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VRL: Development and experimental of embodied lecturer avatar using marker-based landmark-guided re-targeting deformation transfer

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Abstract
This study examines the re-targeting accuracy of landmark points on the embodied lecturer avatar mesh surface to determine the efficiency of the avatar's verbal and non-verbal cues deliverable in Virtual Remote Lecture (VRL). Employing embodied lecturer avatars with different anthropomorphic designs and nominal anonymity examines the efficiency of the deliverable social cues exchanged during communication. This study concludes that landmark points on real human faces cannot be matched entirely or mapped accurately on less visually anthropomorphic avatars. The findings reveal that high re-targeting accuracy on avatar improves pedagogical effectiveness, thus providing a promising education method beyond traditional in-person/online lectures.

Keywords: Virtual Remote Lecture (VRL), Anthropomorphic Embodied Avatar, Nominal Anonymity, Marker-Based Landmark-Guided Re-Targeting Deformation Transfer

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1.0 Introduction

In Malaysia, most students prefer remote lectures as their preferred learning method due to their flexibility and accessibility (Mohd Noor, 2024). Remote lectures conducted online enable synchronous online via video conferencing platforms such as Zoom or asynchronous via recorded lessons be utilized at the student's pace (Shlomo & Rosenberg-Kima, 2024). However, some studies question the effectiveness of remote lectures, arguing that they cannot match that of traditional face-to-face lectures. Face-to-face lectures are preferred over remote lectures for interactions with the educator and peers and for proximity to others (Png et al., 2024). However, students' attendance at remote lectures is much higher than their initial preference for face-to-face lectures (Shlomo & Rosenberg-Kima, 2024). Thus, these contradictions suggest that remote lectures should go beyond face-to-face and conventional online lectures by extending the possibilities of mediated communication technologies using an Avatar.

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This study proposes a novel method for utilizing an avatar in a remote lecture, Virtual Remote Lecture (VRL), in which one virtual lecturer is represented as an interactive anthropomorphic avatar with different visual fidelity design (i.e., anthropomorphism, truthfulness), integrated with deindividuation effect manipulation of nominal anonymity (i.e., pseudonym, orthonym). This method is unique to conventional remote lecturing in video-mediated communication, where it extends the possibilities of avatar-based technologies in avatar-mediated communication. Moreover, it is an utterly different approach from the existing use of avatar-based technologies in remote lectures, in that it focuses on visual fidelity, anthropomorphism, and truthfulness, along with manipulation of the deindividuation effect, rather than solely on the effect of fidelity realism in most papers (Weimann et al., 2022). Examining anthropomorphism and truthfulness fidelity on the avatar is crucial since realism alone is a bad predictor for the eeriness of the uncanny valley effect that produces rejection towards the avatar (Zell et al., 2015).

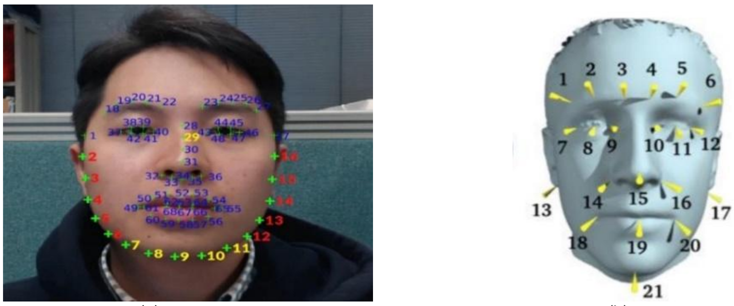
The concept of Virtual Remote Lecture in this study is a marker-based landmark-guided re-targeting deformation transfer method. The focus is on the re-targeting accuracy, which transfers a human user's facial expressions and gestures to an embodied avatar mesh (Onizuka et al., 2019). The avatar and the lecture slides will occupy the virtual background; therefore, to accommodate the available screen space, the lecture slides must be smaller.

The main contributions of this study are (1) To examine re-targeting accuracy of landmark-guided points based on the avatar's visual fidelity design of anthropomorphism and truthfulness with deindividuation effect manipulation, (2) To determine the efficiency of avatar's verbal and non-verbal cues deliverable / exchange for effective communication using the Virtual Remote Lecture, and (3) To verify the significant practical potential of pedagogical agent in remote learning. Examining the re-targeting accuracy of landmark-guided points on avatar is crucial, because it affects the efficiency of avatar's verbal and non-verbal cues deliverable which consequently affects the student engagement and instructor's social presence. The avatar's potential role as pedagogical agent and its human-centered outcomes varies depending on the type of visual fidelity design and the condition of the avatar.

2.0 Literature Review

2.1 Marker-Based Landmark-Guided Re-Targeting Deformation Transfer

Facial expressions are non-verbal cues that are considered the key features of human emotion that help to communicate information along with verbal cues (speech) (Lang et al., 2022). Therefore, they are the key to emotive virtual avatars. Re-targeting deformation transfer works in a way that it transfers the facial expressions of a human user to an avatar mesh based on a human's markers of generated landmark points. The human face provides a surface marker that generates landmark points as a reference to be used on the embodied avatars. However, each human and avatar has a different face structure, generating different surface information with varying landmark points. Matching the coordinates of a human's landmark points to the avatar's face would be challenging. Different faces generate different surface information with various numbers and coordinates of landmark points, thus affecting the re-targeting accuracy differently (Onizuka et al., 2019). Similarly, re-targeting accuracy can also be influenced by avatars with various anthropomorphic designs that visually exhibit multiple shapes and structures.

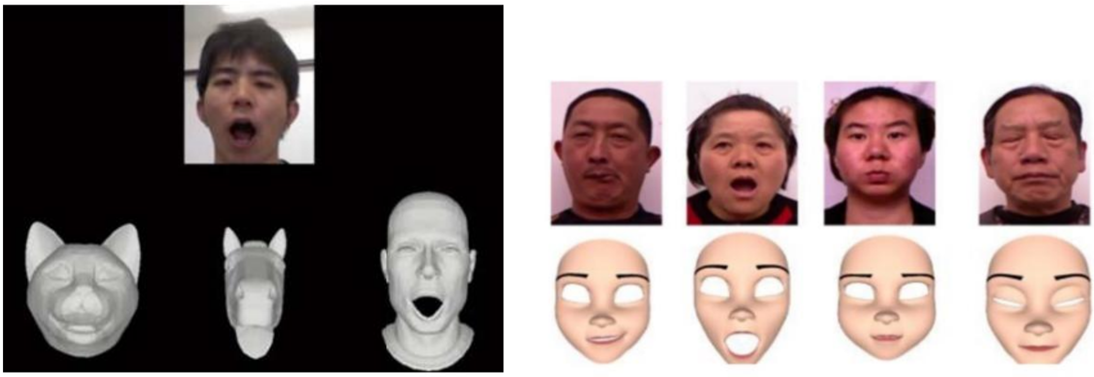


(a) (b)

Fig. 1. Landmark Points Generated: (a) Human face; (b) Avatar face.

(Source: Birla et al., 2022; Yin et al., 2024)

Landmark points reflect the characteristics and structures of various parts of a face. Facial landmark points are key points used to describe a face's structure. Some regions of the face or body with unique structures are selected subjectively as key landmarks. The key points are used to describe specific part of the face and body, such as one landmark point representing the nose tip, two eye corners with several points along it to represent the eyes, and two mouth corners with several points along it are used to represent the mouth, which provides a structured description of the face (Birla et al., 2022; Yin et al., 2024).



(a) (b)

Fig. 2. Re-Targeting Accuracy Results and Projection Resemblance Quality of Non-verbal Cues Facial Expressions: (a) Low anthropomorphism (non-humanoid avatar: animal) to high anthropomorphism (humanoid avatar: 3D human); (b) Cartoon-like Anthropomorphic Avatar.
(Source: Onizuka et al., 2019; Zhang et al., 2020)

Several studies validate the importance of re-targeting accuracy on the projection resemblance quality of non-verbal cues, facial expressions for effective information transmission in communication, in which a low anthropomorphic avatar (non-humanoid avatar: animal) produced lower re-targeting accuracy compared to a high anthropomorphic avatar (humanoid avatar: 3D human) (Onizuka et al., 2019; Zhang et al., 2020). It indicates that the landmark points on real human faces cannot be matched entirely or mapped accurately on a non-humanoid avatar's face, since the structure of an animal avatar generates landmark coordinates that are different from those of humans.

However, based on the mind perception hypothesis and violation of expectation hypothesis, some studies argue that even though less anthropomorphic humanoid-robot avatars produce weak visual resemblance to humans with projection quality of non-verbal cues that is much lower than humanoid avatars with high anthropomorphism fidelity, enhancing familiarity, understanding and social intelligence of the avatar through interaction, the acceptance, affinity and positive perception can be achieved on humanoid-robot avatar (Wahn et al., 2025). Therefore, this study provides new insights into the effect of re-targeting accuracy and tests the impact of deindividuation effect manipulation using avatars.

2.2 Agent or Avatar in Online Education

The number of social cues, which are verbal and non-verbal cues that can be exchanged and presented during communication or interaction, significantly affects the outcome of communication (Gratch, 2023). The interaction of verbal and non-verbal cues in online communication leads to better coordination and improved understanding of the communication, promoting engagement and eliciting trust, empathy, and enjoyment (Weir et al., 2025; Sun et al., 2025). To improve and achieve positive outcomes in communication, technological strategy that simulates and replicates face-to-face communication (FTFC) in an online environment should be implemented (Tobita & Tomisugi, 2025). A sense of connectedness is crucial for promoting positive communication outcomes and is positively correlated with the instructor's social presence (Conklin & Garrett Dikkers, 2021). In other words, interaction must be well facilitated or mediated remotely, regardless of the inability of the facilitator to be physically present or close in proximity.

A recent study by Seymour et al. (2021) revealed that a humanoid 3D avatar that can interact with humans elicited positive emotions from participants, with no revulsion, and was preferred over caricature avatars. Seymour et al. (2021) identified that humanoid 3D avatars could cross the uncanny valley and receive positive reactions from the audience due to two reasons which are (1) the avatar was utilised for interaction, and (2) the backstage controller was a human. Although Seymour et al. (2021) did not consider the effects of non-human avatars, this study also aims to include and examine humanoid-robot avatars with weak visual resemblance to humans, with implications for future agent or avatar research, based on feedback from students in the Virtual Remote Lecture.

3.0 Methodology and Implementation

3.1 System

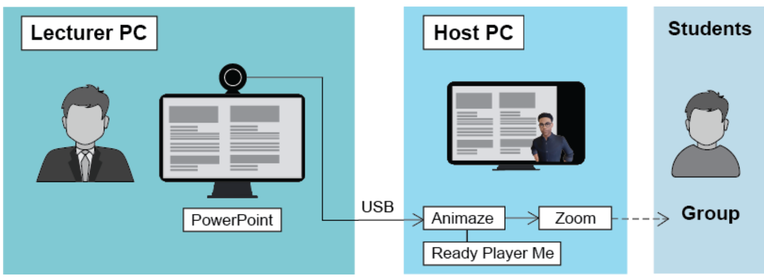


Fig. 3: Experimental system. The lecturer opens a PowerPoint slide on their PC and transfers the screen image to the host PC via USB. Additionally, one webcam captures the lecturer, and the captured images sequence are transferred to the host PC. Animaze then processes the webcam images sequence on the host PC into avatar images sequence. Finally, Zoom combines the Animaze outputs with the PowerPoint slides, and makes the outputs available to the students.
(Source: Author)

3.2 Overview
Figure 3 presents this study's experimental system, adapted from Amemiya (2022). Six Zoom meeting IDs are issued and provided to students in advance, depending on their assigned group. Sharing the same materials for each type of embodied lecturer and avatar for each Zoom meeting ID, the lecturer's PC screen output is transferred to the screen image and sent to the host PC via USB. The webcam captures the lecturer, and the resulting image sequence is fed into the host PC. At an equal distance between the lecturer's PC monitor and the lecturer, the webcam is correctly attached to the lecturer's PC monitor. In the host PC, the webcam image sequence of the lecturer is converted digitally and visualized into an interactive embodied lecturer avatar using Animaze. To make the outputs available to the students, Zoom combines the interactive embodied lecturer avatar and PowerPoint slides into a Virtual Remote Lecture.

3.3 Avatars
Animaze converts the lecturer's webcam image sequence into an avatar image sequence. The lecturer's gestures such as head tilting, eye tracking and facial expressions are tracked and transferred to an avatar mesh by re-targeting landmarks. The human face and body gestures provide surface information as markers that generate landmark points to reference the embodied avatars. As shown in Figure 4, six avatar conditions were developed for this study. Three types of avatars are used in the experiment: a 3D humanoid-robot avatar (3D-R), a 3D humanoid-human non-doppelganger avatar (3D-HN) and a 3D humanoid-human doppelganger avatar (3D-HD). These avatars are also involved in manipulating the avatar's nominal anonymity of pseudonym (P) and orthonym (O). A 3D humanoid-robot avatar is developed and manipulated using 3D authoring tools: Autodesk MAYA and Animaze Editor. For 3D humanoid-human doppelganger avatars and 3D humanoid-human non-doppelganger avatars, these avatars are developed and manipulated using Ready Player Me and Animaze Editor. The manipulation of nominal anonymity on these avatars is executed by displaying the avatars' names in Zoom using pseudonyms (fictitious names) and orthonyms (true names).

3.4 Experiment

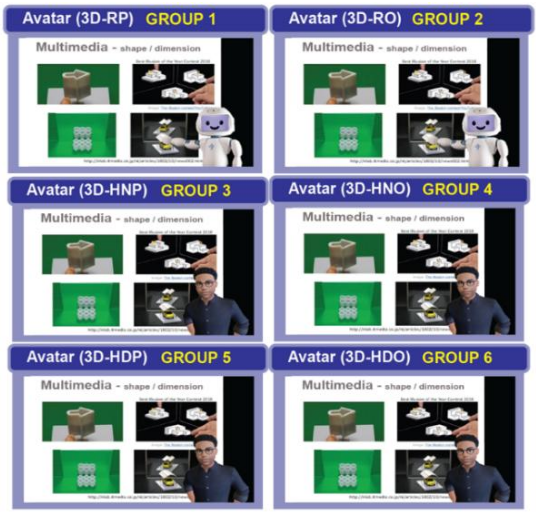


Fig. 4: Experimental design. The students are divided into six groups with avatar's nominal anonymity manipulation of pseudonym (P) and orthonym (O). Group 1 and 2 took a remote lecture from 3D humanoid-robot avatar (3D-R) with different nominal anonymity manipulation; Group 3 and 4 took remote lecture from 3D humanoid-human non-doppelganger avatar (3D-HN) with different nominal anonymity manipulation; Group 5 and 6 took remote lecture from 3D humanoid-human doppelganger avatar (3D-HD) with different nominal anonymity manipulation.

3.5 Design
The experiment uses a factorial design 3x2 (condition of visual anthropomorphism x manipulation of nominal anonymity), as shown in Figure 4. The independent variables are visual anthropomorphism and nominal anonymity, which are the between-participant variables. In this study, there are six groups with six different avatar conditions. For each avatar condition, a lecture is conducted in one session of 40 minutes. Each session consisted of approximately one topic and roughly the same length. The session conducted for the lecture is the within-participant variable. After the lecture session, the students completed the User Experience Questionnaire (UEQ) on three avatar appearances, 3D-R, 3D-HN and 3D-HD, with nominal anonymity manipulation.

3.6 Participants
Thirty undergraduate TVET students from the multimedia program were purposefully selected for each group, all of whom were

familiar with the ZOOM video conferencing platform. The students are notified and explained clearly that they are free to participate or not to participate in the experiment and that their absence or their performance on the tests they participated in had no effect on their actual grades. For this study, students who are unfamiliar with ZOOM or students who are not familiar with the concept of multimedia from the lecture topic in the session are ineligible to participate and respond to the questionnaire.

3.7 Procedures

The experiment of Virtual Remote Lecture was conducted on a multimedia program course at the undergraduate TVET institutes in Malaysia. The lecture was conducted online, and students attended from home or other locations via PCs or other devices that were suitable and available at the time. Students are notified of their Zoom meeting IDs according to their assigned groups (3D-RP, 3D-RO, 3D-HNP, 3D-HNO, 3D-HDP, 3D-HDO) in advance so that half of the students would experience each lecture type.

4.0 Findings and Discussion

All participants completed the UEQ, which was distributed online via Google Forms in this study, without any errors in the transferred data, indicating that all the respondents took the questions seriously as notified. The data are measured on a seven-point scale to measure the six aspects of Attractiveness, Efficiency, Perspicuity, Dependability, Stimulation, and Novelty. A reliability test measures the consistency of UEQ as an indicator of the variables. The Cronbach alpha value is used to determine the consistency of UEQ, and if the Cronbach alpha value is more than 0.6, it is indicated to be reliable. The reliability test results of each aspect of the study using the UEQ instrument can be seen in Table 1.

Table 1. UEQ Reliability Test

Scales	Cronbach Alpha
Attractiveness	0.67
Efficiency	0.78
Perspicuity	0.64
Dependability	0.62
Stimulation	0.74
Novelty	0.66

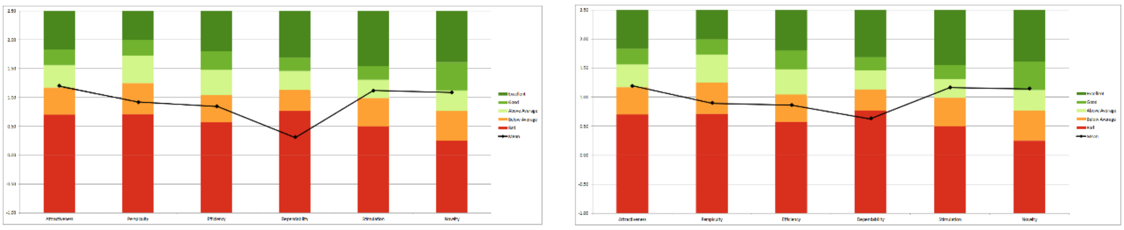
The Cronbach Alpha values for attractiveness, efficiency, perspicuity, dependability, stimulation, and novelty are 0.67, 0.78, 0.64, 0.62, 0.74, and 0.66, respectively. These values indicate that the consistency values for all scales are acceptable and considered reliable. The validity of each item has been consulted by relevant experts in this study. The focus of this study is to examine the re-targeting accuracy of landmark points on the avatar mesh surface to determine the efficiency of the avatar's verbal and non-verbal cues deliverable. Therefore, a benchmark is used to interpret results obtained with the UEQ by comparing them to the results of different avatar conditions. The benchmark helps to interpret results obtained by comparing them with the results of other products in the benchmark. However, according to Hinderks et al. (2018), it is not directly possible to recalculate a benchmark for the UEQ using raw data from existing UEQ studies, which are not available due to data privacy issues, and only the scale means are available for many of the data points in the UEQ benchmark.

4.1 UEQ

Table 2 evaluates UEQ scales evaluation results based on six avatar conditions. All six aspects of the UEQ received positive evaluations. For the Attractiveness aspect, the highest rank is 3D-RO, followed by 3D-HDP, 3D-HNO, 3D-HDO and 3D-RP, respectively. For the Efficiency aspect, the highest rank is 3D-RO, followed by 3D-RP, 3D-HDO, 3D-HDP, 3D-HNP and 3D-HNO. For the Perspicuity aspect, the highest rank is 3D-HDO, followed by 3D-HDP, 3D-HNO, 3D-RO, 3D-HNP and 3D-RP. For the Dependability aspect, the highest rank is 3D-HDO, followed by 3D-HDP, 3D-RP, 3D-HNO, 3D-RO and 3D-HNP. For the Stimulation aspect, the highest rank is 3D-HDO, followed by 3D-HDP, 3D-HNO, 3D-HNP, 3D-RO and 3D-RP. And finally, for the Novelty aspect, the highest rank is 3D-HDO, followed by 3D-HNO, 3D-HDP, 3D-HNP, 3D-RO and 3D-RP.

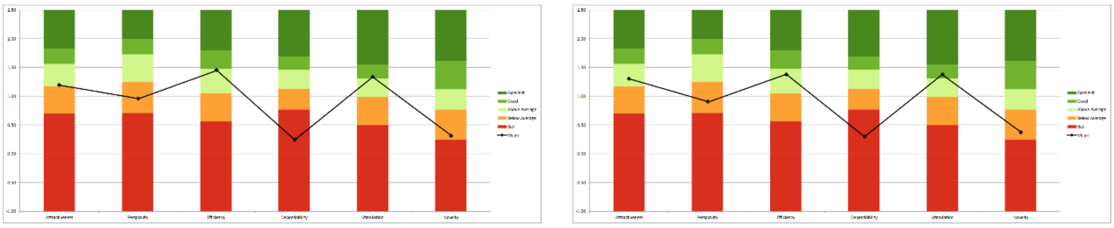
Table 2. UEQ Scales (Means and Variance) Based on Avatar Condition

Scales	3D-RP	3D-RO	3D-HNP	3D-HNO	3D-HDP	3D-HDO
Attractiveness	1.36, 0.82	1.42, 0.90	1.34, 0.80	1.38, 0.84	1.39, 0.86	1.37, 0.84
Efficiency	0.84, 0.66	0.86, 0.72	1.49, 0.93	1.48, 0.91	1.53, 1.14	1.54, 1.22
Perspicuity	0.90, 0.51	0.93, 0.62	0.91, 0.58	0.95, 0.69	0.96, 0.71	1.02, 0.88
Dependability	0.36, 0.17	0.34, 0.16	0.32, 0.13	0.35, 0.18	0.49, 0.24	0.88, 0.87
Stimulation	1.25, 0.32	1.28, 0.38	1.42, 0.54	1.48, 0.65	1.52, 0.87	1.59, 0.94
Novelty	1.33, 1.24	1.36, 1.37	0.37, 0.12	0.44, 0.35	0.41, 0.30	1.78, 1.54



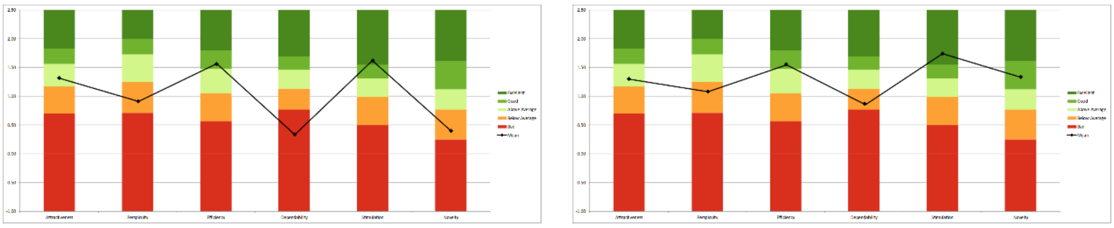
(a) (b)

Fig. 5. Benchmark visualization of (a) 3D-RP; (b) 3D-RO.



(a) (b)

Fig. 6. Benchmark visualization of (a) 3D-HNP; (b) 3D-HNO.



(a) (b)

Fig. 7. Benchmark visualization of (a) 3D-HDP; (b) 3D-HDO.

4.2 Avatars

Table 3 compares the avatar condition to the benchmark. The Stimulation scale monopolizes the Highest-rank scale, which is interpreted as Excellent by 3D-HDO and 3D-HDP. The second-rank scales are Efficiency, Stimulation, and Novelty, which are interpreted as Good by 3D-HDO and 3D-HDP (Efficiency), 3D-HNO and 3D-HNP (Stimulation) along with 3D-HDO and 3D-RO (Novelty). The third-rank scales are Attractiveness, Efficiency, Stimulation and Novelty, which are interpreted as Above average by 3D-RP, 3D-RO, 3D-HNP, 3D-HNO, 3D-HDP and 3D-HDO (Attractiveness), 3D-HNP and 3D-HNO (Efficiency), 3D-RP and 3D-RO (Stimulation) and 3D-RP (Novelty).

For the interpretation of Below average, it is owned by 3D-RP and 3D-RO in the aspect of efficiency, all avatar conditions for Perspicuity aspect and 3D-HNP and 3D-HNO for Novelty aspect. Finally, avatar conditions interpreted as Bad are 3D-RP, 3D-RO, 3D-HNP, 3D-HNO and 3D-HDP.

Table 3. UEQ Scales (Comparison to Benchmark) Based on Avatar Condition

Scales	3D-RP	3D-RO	3D-HNP	3D-HNO	3D-HDP	3D-HDO
Attractiveness	Above average	Above average	Above average	Above average	Above average	Above average
Efficiency	Below average	Below average	Above average	Above average	Good	Good
Perspicuity	Below average	Below average	Below average	Below average	Below average	Below average
Dependability	Bad	Bad	Bad	Bad	Bad	Below average
Stimulation	Above average	Above average	Good	Good	Excellent	Excellent
Novelty	Above average	Good	Below average	Below average	Below average	Good

4.3 Benefit of Re-Targeting Accuracy

Aspect that can be used to examine re-targeting accuracy is efficiency, which measures how efficient and smooth the interaction is (Hinderks et al., 2018). Interaction can be conducted efficiently and smoothly when the avatar accurately projects verbal and non-verbal cues to transmit accurate information (Dubosc et al., 2021; Feine et al., 2019). Based on the data obtained on the Efficiency aspect, four avatar conditions, which are (1) 3D-HDO and 3D-HDP, are interpreted as Good, and (2) 3D-HNO and 3D-HNP are interpreted as Above Average. On the other hand, 3D-RO and 3D-RP are classified as below average in terms of efficiency.

Compared to all avatar conditions, the re-targeting accuracy of landmark points is most effective when using 3D-HDO and 3D-HDP, followed by 3D-HNO and 3D-HNP. On the other hand, re-targeting accuracy is less effective when using 3D-RO and 3D-RP. This indicates that the landmark points on real human faces cannot be transferred entirely or mapped accurately on 3D humanoid-robot avatars, which are less anthropomorphic since the structure of a 3D humanoid-robot avatar generates landmark coordinates that are a bit different from actual human (Onizuka et al., 2019; Zhang et al., 2020). This study has found that giving lectures using avatar with visual fidelity design of anthropomorphism and truthfulness can be used to examine the re-targeting accuracy and improve pedagogical effectiveness of an avatar in avatar-mediated communication. However, the findings also found that both nominal anonymity manipulation of pseudonyms and orthonyms do not influence the results of re-targeting accuracy of landmark points. Nominal anonymity manipulation of pseudonyms and orthonyms does not influence the results of re-targeting accuracy for landmark points because they have different concepts and their connection is not direct. Nominal anonymity refers to a concept in psychological state that can lead to deindividuation effect, while the re-targeting accuracy of landmark points is a technical/scientific measurement problem (Nyatsanga et al., 2025; Coesel et al., 2025).

The embodiment of an avatar, facial expression, eye contact in communication and exchange of verbal cues and non-verbal cues (human gestures) drive students to perceive the avatar more as humans during interactions and increase students' acceptance (Dubosc et al., 2021; Feine et al., 2019). However, the results in this study showed highly negative scores, specifically the Dependability aspect, which was rated Bad for five out of six conditions. It relates to students feeling unsafe or not in control of the avatar's responses or reactions. This result is due to the VRL system limitations. In VRL, the avatar is embodied solely by the lecturer, limiting its control to the lecturer. This limitation causes students to feel unsafe due to a lack of control over the avatar's response or reaction.

5.0 Conclusion

The focuses of Virtual Remote Lecture in this study are limited to two visual fidelity forms: (1) anthropomorphic, examining the visual appearance of 3D avatars ranging from robot-like to human-like, and (2) truthfulness, examining the visual appearance of 3D avatars ranging from human-like not resembling the user (non-doppelganger) to human-like resembling the user (doppelganger). This study also focuses on the deindividuation manipulation of identity, specifically the name, ranging from pseudonym (fictitious name) to orthonym (real name).

The Virtual Remote Lecture is convenient for helping students learn independently synchronously (real-time lecture) and asynchronously (recorded lecture), according to their respective learning styles and speeds. In Virtual Remote Lectures, the lecturer's embodiment of an avatar, facial expression, eye contact in communication and exchange of verbal cues and non-verbal cues (human gestures) drive students to perceive avatars more as humans during interactions and increase students' acceptance (Dubosc et al., 2021; Feine et al., 2019).

The results validate and support this study's first (1) hypothesis that lectures conducted using avatars with a visual fidelity design of anthropomorphism and truthfulness can examine the re-targeting accuracy and improve pedagogical effectiveness of an avatar in avatar-mediated communication. However, the findings found that the second (2) hypothesis is not supported, where both nominal anonymity manipulation of pseudonyms and orthonyms cannot influence the results on the re-targeting accuracy of landmark points.

The stimulation scale is the highest rank interpreted as Excellent by 3D-HDO and 3D-HDP. Based on Hinderks et al. (2018), the result indicates that students have the highest stimulation, motivation and enjoyment when interacting with 3D avatars that visually resemble the real face of their lecturer regardless of revealing or not revealing the lecturer's real name. Most avatar conditions are interpreted as Bad along 3D-HDO, which is interpreted as Below average. This indicates that students felt unsafe and were not in control of the situation when interacting with most avatars, and the students could not predict the actions of the avatars (Hinderks et al., 2018).

The sample of this study is limited to students from a single course, which may affect the generalizability of the findings. However, this may enhance the internal validity of the study for similar contexts. This study provides input and potential solutions for mitigating the negative effect on student engagement by observing the impact of other variables in the relationship. A straightforward extension of this study would be to expand to other variables of study and the scope of participants to include a more diverse range of students across different courses and institutions. This will enhance the study analysis and provide a more comprehensive understanding of the impact of avatar representations on student learning experiences.

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Paper Contribution to Related Field of Study

This study generates insight and new findings to improve the pedagogical effectiveness of an embodied lecturer avatar in virtual remote lectures. Examining the re-targeting accuracy of landmark points on the embodied lecturer avatar determines the efficiency of the avatar’s verbal and non-verbal cues deliverables, which are crucial for effective information transmission in communication. The finding reveals that the landmark points on real human faces cannot be matched entirely or mapped accurately on avatars that are less visually anthropomorphic or differ from the facial structures of the real human user. Re-targeting accuracy emphasises transferring a human's facial expressions and gestures to an embodied avatar by replicating face-to-face communication.

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