



The Effects of a Virtual Instructor with Realistic Lip Sync in an Augmented Reality Environment

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Abstract. In this study, we explore the impact of incorporating a virtual instructor with realistic lip-syncing in an augmented reality (AR) learning environment. The study is particularly focused on understanding if this enhancement can reduce students' mental workload and improve system usability and performance in AR learning. The research stems from previous feedback indicating that a virtual instructor without facial movements was perceived as “creepy” and “distracting.” The updated virtual instructor includes facial animations, such as blinking and synchronized lip movements, especially during lecture explanations. The study aims to determine if there are significant changes in mental workload and usability differences between the AR systems with and without the enhanced virtual instructor. The study found significant differences in the usability scores in some questions. However, there was no significant difference in the mental workload between them.

Keywords: Augmented Reality · Workload · Usability · Lip Sync · Virtual Instructor

1 Introduction

In the realms of education and training, augmented reality (AR) has proven to be an impressive learning platform. This is evidenced by its success in enhancing retention [1], boosting motivation [2], and facilitating significant learning gains [3]. A key strength of AR lies in its ability to foster a personalized ‘learning by doing’ approach [4]. However, AR-based learning requires further improvement to boost its effectiveness in student

learning. Wu, Lee [5] highlighted a critical challenge: students often experience cognitive overload in AR environments due to the influx of multiple information streams. To address this, introducing a virtual instructor equipped with realistic lip-syncing could mark a notable evolution in AR educational experiences. Such an integration promises to deepen student immersion in AR scenarios, offering an experience where virtual instruction mirrors the nuances of real-life human interactions. In this study, the participants were 37 students from an Ergonomics and Workstation Design course. The study was conducted over two consecutive fall semesters, with different groups each year. The participants went through lectures in an AR environment, guided by a virtual instructor, and their performance and subjective workload were measured.

2 Problem Description

In this study, we explored the advantages of incorporating a virtual instructor featuring a natural lip sync in augmented reality learning. In our previous study [6], we developed a virtual instructor without any facial movements. Participant feedback highlighted a shared concern: the facial expression of the animated instructor was deemed “creepy” and “distracting.” To address this issue, the updated virtual instructor now includes facial animations, such as blinking and synchronized lip movements, especially during lecture explanations.

To evaluate the advantages of this enhancement, the experiment was structured to address the two research questions outlined below:

- What are the significant changes, if any, in mental workload following the implementation of an enhanced virtual instructor with realistic lip sync?
- How do the usability levels compare between the two versions of the virtual instructor, and is there a significant difference?

We hypothesized that the introduction of the updated virtual instructor could lead to a significant decrease in students’ mental workload during this AR learning experience. Additionally, it is anticipated that the improvements in user experience might result in an increase in system usability. However, our findings revealed contrasting results.

3 Related Research

AR provides educators with the opportunity to present lessons in a new digital format. Learners would have the opportunity to handle information in a new and interactive format [5, 7]. AR can create an ease-of-use that has been proven to reduce students’ cognitive workloads, which can encourage students to engage more with the content [1, 8–10]. This new way of educating students could help the content become more “fun and entertaining,” allowing them to be more creative inside the AR environment. However, if the virtual content lacks naturalness, it could greatly affect student engagement during the learning process. To improve the impacts of learning outcomes and student engagement in VR/AR/MR environments, many studies are focusing on designing the virtual content based on gamification, which is about using game elements to engage that motivation [11, 12]. Gamification is not about creating complete games, but instead

using game-thinking or mechanics to engage users to learn and solve problems. It will help to improve student motivation and engagement using game elements. According to the study done by Arnold [13], the ideal initiation for gamification lies in virtual or online learning, where students already accustomed to gaming, may find a smooth transition into educational contexts. This approach highlights the significance of maintaining a low workload and ensuring the naturalness of virtual content to enhance the learning experience. Radu further highlighted the importance of keeping workloads light, allowing students ample opportunity to interact with and adapt to the AR learning environment [1]. Because AR does not block students' view of their physical surroundings, and they are still able to interact with peers to discuss content [14]. AR also offers the capability to present students with experiences, such as visualizing complex subjects or simulating locations for field trips, aiding in their understanding of the topics being studied. A study conducted on marine education using AR found that students benefit from close-up examination through the features that AR offers, enhancing their understanding and motivation [15]. In AR-based education, the use of visualization can support differentiated instruction tailored to a variety of learners, a crucial aspect of lesson planning. AR can make the delivery of information more adaptive and personalized for education [16]. However, AR comes with certain limitations. Some students might perceive the new AR learning environment as complex, particularly if they encounter any technical issues associated with the virtual contents [3].

4 Methodology

4.1 Participants

The participants of this study ($N = 37$) were students in an Industrial and Systems Engineering Ergonomics and Workstation Design course at the University of Missouri–Columbia. Data was collected over two consecutive fall semesters. The first set of data, Year 1, was collected in Fall of 2022 during a 3-week period, October 17th to November 3rd, 2022. This first round of data collection had a total of 16 participants. In the second year of the study, data collection occurred over a period of 7 weeks, from September 18th – November 1st, 2023. The second set of data, Year 2 contains 21 participants. The ages of the participants ranged from 20 to 23 and consisted of Juniors or Senior college students. Lecture materials were directly related to the ergonomics class content.

4.2 Procedure

Participants completed two lectures during the experiment. Following the first lecture, they were required to complete the second lecture within a forty-eight-hour period. Lectures took place in an open space lab, which allowed free movement so participants could answer questions after each module on an unfixed table as they moved through the space. Participants were guided through two Biomechanics lectures within the augmented reality environment by a virtual instructor leading each session. The anticipated duration of each lecture was approximately sixty minutes; however, participants were encouraged to proceed at their own pace, allowing for content review or replay as needed

(see Fig. 1). The initial lecture covered fundamental biomechanics and physics concepts, encompassing basic definitions and formulas (see Fig. 2). In contrast, the subsequent lecture applied these definitions, thereby elevating the difficulty level. Lecture 1 was segmented into seven modules, while Lecture 2 comprised of eight modules. Most modules concluded with participants answering a question related to the material, resulting in multiple questions within each lecture. Each lecture had seven questions. Following each response, participants provided a confidence rating indicating their level of certainty regarding the accuracy of their answer.

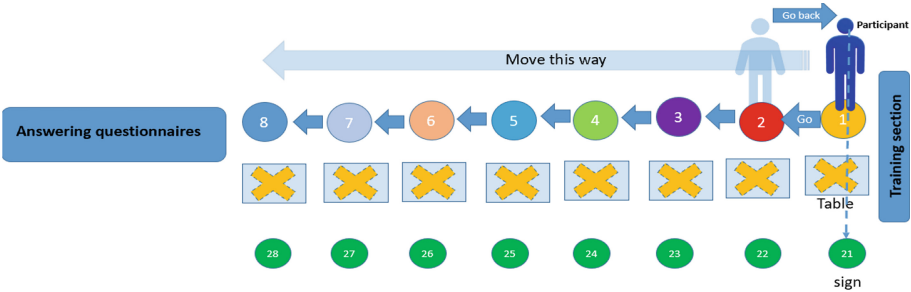


Fig. 1. Diagram of how participants traveled through the lab space.

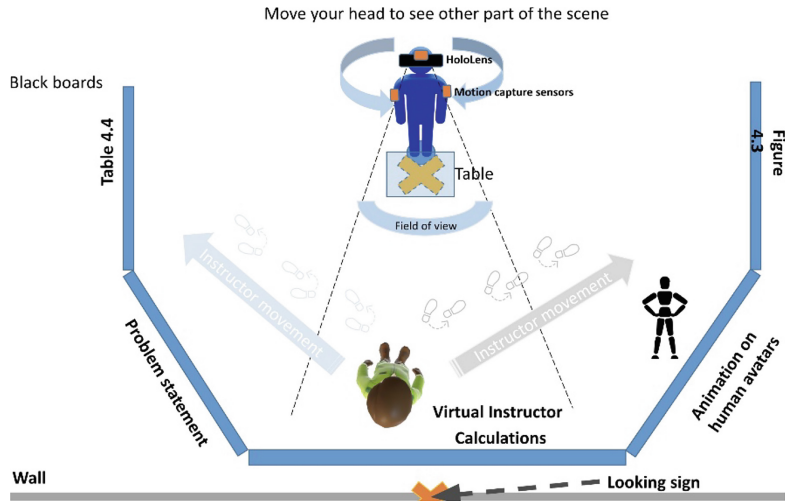


Fig. 2. The immersive learning environment [17].

At the conclusion of each lecture, participants were asked to fill out three survey forms. The NASA Task Load Index method [18] was used to evaluate and rank assessments of subjective demand considered by each participant. This survey asked participants to assign percentages (between 0–100) to predetermined workload dimensions (i.e., Physical Demand, Mental Demand, Temporal Demand, Performance, Frustration,

and Effort) and then to rank those dimensions. Students also filled out a survey titled Student Satisfaction and Self-Confidence in Learning Scale (SCLS). This survey required participants to rate on a 5-point scale how much they agreed or disagreed with statements about learning in an Augmented reality environment. These questions included, but were not limited to, “The way the virtual instructor taught was suitable to the way I learn.” And, “The teaching methods used in this Augmented Reality module were helpful and effective.”

The main difference of the virtual instructor in Year 2 compared to Year 1 is with realistic lip sync, facial expression and more hand motions. Both versions of the instructor are shown in Fig. 3. While there are slight variations among these instructors in aspects like appearance, clothing color, and hairstyle, these differences do not significantly impact student engagement, workload, or usability. Virtual instructors, in contrast to human ones, reduce the likelihood of bias linked to appearance. A virtual instructor, created through 3D animation and powered by the Xsens motion capture system along with Murf AI, enabled realistic movements and synthesized a voice that sounded natural.



Fig. 3. Virtual Instructor in Year 1(left) and Virtual Instructor in Year 2 (right).

4.3 Apparatus

A HoloLens 2 AR headset was used to display the lecture modules (see Fig. 4). Motion-tracking sensors were attached to the upper bodies of participants. The lectures were conducted in a spacious lab environment. This setup enabled students to walk around the lab, activating different sections of the virtual lecture as they moved.



Fig. 4. A student participant wearing HoloLens and sensors in the testing area.

5 Results

Upon assessing the usability score over the two years, notable disparities were observed in the participants’ answers to two out of the ten usability questions. A significant difference was particularly evident in the response to Question #3 on the survey. This particular question asked for participants’ perspective on the system’s user-friendliness. It read: “I thought the system was easy to use.” (Fig. 5)

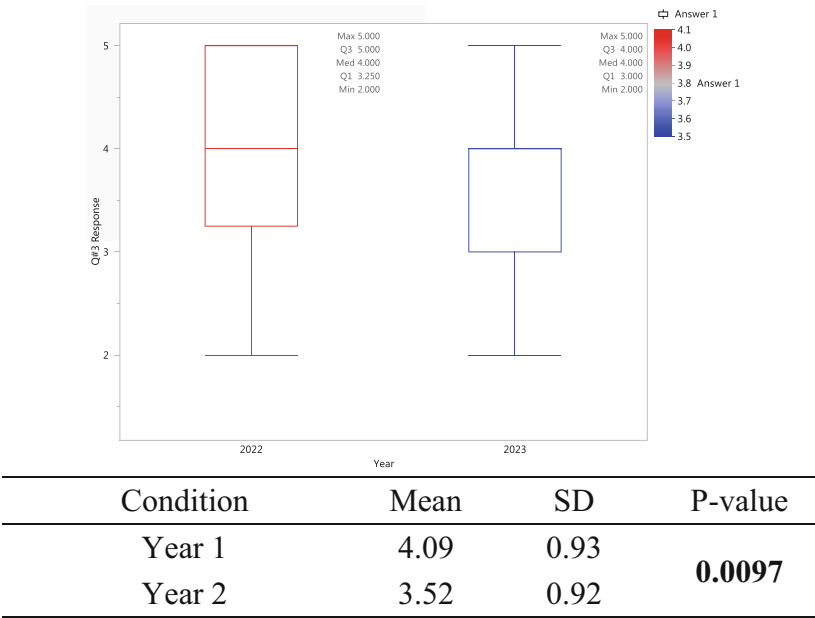


Fig. 5. Statistical results of Usability Question #3 between Conditions.

The above figure illustrates a decline in participants’ perceived ease of use in Year 2 as opposed to Year 1. The average score for the statement ‘I thought the system was

easy to use’ dropped from 4.09 in Year 1 to 3.52 in Year 2. This decrease highlights that participant in Year 2 found the system to be relatively more difficult compared to those in the previous year.

The other question that showed notable differences was Usability Question #4, which asked “I think that I would need the support of a technical person to be able to use this system.” (Fig. 6).

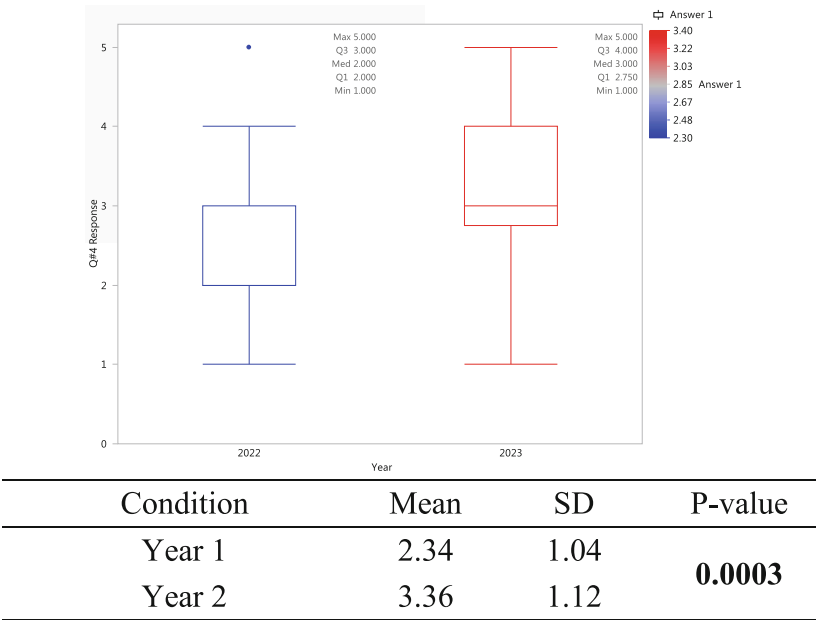


Fig. 6. Statistical results of Usability Question #4 between Conditions.

This question shows a significant increase in students’ ratings indicating a higher need for seeking assistance during the operation of this system. This once again implies that students perceive an increased complexity. Additionally, another survey extensively examined was the students’ workloads, assessed using the NASA TLX. In a manner akin to the usability analysis, participants’ workloads were compared year-to-year to observe any shifts in the data (Fig. 7).

This graph illustrates that there was no significant statistical difference between years. We believe the updated virtual instructor, which featured facial animations like blinking and synchronized lip movements, did not have a significant impact on the work-load.

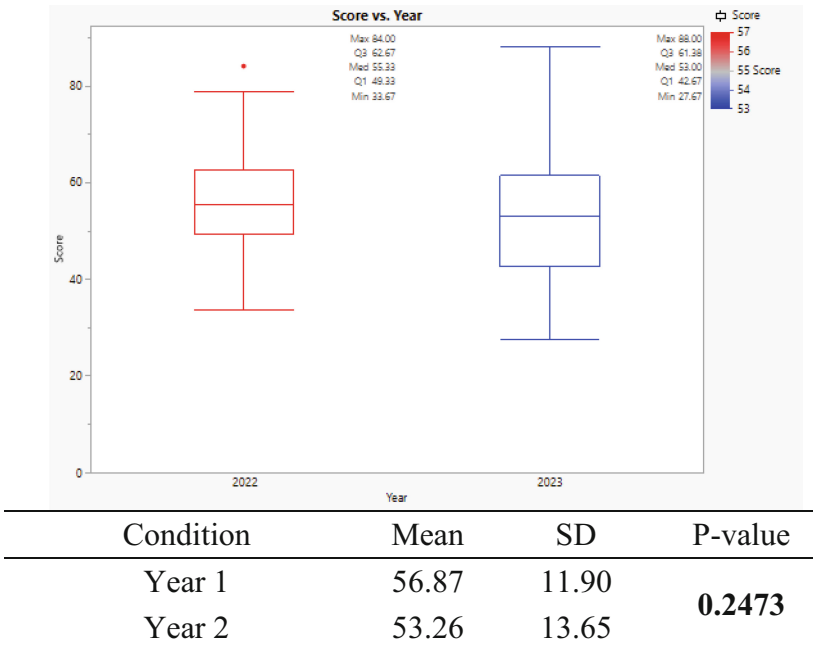


Fig. 7. Statistical results of participants’ workloads between Conditions.

6 Discussions and Conclusions

The analysis of usability results shows a consistent perception among participants that the Year 2 system is comparatively more complicated to use than its Year 1, as evidenced by participant responses to Question #3. Furthermore, responses to Question #4 further support the conclusion that the system is perceived as more challenging to use. There’s a clear correlation: participants who perceive the system as harder to use are likely to feel an increased need for assistance. In other words, the participants in Year 2 perceived the AR classroom, enhanced with the upgraded virtual instructor incorporating facial animations such as blinking and synchronized lip movements, as not beneficial for AR lectures. A possible explanation for this phenomenon could be that participants are sensitive to any imperfections in realism, such as minor inaccuracies in lip-syncing or a limited range of expressions. These flaws might result in feelings of dissatisfaction or make it more challenging to engage with the AR content. Additionally, realistic animations demand considerable processing power and advanced software. Therefore, any constraints or deviations in the animations from actual human movements and expressions might interrupt the learning experience, thereby making it more difficult for users to concentrate on the educational material. Another possible explanation could be the realistic facial expressions and synchronized lip movements of a virtual instructor could unintentionally shift focus away from the educational content. Users may become more preoccupied with observing the instructor’s animations rather than concentrating on the

les-son itself. Furthermore, if students are not used to interacting with virtual instructors of this nature, the unfamiliar experience may initially seem more demanding.

Interestingly, even though there was a reported decline in the system's usability, the comparison of workloads between Year 1 and Year 2 did not reveal any statistically significant differences. According to the previous study [19], the observation that a virtual instructor in AR learning reduces workload compared to scenarios without one. However, in this study, a virtual instructor with facial expressions and realistic lip sync does not further reduce workload compared to a virtual instructor without these features. Despite the decrease in the system's usability, it's possible that the workload could have increased. Yet, no significant difference in workload results was observed. This suggests that while a virtual instructor can streamline learning through step-by-step guidance, the inclusion of realistic facial expressions and lip syncing may not significantly impact cognitive load.

This indicates that modifications like the updates to the virtual professor incorporating facial animations such as blinking and synchronized lip movements did not increase the workload or stress levels of the participants. Despite Year 2 students perceiving the system usability as more challenging, this did not lead to a rise in their workload.

In contrast to our initial hypothesis, the results did not support the idea that the introduction of the updated virtual instructor with realistic lip sync and facial expressions resulted in a significant change in students' mental workload during the AR learning experience. Furthermore, the anticipated improvements in user experience were not apparent based on the collected data. Hence, if the realistic animations do not offer extra educational value or enhance content comprehension, they may be viewed as unnecessary.

Although the data did not align with our initial predictions, there is still valuable insight to be gained from these results. These findings show the relationship between the perceived system difficulty and the impact on the workload and suggest further exploration is needed to understand the many factors that influence user experience.

The study concludes that while the virtual instructor with realistic lip sync may not have reduced cognitive load and improved usability as expected, it provides valuable insights into the complexity of user experience in AR education systems. This suggests a need for more research in this area to better understand and optimize AR learning environments. To enhance usability and lessen the workload in AR learning via modifications to the virtual instructor, we suggest opting for a simpler or more stylized design over hyper-realism. This approach can lower cognitive load and improve user-friendliness. Where realistic lip syncing and facial expressions are essential, it is vital to ensure their accuracy and naturalness to bypass the uncanny valley effect [20] and boost comprehension. Additionally, allowing for customization of the virtual instructor's appearance and behavior, if feasible, can render the learning experience more approachable and less intimidating for students. Finally, implementing a system where the virtual instructor adjusts to each student's learning pace and offers relevant feedback is key to making the learning process more effective.

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References

1. Radu, I.: Why should my students use AR? a comparative review of the educational impacts of augmented-reality. In: 2012 IEEE International Symposium on Mixed and Augmented Reality (ISMAR). IEEE (2012)
2. Gutiérrez, J.M., Fernández, M.D.M.: Applying augmented reality in engineering education to improve academic performance & student motivation. *Int. J. Eng. Educ.* **30**(3), 625–635 (2014)
3. Akçayır, M., Akçayır, G.: Advantages and challenges associated with augmented reality for education: a systematic review of the literature. *Educ. Res. Rev.* **20**, 1–11 (2017)
4. May, D.B., Etkina, E.: College physics students' epistemological self-reflection and its relationship to conceptual learning. *Am. J. Phys.* **70**(12), 1249–1258 (2002)
5. Wu, H.-K., et al.: Current status, opportunities and challenges of augmented reality in education. *Comput. Educ.* **62**, 41–49 (2013)
6. Mostowfi, S., et al.: The Effect of Metacognitive Judgments on Metacognitive Awareness in an Augmented Reality Environment. Springer, Cham (2023)
7. Kim, J.H., Chan, T., Du, W.: The Learning Effect of Augmented Reality Training in a Computer-Based Simulation Environment. Springer, Cham (2015)
8. Guo, W., Kim, J.H.: How Augmented Reality Influences Student Workload in Engineering Education. Springer, Cham (2020)
9. Guo, W., Kim, J.H.: How Metacognitive Monitoring Feedback Influences Workload in a Location-Based Augmented Reality Environment. Springer, Cham (2021)
10. Guo, W., Hyup Kim, J.: Investigating academic performance using an AR-based learning environment with retrospective confidence judgments. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications, Sage CA, Los Angeles, CA (2022)
11. Buckley, P., Doyle, E.: Gamification and student motivation. *Interact. Learn. Environ.* **24**(6), 1162–1175 (2016)
12. Chapman, J.R., Rich, P.J.: Does educational gamification improve students' motivation? If so, which game elements work best? *J. Educ. Bus.* **93**(7), 315–322 (2018)
13. Arnold, B.J.: Gamification in education. *Proc. Am. Soc. Bus. Behav. Sci.* **21**(1), 32–39 (2014)
14. Galembeck, E., Magrini, M., Garzon, J.: Using augmented reality to bring interactivity to metabolism teaching. *Revista de Ensino de Bioquímica* **12**(1), 84 (2014)
15. Hsieh, M.-C.: Development and application of an augmented reality oyster learning system for primary marine education. *Electronics* **10**(22), 2818 (2021)
16. Aljowaysir, N., Ozdemir, T.O., Kim, T.: Differentiated learning patterns with mixed reality. In: 2019 IEEE Games, Entertainment, Media Conference (GEM). IEEE (2019)
17. Yu, C.-Y., et al.: Developing an Augmented Reality-Based Interactive Learning System with Real-Time Location and Motion Tracking. Springer, Cham (2023)
18. Hart, S.G.: NASA-task load index (NASA-TLX); 20 years later. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. Sage publications, Sage CA, Los Angeles, CA (2006)
19. Kim, J.H., et al.: The effect of virtual instructor and metacognition on workload in a location-based augmented reality learning environment. In: Proceedings of the Human Factors and Ergonomics Society Annual Meeting. SAGE Publications, Sage CA, Los Angeles, CA (2023)
20. Seyama, J.I., Nagayama, R.S.: The uncanny valley: effect of realism on the impression of artificial human faces. *Presence* **16**(4), 337–351 (2007)