behavior of others. This led to a better interpretation of facial expressions which is essential for understanding social context [14].

Reflecting the importance of conveying facial expressions in social interactions, there has been research on utilizing the facial expressions of an avatar for a VR environment. Hart *et al.*, for instance, [10] investigated if having an avatar's facial expressions improves social VR experiences while playing cooperative games. Furthermore, Oh *et al.* [11] found that participants used more positive words and felt more intimacy with the avatar that smiled more often. In addition, Rugiero *et al.* [15] assessed the impact of facial expressions on social interaction in a VR environment, and found that participants tend to stay closer to the avatar with a happy face than with an angry face. While inspiring, these studies did not differentiate the impact of visualizing the opponent in a different form from presenting facial expressions, and their context is limited to a certain task. Thus, we conducted a user study to make direct comparisons to assess the impact of facial expressions under various contexts.

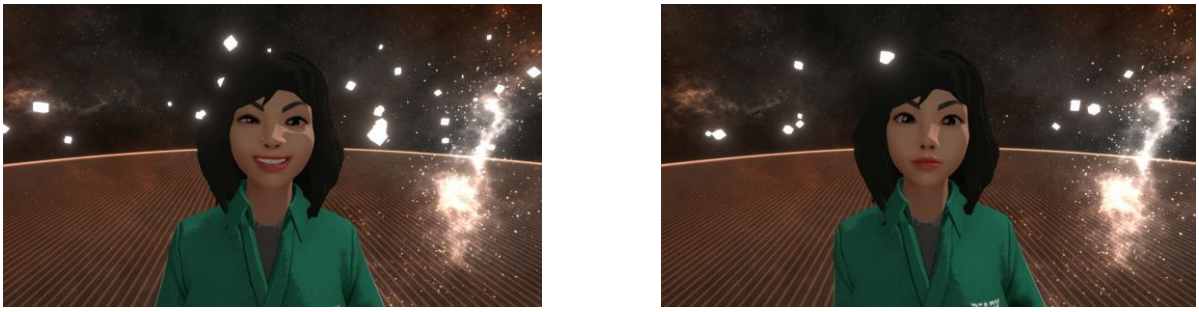
## 3. METHOD

To understand the effects of displaying the facial expressions of an avatar in VR and how it differs in various contexts, we designed a single-session user study with two tasks. The first one was a conversation task (Task1) as various nonverbal elements such as tone and expression including facial expressions play an important role during verbal communications unlike those conveyed in the text [16]. The second task (Task2) is charades, a quiz game where a person has to guess a specific keyword expressed by another person using only gestures and

facial expressions, which we expect to see a difference depending on the topic and presence of facial expressions as in conversations.

### 3.1 Participants

We recruited 24 participants (6 male, 18 female). Their average age was 25.9 ($SD$ = 3.3) and all had little experience with VR; played VR games only a couple of times.



**(a) Expressive condition** **(b) Non-expressive condition**

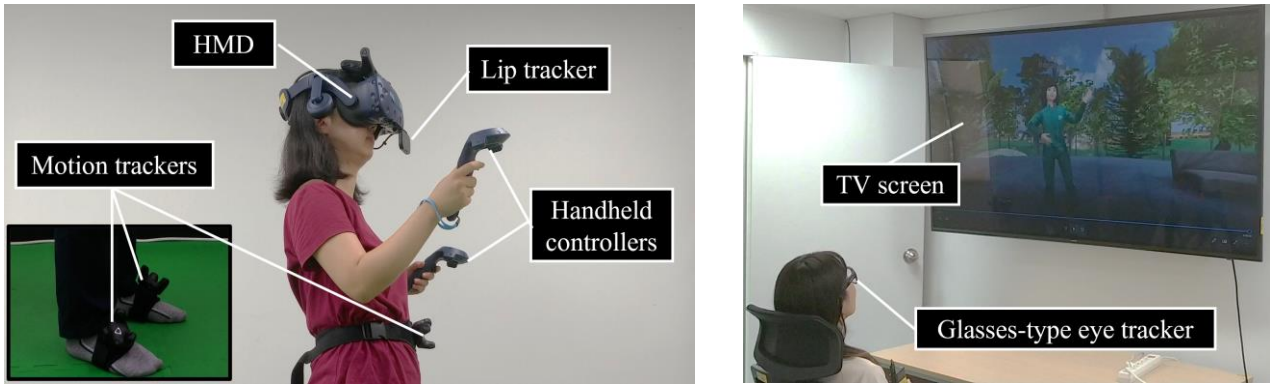
**Figure. 1. Screenshot examples of two conditions during a conversation in Task1: (a) expressive condition where the facial expression of the avatar changes dynamically, and (b) non-expressive condition where the avatar shows no facial expressions.**

### 3.2 Conditions

As shown in Figure 1, we had two conditions (1) expressive condition where a human avatar displayed on the screen had various facial expressions that changed dynamically and (2) non-expressive condition where the avatar had a consistent neutral facial expression while a participant is performing a task in VR.

### 3. 3 Apparatus

During the study, participants were seated in a room in front of a 75-inch TV screen with a resolution of 3840 × 2160 as shown in Figure 2b. To collect eye gaze data, we asked all participants to wear Tobii Pro Glasses 3. As for the conversation task (Task1), the facilitator wore a HTC Vive Pro Eye, a VR Head-mounted display (HMD) with a Vive facial tracker, to mirror the facilitator's facial expressions to the avatar displayed on the screen. The facilitator was in another room next to the participants' so that they can listen to each other's voices while communicating. As for the charades task (Task2), we played pre-recorded videos for each keyword on the screen. The videos show an avatar expressing each keyword with body gestures with and without facial expression, which was acted by one of the researchers while wearing the same HMD device with hand-held controllers and motion trackers (see Figure 2a). For the non-expressive condition for both tasks, we used a sticky note to block the facial tracker from sensing the facial expression. Throughout the study, we used a virtual environment program, Neos VR and used a young Asian female character that is visually similar to the facilitator as shown in Figure 1, considering that a high level of resemblance between an avatar and the user led to positive attitudes [17], The CPU of the computer used in both tasks was AMD Ryzen 71700 Eight-Core Processor 3.00 GHz with a graphics card of NVIDIA GeForce RTX 2080. For video recordings, we used an Intel Xeon Bronze 3106 CPU, 64 GB RAM and NVIDIA Quadro P40000 graphic card.




**(a) A facilitator's side** **(b) A participant's side**

**Figure. 2. Experiment environment: (a) a facilitator wearing HMD with facial tracker while holding hand-held controllers and wearing motion trackers on her waist and feet, (b) a participant wearing glasses-type eye tracker and staring at a TV screen.**

### 3. 4 Procedure

The study began by signing a consent form after a brief introduction of the study. We then explained Tobii Pro Glasses 3 and asked them to put the glasses on for calibration. All participants were asked to perform Task1 followed by Task2 wearing the glasses and gazing TV screen. Subjective ratings were collected at the very end of the study after completing both tasks.

#### 3.4.1 Task 1 : Conversation

In this task, participants were asked to have a real-time conversation with a facilitator while looking at the avatar displayed on the screen as if they are talking with the avatar. During the conversation, they were given nine ice-breaking questions (*e.g.*, "If you could go back and visit any time period, what time would you travel to and why?"). These questions include one practice question, which was given under expressive conditions where the avatar's facial expression changes dynamically. Then half of the participants answered the first four questions under expressive conditions, and the rest four under non-expressive conditions, while the order was the opposite for the other half. The duration of this task was set to 15 minutes.

#### 3.4.2 Task 2 : Charades

As depicted in Table 1, participants were asked to guess 12 keywords by watching 5-second long pre-recorded videos of an avatar expressing each keyword using body gestures with and without facial expressions. Of 12, 6 keywords related to physical activities 4 were presented first followed by the remaining 6 emotion types from Plutchik's Wheel of Emotion [18]. While there was no time limit, the video was played only once, participants were allowed to make three guesses, and watch the video once more if requested for each keyword. They have informed the keyword category before watching the video as a hint. Similar to Task1, the half of the keywords for each category were displayed under expressive conditions first, and the order was opposite for the remaining half.

**Table 1. Twelve keywords for charades were selected from the two categories: (1) activity including exercise and playing musical instruments, and (2) emotion.**

| Category | Keywords |
|---|---|
| Activity | Running, Playing Basketball, Playing Drums, Playing Guitar, Waking Up, Drinking Water |
| Emotion | Surprise, Joy, Anger, Sadness, Disgust, Fear |

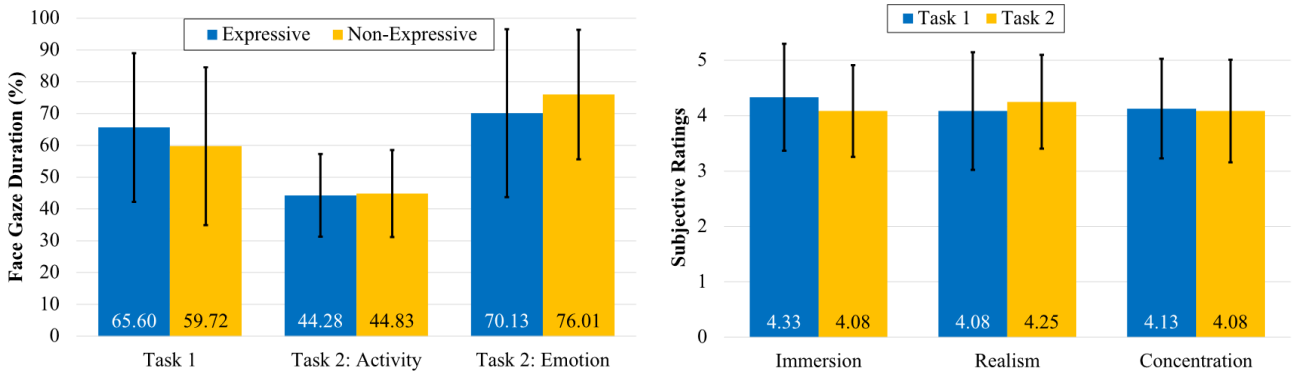
### 3. 5 Data and Analysis

For both tasks, we collected video recordings of gaze data using Tobii Pro Glasses 3 and used Tobii Pro Lab for analyzing the data in terms of the relative duration for gazing at the face region over total duration; note that we used the relative duration as the total duration differs from one participant to another. For Task1, we had 20 data for the analysis as four recordings had poor gaze recognition results ($N$ = 2), a brightness issue ($N$ = 1), and an unknown issue ($N$ = 1). For Task2, we used 21 data out of 24, three data are excluded because they could not be analyzed with Tobii Pro Lab properly. The reasons for excluded videos were poor gaze recognition calculated by Tobii Pro Lab ($N$ = 2) and brightness issue ($N$ = 1). In addition to the faze gaze duration, we collected 5-point subjective ratings in terms of immersion, realism, and concentration when facial expressions are present. As for the analysis, we conducted two-way ANOVA to check for an interaction effect between two factors when applicable, and pairwise t-tests for two independent samples as a posthoc analysis for face gaze duration. Friedman tests and Mann-Whitney U tests were used for ordinal data.

## 4. FINDINGS

### 4. 1 Face Gaze Duration

To understand if participants pay more attention to the avatar's face when facial expressions are present, and if the level of attention is different depending on the context, we assessed the percentage of the time taken for gazing at the avatar's face region relative to the total duration. As shown in Figure 3a, all participants stared at the face region for the majority of the time when having a conversation (Task1) or when guessing emotion-related keywords during charades regardless of the presence of facial expressions. Indeed, while there was no statistical difference between expressive and non-expressive conditions, the percentage of face gazing duration was significantly different depending on the contexts. Participants spent less time gazing at the face region when guessing activity-related keywords than emotion-related keywords during charades ($t$ = -5.13, $p$ < .001) in Task2 and during a conversation in Task1 ($t$ = -3.31, $p$ = .001).




**(a) Face gaze duration (%)** **b) Subjective ratings (1-5; 5 is the best)**

**Figure. 3. The participants' average (a) face gaze duration, and (b) 5-point subjective ratings in terms of immersion, realism, and concentration. Error bars indicate standard deviation ($N$ = 24).**

### 4. 2 Subjective Ratings

At the end of each task, we collected subjective feedback including the perceived levels of immersion, realism, and concentration when facial expressions exist. Most of the participants rated 4 or higher for all

metrics regardless of the task type as shown in Figure 3b.

#### 4.2.1 Overall Feedback

When asked if participants prefer having facial expressions in virtual reality, all participants said 'yes' for both tasks except for P14 for the conversation task. In particular, six participants emphasized the importance of nonverbal expressions during conversations.

*" I think it is important to have a facial expression when talking to each other so that you can understand the other person's feelings and intentions when talking."* (P15)

*" I think one can have a more detailed and accurate communication with facial expressions because there is a big difference between frowning and smiling even when the tone is positive for both cases.*" (P10)

In addition, 17 out of 24 participants answered that facial expressions are more needed in the conversation task (Task1) than charades task (Task2) reflecting the face gaze duration results. They specified that they focused more on the body gestures than facial expressions. Still, 9 participants answered that facial expressions played an important role for emotion-related keywords because it is easy to recognize emotion with facial expressions.

#### 4.2.2 Immersion

Fourteen out of 24 participants mentioned that the level of immersion was stronger when facial expressions were present for Task1. For instance,

*" Even if you are talking to an avatar who is not a real person in a virtual environment, you have to have facial expressions to be more immersed and feel like you are having an actual conversation."* (P15)

On the other hand, only 8 participants stated that facial expressions were important for having an immersive experience in Task2. Yet, P9 specified that,

*"I feel like facial expressions make the game [charades] more immersive because I feel stronger engagement [compared to when there are no expressions]."* (P9)

#### 4.2.3 Realism

Eleven participants responded that the virtual environment seemed more similar to the real world under expressive conditions. Participants said that it did not feel like talking to a real person without facial expressions ($N$ = 3 for Task1, $N$ = 4 for Task2).

*" No matter how realistic the appearance or the movement is implemented in a virtual reality, it does not look like a real person if there is no [facial] expression, which is less realistic."* (P1)

In particular, three participants said that the unnaturalness of the avatar due to limited expressiveness makes facial expressions more important for getting additional information.

*" In charades, the gestures of the avatar didn't seem real compared to those performed by the actual humans. So it was helpful to understand the context by examining the details of the facial expressions."*(P6)

At the same time, P14, the only participant who prefers not to have facial experience during conversations, emphasized the importance of supporting realism as one can feel uncomfortable watching unrealistic facial expressions, which is known as an uncanny valley [19].

#### 4.2.4 Concentration

Four participants reported that it was easier to focus on the conversation and the charades game with facial expressions than without the expressions.

> *" It would be okay if it's a simple voice chat. But in a face-to-face scenario, I need facial expressions to focus more on the conversation."* (P19)

At the same time, five participants also mentioned that it is helpful to know if the partner is focusing on the conversation when facial expressions are present. P1 said that she did not feel like the avatar that she is talking to is actually listening to what she is saying when there was no facial expression.

## 5. DISCUSSION

### 5. 1 Facial Expressions for Understanding Context

While we did not find a significant impact of having facial expressions when interacting with a virtual avatar, our study showed that having facial expressions is preferred especially when having a conversation mainly because it can serve as a nonverbal cue for understanding the emotion and intention more accurately as found in a prior study [20, 21]. In addition, confirming the finding by Scott *et al.* [22] that people are more likely to stare at the actor's face when watching his monologue video than watching the actor making tea, our results show that participants also tend to watch the facial area more often during a conversation then guessing activity-related keywords in charades. This suggests that people the amount of attention paid to the face region differs depending on the task, and that people focus more on the face in a scenario like having a conversation or listening to one's talk (*e.g.*, recorded lecture). Still, regardless of the task, we recommend presenting facial expressions when understanding one's emotion is important as our face gaze duration results suggest.

### 5. 2 Facial Expressions for Immersive Experience

In our study, we found that facial expressions provide a sense of having a conversation with real people, which allowed participants to be more immersed in the situation. This reflects prior studies that social presence can be achieved by both nonverbal and verbal signals such as facial expressions [23], and a stronger sense of social presence can provide more immersive experience [24, 25, 26]. Although we were not able to assess the performance benefit of presenting facial expressions, we recommend supporting these in terms of immersion.

### 5. 3 Facial Expressions for Complementing Low Realism

Our findings show that a virtual avatar is perceived to be more realistic when facial expressions are conveyed. Thus, it is better to implement a photo-realistic representation of the visual appearance of an avatar with facial expressions is important. However, it is difficult to generate this level of realism in real time, and it may create an uncanny valley experience [19]. Fortunately, we show that there is a potential for using facial expressions to provide additional information to complement the missing gap especially when avatars look less realistic.

### 5. 4 Facial Expressions for Concentration

The findings imply that facial expressions can be used both ways in terms of concentration. To be specific,

participants felt that they paid more attention when facial expressions exist. At the same time, participants relied on the opponent's facial expression to monitor and confirm if the person is concentrating on the conversation. As we have seen in previous papers that emotions are correlated with concentration in educational contexts such as e-learning environments [27, 28], it would be interesting to conduct a study for investigating the effect of facial expressions for lecture videos focusing on how the expressions of the lecturer and the students improve the level of attention.

## 6. CONCLUSION

We conducted a user study with 24 participants to assess the importance of presenting the facial expressions of a virtual avatar under different contexts both quantitatively and qualitatively. As a result, we found that the portion of gazing at the face region is different depending on the tasks, and it is higher during a conversation or when trying to understand one's emotion. However, while we expect to have a longer face gaze duration with facial expressions that without the expression, we were not able to find a significant impact. Still, we confirmed that participants prefer having facial expressions of an avatar in virtual reality as in a reality to better understand the contexts such as one's intention and emotion, and to feel more immersed and focused.

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