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Comparing Realities: A Study on the Impact of Virtual Reality versus Paper-Based Reading on Higher Education Students' Comprehension Skills

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Virtual Reality (VR) stands at the forefront of transformative educational technologies in the 21st century, promising to redefine traditional learning paradigms. This research delves into the impact of VR on higher education students' Reading Comprehension (RC) skills, contrasting it with conventional paper-based reading environments. By conducting a comparative analysis of RC skills among students engaged in reading a selected narrative through VR glasses and those using a paper-based format, this study offers valuable insights into the efficacy and challenges of VR in enhancing reading comprehension. A cohort of 98 undergraduate students participated in this study, which employed a mixed-methods research approach to scrutinize the differences in RC outcomes between the experimental (VR) and control (paper-based) groups. The findings reveal a notable disparity in RC scores, with the control group outperforming their VR counterparts, highlighting the need for further investigation into the obstacles faced by students when reading in a VR setting. Qualitative analysis sheds light on the underlying reasons for the diminished RC levels observed in the VR group, providing a nuanced understanding of the interaction between medium and comprehension. The implications of this research are far-reaching, offering crucial guidance to educational technologists, curriculum designers, policy makers, and educators contemplating the integration of

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VR into educational frameworks. By identifying the constraints and potential of VR in reading instruction, this study paves the way for optimizing VR-based learning environments to foster higher levels of reading comprehension among students.

Introduction

Virtual Reality (VR) is a 3D virtual world that simulates reality as it is experienced by the user's senses and allows users to explore and interact with it (Rubio-Tamayo et al., 2017). It has the potential to improve learning (Khan et al., 2022). It allows students to experience environments where they are not physically present and to manipulate objects in the environment. For example, students can grab an object in the VR environment with the help of virtual hands. It offers a real-time, authentic, interactive technology that goes beyond textbooks and allows the development of flexible and appropriate learning strategies (Chung, 2012). Literature suggests that this technology has a positive effect on learning motivation and performance (Chen et al., 2022; Coban et al., 2022). VR is widely adopted in classrooms that have blooms (Khukalenko et al., 2022; Tomczyk, 2020). Related research has suggested that visualization and interaction components offered by VR can enhance student learning (Kemp et al., 2022; Schott & Marshall, 2021). However, the literature has mixed findings on how VR affects student reading. For example, Flores-Gallegos et al. (2022) suggest VR is not able to improve reading performance while Kaplan-Rakowski and Gruber (2024) suggest it could enhance student reading. Therefore, this study aims to investigate this effect in a new context-higher education in Turkey.

Reading is a process that recognizes words, leading to the development of comprehension (Alyousef, 2006). Reading Comprehensive (RC) skill is defined as “the ability to understand and appropriately interpret the information in a text” (Grabe & Stoller, 2011, p.11). RC is associated with cognitive development, academic achievement, critical thinking, and improving problem-solving skills (Kao et al., 2016; Robasto et al., 2022). Reading in digital environments is very common for higher education and adult learners. The design of text in digital environments such as the structure, complexity, form, organization, and density affect student RC (Meniado, 2016). Research has been conducted to examine whether digital environments have fostering or hindering effects on student RC (Danaei et al., 2020). More research is needed to understand how digital environments provided by emerging technologies affect RC (Ben-Yehudah & Eshet-Alkalai, 2021; Reiber-Kuijpers et al., 2021). Accordingly, this study aims to examine whether university students can comprehend text in VR better than in paper-based environments.

Literature review

Reading comprehension

RC is an active and internal process of associating previous knowledge and experiences with new information derived from the text to create meaning (Alyousef, 2006; Danaei et al., 2020; Grabe & Stoller, 2013, p.11). Since RC is an internal process, researchers continue to study the components of this process and different ways to improve it (Danaei et al., 2020). In this context, researchers highlight that RC should be considered with some basic components, including but not limited to vocabulary (Quinn et al., 2015), decoding words (Ehri, 2014), reading fluency (Fuchs et al., 2001), prior knowledge (Ertem, 2009), working

memory level (Al-Jarrah & Ismail, 2018), and motivation and attitude (Kuşdemir & Bulut, 2018).

Literature suggests that retelling and recalling techniques are reliable for measuring RC (Brown & Cambourne, 1987; Danaei et al., 2020; Ertem, 2009; Leslie, 1993). Retelling refers to how well a reader reconstructs and integrates parts of an article (Gibson et al., 2003); recalling refers to how well a reader recalls from an article (Danaei et al., 2020). These two techniques indicate how well a reader understands and remembers an article (Owocki, 1999). Retelling shows how well a reader understands the story structure and that the answers to the implicit and open-ended questions reveal that the reader understands and remembers the story content based on their prior knowledge and inferences (Danaei et al., 2020; Ertem, 2009). Therefore, the researchers of this study use the "retelling" technique to assess the reader's understanding of the structure of the story and then ask "recalling" questions to find out to what extent each reader understands the meaning of the story.

Reading in VR education settings

Literature investigated how well learners comprehend text in various VR environments. Baceviciute et al. (2021) compared the performance of higher education students on a text they read in a VR-supported environment, like a hospital room and a in natural environment. They concluded that students in the VR group performed better regarding knowledge transfer, but reading in VR was more cognitively demanding and less time efficient. Flores-Gallegos et al. (2022) investigated the effects of a VR-supported game on reading performance (accuracy, speed, and comprehension), visual attention, motor balance, and coordination of children with reading difficulties. The study findings revealed that the VR-supported learning environment had a significant effect on the variables examined, while the participants in the control group did not show any change. The findings also suggested that no significant change was observed in students' reading performance. Kaplan-Rakowski and Gruber (2024) compared reading effectiveness in a VR-based environment with a tablet-based environment. The results showed that reading activity was more effective in a VR-based environment than in a tablet-based environment. Chuang and Cheng (2023) emphasized that VR-based learning environments improve learners' RC skills.

As a result, existing studies in the literature have examined VR technologies from a functional perspective, investigated VR-supported foreign language teaching, and provided training with VR-supported games. Kwok et al. (2023), stated that developing RC skills in VR learning environments is challenging and has not yet been sufficiently researched. Therefore, the purpose of this study is to compare higher education students' RC skills in VR and paper-based environments and reveal students' opinions and experiences regarding reading practice.

Rationale of the study and research questions

This study is significant in terms of providing the following five main contributions to the literature. The first contribution is that the points that can be considered to increase the level of reading skills in the virtual reality environment are revealed based on the students' perspectives. Secondly, it is stated in the literature that there is a need for new studies to investigate students' RC skills in a VR environment. The third contribution is that this study aims to be a pioneering study that investigates the RC skills of higher education students in a VR environment and aims to fill the gap in this field. Fourthly, this study tests the effectiveness of VR environments, which are seen as the learning tool of the future, in teaching RC skills. Fifthly, it provides suggestions for the precautions that can be taken before

integrating VR technologies into learning environments. Accordingly, the research questions (RQ) are formulated as follows:

RQ1: Is there a statistically significant difference between the RC skills of students who read the story in a VR environment and those who read the story paper-based?

RQ2: Is there a statistically significant difference between the retelling and recall skills of the students who read the story in a VR environment and those who read the story paper-based?

RQ3: What are the opinions and experiences of the students about the reading activity in the VR environment?

Material and methods

Research approach and design

This study adopted an explanatory sequential design to answer the three RQs. The explanatory sequential design is a commonly used approach in mixed methods research and is defined as a two-phase process (Hirose & Creswell, 2023). In the first phase, researchers collect and analyse quantitative data. The results of this analysis are then examined and explained in detail during the qualitative research phase (Creswell & Creswell, 2022). The primary purpose of this research design is to gain a deeper understanding of the reasons behind the quantitative findings. This allows researchers to obtain broadly generalizable results while also providing in-depth and contextual interpretations of these findings (Creswell & Plano Clark, 2011). In this study, qualitative data were utilized to further explore the quantitative results regarding participants' RC skills in the VR environment and to better identify potential reasons affecting their RC skills.

In the quantitative approach, an experimental design with random assignment was adopted to examine whether VR environments are more beneficial for student RC. A qualitative approach using a semi-structured interview form was adopted to explain the quantitative findings. Figure 1 summarizes the quantitative and qualitative research designs.

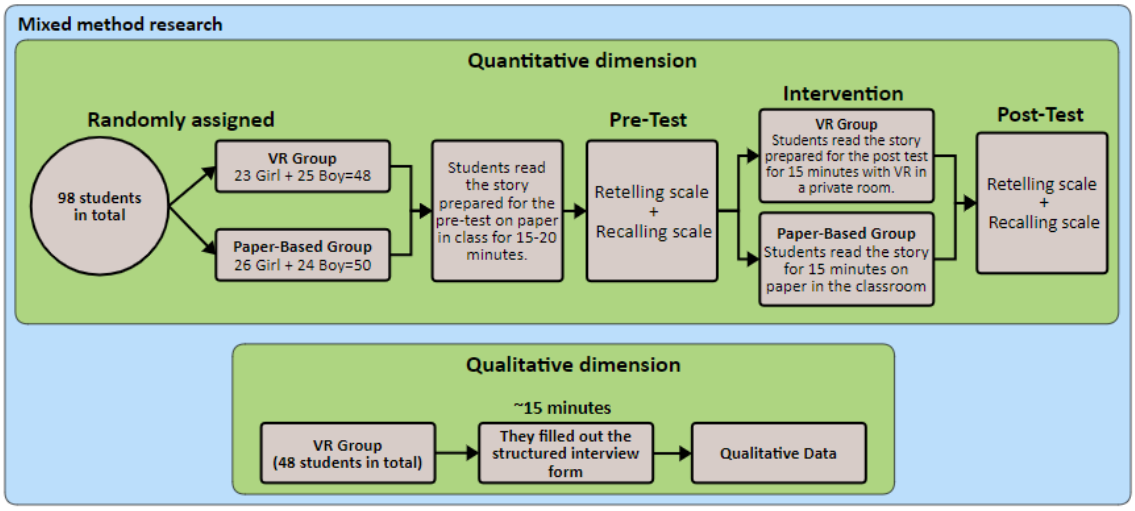

Figure 1. Design of the quantitative and qualitative research

Participants

Participants consisted of 98 (49 females and 49 males; age: 18-22 years old) students in Turkey. Their majors are Turkish Language Teaching (n=30), Psychological Counselling and Guidance (n=15), Classroom Teaching (n=33), Science Teaching (n=13), and Mathematics Teaching (n=7). Teachers play an important role in the process of integrating technologies such as VR into learning environments and deciding on the use of these technologies. It is advocated that teachers' RC skills are important in the process of transferring knowledge (Okkinga et al., 2018). In addition to these reasons, teacher candidates from different departments were selected as samples to diversify the sample and add practicality to the research. They were randomly assigned into two experimental conditions: VR - 48 students (23 females and 25 males), and paper- 50 (26 females and 24 males). This study obtained ethical clearance from the authors' university ethics committee (Decision dated 30.12.2022 and numbered E.60462).

Materials

In this study, researchers (1) determined two stories written in the participant's native language (Turkish). The first story was prepared to reveal the pre-test results of participants' RC skills. The second story was prepared to be used during the experiment process. (2) Developed VR-based digital material, and (3) prepared paper-based material so that students could read in virtual and real environments.

The stories were selected from *Refik Halid Karay*'s works. The first story was called "*Şeftali Bahçeleri* (Peach orchards in English)". The second story is "*Eskici* (Junkman in English)". Two criteria were considered in the selection of the stories. The first criterion is that a story writer is competent in the field. The chosen short story writer won the *Mark Twain Award* in 1953 for his contributions to the story genre. The second criterion is that the selected stories are appropriate in terms of textuality. For this, opinions were received from three experts in the field of Turkish Education in terms of the suitability of the stories for the students in the sample group and their textuality criteria. The importance of native language and cultural elements is emphasized in the selected stories. Therefore, the stories are preferred is that they are general works and are suitable for a common theme according to the age, culture, and education level of the students, and the department they study.

VR-based digital material

Researchers have developed a flip book for students who will do reading activities in a VR environment. The game engine used in the development process of this book is *Unity 3D*, and the programming language is C#. The developed book was loaded into a VR headset of *Meta Quest 2*. Students can open the book, turn the pages, and close the book by using the hand-control devices of the VR glasses. The features added to increase the perception of the reality of the book in the VR environment are the buttons for opening and closing the cover, page numbers, and navigation buttons for switching between pages. Besides, sound effects such as turning on and off the sound and turning the pages have been added to the book to recreate the VR environment of a real book. Figure 2 shows a screenshot of one of the inner pages of the VR-based book.

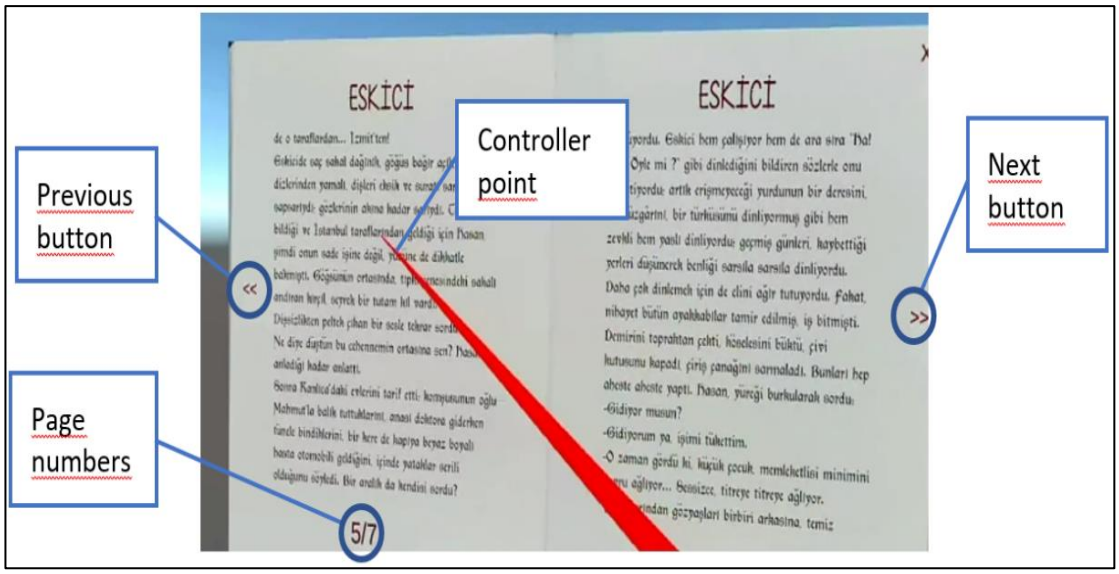

Figure 2. Screenshot of the book in a VR environment

Since this study focused on the RC skills of the participants in the VR environment, the researchers preferred a text-based design rather than an environment design that highlights the authentic and visual features of VR.

Paper-based material

The researchers first transferred the story called "*Eskici*" from a book to the digital environment through a browser so that the control group students could make the reading activity paper-based, and the text appearance of the story resembled the book designed in the VR environment. The effects caused by the design difference of the materials on the RC levels of the students reading in VR and real environments were minimized.

Data collection tools

This study employs three data collection tools: (1) retelling scale, (2) recalling scale, and (3) structured interview form. The quantitative data collection tools of the retelling scale and recalling scale were used to measure students' VR and RC skills in a real environment, and the qualitative data collection tool of structured interview form was used to get students' opinions on reading activity in the VR environment.

The study used Morrow (1985)'s 10-point scale to score the retelling variable. This scale measures the reader's ability to retell the story in a structured way. According to this measurement, the story structure consists of the setting, theme, plot parts, analysis, and sequence. Participants can score a maximum of 10 overall retelling points from the scale. Morrow (1986) reported *Cronbach's alpha* (α) value of the scale's reliability coefficient as .90. To verify the scale's reliability, the α coefficient was re-calculated within the scope of the research. The α = .88 value obtained in the calculation shows satisfactory reliability. Table 1 presents the retelling questions.

Table 1. Retelling Questions

Questions	Comments
What emotion is emphasized in the story?	Theme
When did the story take place? Day or night, summer, or winter?	Setting
Where did the story take place?	Setting
What was the main character's name?	Analysis
How did the main character try to solve his problem? (What did he do before and after?)	Plot parts
How did the story end?	Sequence

This study was based on the method proposed by Leslie (1993) to measure the recall level. Leslie (1993) designed a total of six questions, three of which are implicit and three explicit. While answers to open-ended questions can be found explicitly in the text of the book, answering implicit questions requires inferences from previous information and clues in the book.

To verify the reliability of the scale, *Cronbach's alpha* value was re-calculated. The value of $\alpha = .93$ calculated in this context shows that the reliability is relatively high. Table 2 presents the questions related to the recalling variable. To reveal the pre-test results of the participants, questions like the questions in Table 1 and Table 2 were asked about the selected story.

Table 2**.** Recalling Questions

Question type	Questions	Comments
Explicit	What is it that Hasan lacks or misses in the story?	Recall of details
	What emotion, situation, or thought might lead Hasan to what he longed for?	Interpretation of feelings
	What could be the reason for Hasan's silence despite starting to understand Arabic?	Interpretation of feelings
Implicit	How have the geographical places in the story changed?	Problem-solving
	What longing did "*Eskici"* satisfy for Hasan?	Recall of details
	How would you feel if you were in Hasan's place?	Cause-and-effect relationship
	How have the geographical places in the story changed?	Recall of details

To reveal the experiences of the participants in the experimental group, the researchers created a structured interview form. Table 6 shows the questions in this qualitative data collection form. Two field experts checked the interview questions. Besides, a Turkish language expert checked the questions for spelling and expression problems. After a pilot study was conducted with two undergraduate students, the interview form was finalized. Only participants who read with VR glasses answered the structured interview form.

Implementation and data collection process

To reveal the pre-test results regarding the participants' RC skills, the first story was read to the experimental and control groups in a classroom environment. The reading process took approximately 15 minutes. Students who completed the reading activity were presented with retelling and recalling scales. The data collection process was completed in approximately 15 minutes. Then the experimental process started.

Two reading activities, (1) VR-based and (2) paper-based, were administered in the

experimental process. While the students in the experimental group read the selected story alone in a special room through VR glasses, the students in the control group read it all together on paper in the classroom environment.

The students in the experimental group rehearsed to gain reading skills with VR glasses before reading in the VR environment. Students used ready-made content in *Meta Quest*'s library for about 15-20 minutes to gain an inclination to read with VR glasses. Thus, the participants learned how to use the glasses set by experiencing the functions of the glasses and control devices. Students who completed the rehearsal period moved on to reading the VR book and read the story for 15 minutes. The reading process with VR glasses was carried out in a room of approximately 5 m^2 and a temperature of 25ºC. Since the number of VR glasses used in the study was limited to one, the data were collected one by one from the students in the experimental group. Figure 3 shows the development and use of the VR book.

Figure 3. The process of developing and using the VR book

Then the data collection process started. In addition to the retelling and recalling scale, the interview form, the details of which are shown in Table 6, was also presented to the students who completed the reading activity. Each student completed the data collection tools in approximately 20 minutes.

The students in the control group came together in a classroom to perform the reading activity. Each student who came to the class took a printout of the selected story and read it for 15 minutes. After the reading activity, students filled out the retelling and recalling scales. The process was completed in approximately 15 minutes.

Data analysis process

The data analysis process of this study includes the steps of (1) analysis of quantitative data and (2) analysis of qualitative data.

During the quantitative data analysis, first, a field expert read the answers to the retelling scale given by the students in the experimental and control groups (6 items) and the recalling scale (7 items) and evaluated the items in the scales over 10 points. The retelling score was obtained from the sum of 6 items, and the recalling score was obtained from the sum of 7 items. Then, the researchers converted these two total scores into a hundred system for ease of evaluation. The researchers averaged the scores obtained with the retelling and recalling scales to obtain data showing RC levels.

It was observed that the *Kolmogorov-Smirnov* test results of the pre-test RC data met the normal distribution condition, and the variances were homogeneous (p = .186; p > .05). Accordingly, independent samples *t-test* was used to determine whether there was a

significant difference between the averages of the pre-test results of the groups. As a result of the analysis, there was no significant difference between the averages of the experimental (M = 57.92, SD = 16.59) and control (M = 59.80, SD = 17.49) groups (t (96) = .564, p = .586).

The *Kolmogorov-Smirnov* normality test result on post-test data showed that the p significant value of all variables was $p < .05$. According to this result, it was understood that quantitative data should be analysed with non-parametric tests in the study since the quantitative data did not show a normal distribution. Accordingly, the *Mann-Whitney U* test was used to find the difference between the experimental and control groups.

In the qualitative data analysis, the researchers used the content analysis method, which is a method in which data are categorized and logically designed, and themes that can explain the data are obtained (Klenke, 2008). Two researchers analysed the qualitative data, determined the codes, and gathered these codes under categories. The statistical method used to measure the reliability of the agreement between the two researchers coding in the study is *Cohen's kappa coefficient* (Cohen, 1968). In the study, *Cohen's kappa value* was calculated as 0.87, which showed that the study's coding process was reliable.

Results

This section presents the results obtained because of the data analysis within the framework of the research questions.

Differences in RC skills of students depending on VR and paper-based reading

Table 3 shows the results of the *Mann-Whitney U* test, which reveals whether the difference between the RC skills of the two groups is statistically significant. According to Table 3, the mean RC of the participants who did the paper-based reading in the control group (M=58.01; SD=20.34) was higher than the mean RC of the participants who did VR-based reading in the experimental group (M=40.65; SD=23.07).

Table 3. Results of Participants' Reading Comprehension Skills

Group	N	Mean Rank	Mann-Whitney U	p (2-tailed)	μ^2
Experimental	48	40.65	775.0	.002	.31
Control	50	58.00			

The results indicate that this difference between the two groups regarding the general comprehension level is statistically significant. Besides, according to the calculated effect size value (μ^2= .31), the effect of this difference is also high.

Differences in retelling and recalling skills of students

Table 4 shows the results of the *Mann-Whitney U* test, which reveals whether the difference between the retelling and recalling skills of the experimental and control groups is statistically significant. According to Table 4, both retelling and recalling scores of the participants in the control group were higher than the students in the experimental group.

Table 4. Results on Retelling and Recalling Scores of the Groups

Variable	N	Mean Rank	Mann-Whitney U	*p* (2-tailed)	μ^2
Retelling			894.5	.028	.22
Experimental	48	43.14			
Control	50	55.61			
Recalling			805.5	.004	.28
Experimental	48	41.28			
Control	50	57.39			

The results show that these differences are statistically significant (p <.05). According to the effect size values, the effect of these differences is moderate for retelling (μ^2 = .22) and high for recalling (μ^2 = .28).

What are the opinions and experiences of the students about the reading activity in the VR environment?

Table 5 shows the questions asked to the students to reveal their experiences. The positive and negative factors were determined by analysing the students' answers to these questions. In particular, the identified negative factors provide an understanding of what caused the difference in retelling and recalling scores between VR and paper-based reading comprehension activities.

Table 5. Opinions and Experiences of Participants Who Participated in VR Reading Activities

Questions	**Positive**		**Negative**		**Category**
	Code	***f***	**Code**	***f***	
What do you think about the VR environment?	Realistic, clear, different, fantastic, and remarkable environment	49	Partially emerging sounds in the practice environment	3	Physical environment
			The font size and style of the book, the effect of turning pages, limited animations	3	Software
			Heavy headset, poor usability, and difficult adjustment of straps	6	Hardware
			VR equipment causes headaches, eye strain, and tearing	5	Side effects
What did you feel during your experience in VR?	Happy and exciting, realistic, calm, different, and fun environment	39	Creating excitement, fear, tension, difficulty, uneasiness, and a strange feeling	5	Affective effects
			Difficulties in adaptation and the reading process	3	Experience-related adaptation problems
			Causes dizziness and headaches	7	Side effects
What are your opinions on VR hardware and components?	Realistic, good visibility, and a clear environment	41	The image is a bit blurry, and the laser pointer object is tiring the eyes	13	Software
			The headset is difficult to control and heavy, the head straps are uncomfortable, and the hand controls are a bit large	13	Hardware

			Difficult use of the headset for glasses wearers	7	Individual factors
Did you encounter any problems or difficulties in the process of experiencing VR?	No	37	The poor writing style of the VR book and the low resolution of the title	5	Software
			The headset is heavy and difficult to place on the head	4	Hardware
			Difficulties in adaptation due to first-time experience and reading difficulties	5	Experience-related adaptation problems
			Causing pain and tearing in the eyes and giving a feeling of drowsiness	3	Side effects
Do you feel you can focus enough on a task in VR?	Yes	33	No	16	-
			The image resolution is not clear enough	11	Software
			Difficulty in adaptation due to the first experience, creating excitement, lack of focus, and feeling of distancing from the environment	3	Experience-related adaptation problems
			The distraction of partially emerging sounds in the practice environment	2	Physical environment
Did anything distract you during the process of experiencing VR?	No	33	Yes	17	-
			The image resolution is not clear enough, the laser pointer object is present, the page-turning effects are not liked, and the environment feels cluttered	10	Software
			The headset does not fit well on the head	5	Hardware
			The human presence in the application environment, partly due to the presence of sounds and the excitement associated with the first experience	2	Physical environment
What are your opinions on the process of interacting with objects in VR?	Realistic, fun, exciting, and beautiful experience	38	Limitation of interaction options	4	Software
			Heavy headset	2	Hardware
			VR equipment causes headaches	1	Side effects

According to the results, the majority (~73%) of the participants who read in a VR environment expressed positive opinions about the VR application. The participants stated that they enjoyed using the environment, had a very realistic experience, and that the VR environment was different, fantastic, and fun. In addition, many of the participants stated that they did not encounter any difficulties and that they were able to focus sufficiently on the reading activity. The opinions and experiences of the participants were presented with a code indicating gender and sequence number (e.g., M1: male 1, F5: female 5). Accordingly, some participants expressed their opinions as follows:

> *"The VR environment was stimulating. I enjoyed reading the book, it was a happy experience for me..."* (M5).
> *"The environment was beautiful, realistic, and fun. I was able to read the book [VR book] comfortably and enjoyably. The viewing angle was excellent..."* (F6).

On the other hand, some of the participants (~27%) who read books in a VR environment reported negative opinions about the VR application. For instance, they stated that they encountered various issues in the process of reading the VR book. These kinds of challenges were grouped under the following seven categories: (1) software, (2) affective effects, (3) hardware, (4) individual factors, (5) experience-related adaptation problems, (6) side effects caused by VR application, and (7) the physical environment in which the VR is used. Most of the participants who expressed negative opinions about the VR application complained about the usability problem of the VR headset. For instance, they stated that the headset was heavy, the straps were uncomfortable, the resolution quality was not good, and it was difficult to control. They also expressed that they were not satisfied with the font style and size of the VR book, the viewing angle was not enough, the image was sometimes blurred, they were negatively affected by the presence of the laser pointer object, and they did not like the page-turning effects. Some participants reflected their opinions on these issues with the following statements:

> *"I had a hard time putting the headset on my head. It was a bit heavy. Sometimes I could see blurry, and the viewing angle and resolution of the headset were not good..."* (F11).
> *"I did not like the writing style and size of the book. Different fonts could have been chosen. I was sometimes distracted by the sound of turning the pages and the laser pointer..."* (M12).

Some participants highlighted that they felt uneasy, nervous, excited, and scared, had difficulty adapting to the environment, and were effectively affected because they experienced the VR environment for the first time. One participant reflected on their opinion about this situation by using the following statement:

> *"I was very excited to do a reading activity in such an environment [VR environment] for the first time. I felt like I was in a strange place... I wanted the application to end as soon as possible..."* (F6).

Some participants experienced various health problems while experiencing the VR environment. Participants stated they were exposed to side effects such as headache, dizziness, nausea, tearing, fatigue, and drowsiness while using the VR device. One participant expressed their opinion about this situation with the following statement:

> *"I had a burning and stinging sensation in my eyes. I also had a headache and felt nauseous. So, sometimes I couldn't focus on reading..."* (M17).

Although very few (*f*=3), some participants stated that they were not satisfied with the physical environment in which the application was carried out and suggested that the environment should be quieter and warmer.

> *"Since the window of the room was open, I was disturbed by hearing my friends' conversations outside and the cold air coming from the window while I was reading…"* (M4).

Discussion

This study examines the reading performance of higher education students in VR by comparing RC skills in VR and paper-based and reveals the barriers on students' readings in VR. The quantitative results revealed that the RC skills of students who read paper-based were higher than the students in the VR group. Moreover, there was a significant difference between the retelling and recalling scores of the students in the two groups in favour of the control group (paper-based readers). Analysing the opinions of VR-based readers provided a better understanding of why reading in VR is complex and what can be done to make it easier.

Flores-Gallegos et al. (2022) concluded that VR environments had no significant effect on reading performance. Contrary to this, some studies reported that VR-supported environments positively affect RC performance (Kaplan-Rakowski & Gruber, 2024). Therefore, the design of the VR book and the interaction options offered by the VR equipment to the user may be another factor affecting readers' RC performance. In the literature, the design of books supported by technologies such as VR in the context of teaching principles (Kao et al., 2016) and the usability features of VR equipment effectively provide readers with a pleasant user experience (Danaei et al., 2020). Besides, students' first reading activity in a VR environment and the emotions such as excitement, fear, and uneasiness that arise due to the first experience may be another factor affecting their RC performance. The reason is that the challenges users face in adapting to the VR environment may cause them to exert more mental effort to encode information. Due to this effort, which is defined as cognitive load in the literature, students may have missed the meaning of the story as they would focus more on reading the story correctly (Frederiksen et al., 2020). On the other hand, some researchers state that when a large amount of printed text is blended with multimedia content and presented to the user, the cognitive load decreases, increasing the story's comprehension (Kao et al., 2016). Therefore, the fact that the VR book presented to the students was presented in plain text format without being supported by multimedia components such as graphics, videos, and animations may have affected the story comprehension performance of the students (Meniado, 2016).

There are many challenges to using technology (Ozmen et al., 2023). Some studies have shown that reading from a screen on a technological device such as VR can distract users and harm reading performance compared to paper (Clinton, 2019; Liu, 2022). Various meta-analysis studies comparing reading on traditional paper and screens emphasize the advantage of paper-based reading (Delgado et al., 2018). In this direction, students' RC performance may have been negatively affected due to reading from a screen on technological equipment.

In the study, it was observed that the recalling skills of the students in the control group had a higher impact value than the retelling skills of the participants in the VR group. In the context of retelling, questions usually consist of knowledge-based questions with concrete answers in the story. However, questions in the recalling type consist of questions based on understanding and interpretation. Considering the overall RC scores of the students in the VR group, the students in the VR group may not have been able to answer the questions about interpreting and inferring the story correctly at the desired level because they understood the story less than the control group.

Baceviciute et al. (2021) reported that reading in a VR environment is a cognitively more laborious and challenging process. Both quantitative and qualitative results of this study support this difficult and laborious situation. Students' lower RC performance in VR may have stemmed from side effects such as headache, nausea, and eye discomfort they experienced during the VR application process. These side effects, defined as *simulator*

sickness in the literature, usually occur when users watch the movements of objects on a screen in hardware such as VR (Kim et al., 2018; Wienrich et al., 2022). In this context, users experiencing a VR environment may experience common symptoms such as discomfort, drowsiness, vomiting, and nausea, as well as more visual and visuomotor symptoms such as eyestrain and dizziness.

The findings of this study provide critical insights into the use of VR technology in education. By comparing reading performance in higher education between VR and paper-based methods, the results show that paper-based reading is more effective than VR reading. This highlights the need for a cautious approach when integrating VR technology into educational settings.

The study's findings offer education policymakers and technology developers opportunities to develop strategies for optimizing VR reading materials. Additionally, analysing student feedback helps identify specific areas for improvement to make the VR reading experience more accessible and effective. This study provides valuable insights into the current state and future potential of VR in education, contributing to the more effective and widespread use of educational technologies.

Limitations

While evaluating the results of this study, the following six limitations should also be considered. Firstly, in this study, students in the VR group performed reading activities for the first time and in a limited time interval. However, RC skill is a skill that requires a long time to develop. Therefore, although there were significant differences in RC skills between the experimental and control groups, it is predicted that an intervention covering a more extended period is needed to improve students' reflection and evaluation of RC skills.

Secondly, there were some limitations in terms of the interaction options offered in the VR learning environment. For instance, students used the version of a typical e-book in the VR environment. The developed VR environment had limited multimedia components such as audio, graphics, video, and animation. Moreover, the VR environment does not include the ground in the real world and the objects people commonly see around them.

Thirdly, the story content presented is not sufficiently supported by other multimedia components. Therefore, designing a VR learning environment with interactive functions can be a guiding option for future research.

Fourthly, the individual characteristics of the students participating in the research process, such as age, education level, and VR experience, can be regarded as a limitation. The reason is that students' affective reactions (such as excitement, fear, and uneasiness), attitudes towards reading in the environment, motivation, and self-confidence in the individual context towards the VR experience may have affected their RC skills in the VR environment.

Fifth, some factors, such as the presence of researchers in the environment and students' entry-exit circulation, may have negatively affected readers' concentration during the reading process in the VR environment.

Finally, another issue that should be considered to generalize the results obtained in the study is the limited number of participants in the study. Depending on the number of participants, the results of the study may vary.

Conclusions

This study experimented to investigate higher education students' RC skills in a VR environment. To this end, the retelling and recalling skills of two groups of students who read a story in VR (experimental group) and on paper (control group) were measured, and the opinions of students who read in VR were collected. The quantitative analysis results showed that the retelling and recalling RC scores of the control group (paper readers) were higher than the experimental group (VR readers). Qualitative data were used to explain what might have caused this difference, which was revealed with quantitative data in the research. In this direction, seven issues encountered by the participants during the VR experience were revealed and the reasons for these difficulties were discussed in the study. Thus, based on the opinions of the students (shown in Table 6), this research presents very important findings on how to improve the reading comprehension and recalling skills of the students in the VR environment and what should be considered to increase the usability of VR technology.

In conclusion, this study supports using VR technologies as an auxiliary tool for teaching higher education students and reveals that VR and flipbook technologies should be further developed to increase students' RC skills. It is vital to increase the usability of VR equipment, reduce the simulator sickness effect, and develop solutions for instructional design in a VR environment. In this direction, to ensure that students' reading comprehension skills are high, the following four suggestions regarding future studies may be helpful for designers, researchers, system (VR) developers, decision-makers, educational policymakers, and educators.

- The results of this study can guide to improvement of students' RC skills in VR for first language educators, language and literature teachers, instructional designers, engineers producing VR equipment, instructional designers developing learning content for VR, and other stakeholders.
- Further studies on the development of RC skills in VR are needed. For example, new research could be conducted on how students' RC performance is affected when there are interactive options supported by multimedia components rather than just plain text in VR or when 3D images are used in VR books. Besides, although it is stated in the literature that reading in VR is a cognitively more demanding and challenging process (Baceviciute et al., 2021), new research can be conducted to reveal techniques that reduce the cognitive load of learners.
- Since students' learning in the VR environment differs according to gender (Yeh et al., 2018), future research could seek answers to whether there is a difference between reading levels in VR environments based on gender.
- The integration of immersive VR equipment into classroom environments can be a costly and challenging process. Therefore, before integrating technologies such as VR into classroom environments, it may be useful to provide an optimum time interval for students to adapt to these environments and to identify possible negative situations they may encounter in advance.

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