A Review of Research on the Design of IVR Reading Experiences for High-Cognitive-Load Texts

Yining Cheng[1], Jing Lu[1*]

[1]Jiangnan University, Wuxi, China
**Corresponding Author. Email: luqing@jiangnan.edu.cn*

Abstract. Compared with traditional paper reading and screen reading, Immersive Virtual Reality (IVR) provides new media and new experiences for reading. For high-cognitive-load texts such as ancient books, philosophy works and professional materials, reading needs continuous attention, meaning understanding and logical thinking. These texts also need stable and continuous reading conditions. This paper systematically reviews the current situation, main research points, basic structure and future directions of IVR reading experience design for high-cognitive-load texts. Existing studies show that IVR reading experience is not only decided by immersion. It is closely related to text interface, interaction control and virtual environment. This paper holds that the key of IVR reading design for high-cognitive-load texts is not to simply increase immersion. It is to support text understanding through text interface, interaction control and virtual environment. We need to balance immersion and text understanding. IVR should change from an immersive display medium to a reading medium that helps people understand complex texts deeply.

Keywords: high-cognitive-load texts, Immersive Virtual Reality, IVR reading, reading experience design, deep reading

1. Introduction

Digital technology keeps changing the way people read. From paper to screen, and then to immersive reading with head-mounted devices, reading is no longer only simple linear reading on a flat interface. It slowly becomes a complex situation with space feeling, environment atmosphere and body interaction [1]. Some review studies show that IVR use in education and training has changed. At first, people only tested whether the technology can work. Now they study learning process, user experience and task matching in more detail [2]. This means, when we talk about IVR reading today, the main question is not only "can we read text in IVR". It is "what kind of text, in what environment, with what design method, can be read effectively".

High-cognitive-load texts, such as ancient books and philosophy works, usually have high meaning density, short structure, complex logic and unclear explanation. When readers read these texts, they not only need to understand words and sentences. They also need to connect context, think about concepts and rebuild the situation. Cognitive load theory tells us that people have limited resources when processing information. If a task already uses many necessary resources, and

then extra useless stimulation is added, it will easily influence effective learning and understanding [3,4].

This risk is more obvious in immersive environment. Multimodal learning theory says that words, pictures, sounds and situation clues are not just put together. They should be organized well to support the main task [5]. When multi-channel information in immersive environment works well with reading goals, it may help readers build reading situation, increase attention and improve information organization. On the other hand, if environment information competes with the main text task, it may add extra burden and stop deep processing.

Based on this, this paper uses the literature review method. It searches and studies papers from databases such as CNKI, Web of Science, Scopus, Google Scholar. These papers are about immersive VR reading, text readability, interaction design, cognitive load and virtual environment influence. This paper mainly looks at important studies about IVR text reading experience in the past ten years. It also analyzes these studies with the task features of high-cognitive-load text reading. This paper focuses on IVR reading experience design for high-cognitive-load text reading. It reviews the development and current situation of immersive reading research. It analyzes special requirements of high-cognitive-load texts for IVR design. Then it summarizes the basic structure, key influence factors and main research points of IVR reading experience. On this basis, it puts forward future research directions. The goal of this paper is not to build a closed design model. It is to form a clear problem map based on existing papers. It aims to provide more targeted reference for related research and design practice.

2. Development and current status of IVR reading experience research for high-cognitive-load text reading

2.1. The rise of high-cognitive-load text reading as a subfield in IVR research

We need to study high-cognitive-load text reading separately in IVR experience design. It is not only an extension of reading research. Many studies show that VR is useful in education. But these studies are about common learning tasks, experience and interest. They cannot explain high-cognitive-load text very well.

Early VR research mainly focused on training, skill practice, games, industry and other fields. Later it slowly spread to education. Many studies now show that IVR teaching can improve learning interest, experience and some learning results [6].

But this good effect does not always appear in all learning tasks. Researchers begin to notice that immersion and interaction may cost extra cognitive resources. Petersen et al. show that immersion and interaction do not always bring better learning. They can increase motivation, but also bring extra trouble [7]. Poupard et al. reviewed 36 studies. They say IVR can improve learning motivation, but also bring too much extra cognitive load. This is especially bad for new learners. It can stop good learning [8].

So we can see: past studies mainly talk about common education. They study interest, experience and results. But for high-cognitive-load texts that need long attention and deep thinking, we still do not know clearly whether immersion helps or troubles. Because of this research gap, high-cognitive-load text reading becomes a special subfield in IVR research.

2.2. Research characteristics and design difficulties of high-cognitive-load text reading

High-cognitive-load text reading is special. It needs long attention, deep processing and information integration. Unlike common texts, ancient books, philosophy works and professional materials have high meaning density, short structure, complex logic and unclear understanding ways. Readers need to know words and sentences. They also need to connect context, understand ideas and think logically. Cognitive load studies say: when a task uses many necessary resources, extra useless stimulation becomes extra burden and hurts understanding [9]. This is very true for high-cognitive-load texts.

This task means IVR reading for such texts needs higher quality. If reading is broken, readers must use extra effort to connect context again. Such reading needs not only clear text, but also stable and low-trouble reading and thinking for a long time. Multi-modal Learning Theory says designers should organize words, pictures, sounds and touch well. They should reduce useless information and show key information. This helps people get information quickly [10]. When high-cognitive-load texts are in IVR, design difficulties become bigger. Ak reviewed IVR for "serious games". He says when making IVR applications, we should use different learning theories for different learning objects to get the best learning effect [11]. So we cannot use common IVR learning or digital reading design for high-cognitive-load texts. We need special design ideas for continuous, focused and understandable deep reading.

2.3. Evolution and existing deficiencies of IVR research for high-cognitive-load text reading

From existing papers, IVR reading research for high-cognitive-load texts is not a completely independent big field. But its research questions have appeared in common immersive reading research. Early studies mostly came from immersive learning, information showing and common reading. They mainly studied whether immersion can improve information efficiency, reading interest, or text clearness and readability. These studies help us understand basic IVR features. But they often study short-time tasks and common texts. They do not pay enough attention to continuous understanding and cognitive stability in complex text reading.

For ancient books, philosophy works, professional materials and other high-cognitive-load texts, reading needs not only clear text. It also needs long attention, meaning integration, logic and low-interruption reading. So compared with common reading, such texts need more from immersive reading systems: basic clearness and easy use, and also less extra cognitive burden from media, operation and environment.

In general, present studies still use the design logic of common immersive learning and information showing. They do not pay enough attention to the special features of high-cognitive-load text reading: task structure, continuous understanding and cognitive load control.

3. Basic structure of IVR reading experience design for high-cognitive-load texts

Earlier studies mainly talked about specific influencing factors. But if we want to better explain how IVR reading experience works for high-cognitive-load texts, we need to organize these factors into a clear structure. Existing studies do not have the same structure, but they mainly focus on three connected parts. One part is the readability of the text itself, such as words and layout. Another part is interaction and control in IVR, which mainly influences reading continuity and cognitive load control [12,13]. At the same time, some studies say virtual environment influences attention and reading experience. Following this idea, as shown in Figure 1 "Structure Model of IVR Reading

Experience for High-Cognitive-Load Texts", this paper divides IVR reading experience into three connected levels: text interface level, interaction control level and virtual environment level. This helps us clearly understand the role and relationship of different design elements in reading.

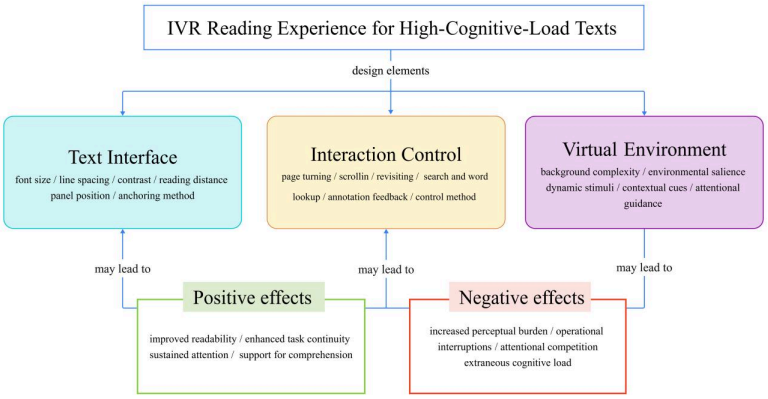

Figure 1. Structure model of IVR reading experience for high-cognitive-load texts

3.1. Text interface level: direct carrier of reading tasks

Text interface level directly helps text understanding. For reading, text interface first carries word information. Some studies say text readability in space is strongly influenced by text display, background, light and so on. If readers cannot see and recognize text stably, they cannot understand it later [14]. So the most important task of text interface is to let users feel words clearly, stably and with low burden [15].

Rau et al. studied fast reading in VR/AR. They found text size, display device and reading speed strongly influence reading result [16]. Kojić et al. studied proper text distance, size and contrast in VR. They said comfortable reading does not happen naturally; it needs parameter adjustment [17]. Novotny et al. also found text position and visual situation in virtual space influence reading speed and eye stability [18].

In high-cognitive-load text reading, readers need a clear, continuous and stable reading interface. These texts are already hard to understand. If the interface gives extra visual burden, it will reduce cognitive resources for understanding ideas and context. So text interface level is not a small part in immersive reading. It is the core starting point of the whole reading experience.

3.2. Interaction control level: rhythm regulator of reading process

If text interface level decides "whether users can see clearly", then interaction control level decides "whether users can read smoothly". In IVR reading, page turning, scrolling and searching are usually done by controller, hand gesture, eye control or space menu. So interaction is not just a technical action for showing content. It directly influences reading rhythm.

For high-cognitive-load texts, interaction control level is more important. Reading these texts needs continuous meaning follow-up and logic progress. If complex operations break reading at important places, readers need extra effort to rebuild understanding [19]. When reading needs extra operation decisions and visual processing, users spend more cognitive resources on navigation and operation. These operation changes can break understanding and reduce reading continuity [20]. Operations like page turning, looking back, word checking, note taking should help reading. But bad

design can make them "break points" in reading [21]. For high-cognitive-load text reading, interaction control should first support continuous understanding, not new or strong space feeling [22]. In an ideal situation, users can do necessary operations naturally and with low burden, without always feeling that they are "operating the system" [23].

3.3. Virtual environment level: both immersion and attention influence

Virtual environment level is the biggest difference between IVR reading and traditional digital reading [24]. Space structure, background objects, material details, light and shadow, color and sound together make the immersive situation. Environment is not just for decoration. It can increase feeling of entering, presence and situation support. Especially for texts with culture or history background, proper environment clues help reading expectation and mental investment [25].

But at the same time, virtual environment level can easily compete with reading tasks. If environment is too strong, has too much information or too many continuous movements, it is no longer just background. It becomes something users need to see, process or even explore. Cauz et al. reviewed AR text readability. They said background complexity, separation between text and background, and visual rules in environment all influence text readability and information efficiency [26]. In Kaplan-Rakowski and Gruber's study, students using simple and clear VR environment had better reading understanding and motivation than the control group, and cognitive load did not rise much. This shows well-controlled visual environment helps focus and understanding [27]. For high-cognitive-load texts, if environment is too "interesting", it competes for attention more easily than with common texts. Cognitive resources for understanding and thinking are divided. So virtual environment level has two roles in IVR reading for high-cognitive-load texts: it can support immersion, but also bring attention trouble. Design for this situation does not just decide "whether to use environment". It needs to answer "how environment helps text reading".

4. Future research directions

In recent years, IVR reading research has changed from discussing technical possibility to task fitting and experience improvement. But research on high-cognitive-load texts is still in the developing stage. Existing studies provide an important basis for understanding text display, interaction organization and environment control in immersive environments. But there is still room for improvement in research objects, process measurement and design fitting. At present, most related studies use common explanatory texts, speed reading tasks or low-complexity materials. There is still not enough systematic discussion on high-cognitive-load texts such as ancient books, classical Chinese texts, philosophical works and professional theoretical materials. Different types of high-cognitive-load texts are very different in meaning density, structure and dependence on background knowledge. Their needs for immersive environments should not be regarded as the same. So future studies should further compare the suitability of different design conditions in more text types and reading situations.

At the same time, existing studies still mainly use result indicators such as reading performance, comprehension tests and subjective questionnaires to evaluate IVR reading effect. They still lack enough process measurement and mechanism analysis of attention distribution, cognitive load change and environment interference during reading [28]. For high-cognitive-load texts, the really important question is not only "whether readers finish reading" or "whether readers feel it easy to read". The key is whether readers can keep continuous understanding and stable reasoning during

reading. Future studies can further strengthen the dynamic observation of the reading process. This can push related discussion from the result level to the mechanism level.

Besides, IVR reading design for high-cognitive-load texts should not only look for a fixed "best solution". High-cognitive-load text reading has clear stages. Different reading stages need different interface, interaction and environment. Users are also different in IVR experience, reading habits and attention ability. So future research should pay more attention to the matching between design conditions, reading stages, text types and user characteristics. This can change IVR reading from general immersive display to a more targeted deep reading support system.

5. Conclusion

IVR reading experience design for high-cognitive-load texts is essentially about finding a balance between immersion and reading comprehension. Existing studies show that immersive VR is not naturally better than traditional reading media. Its value can be improving situation feeling, participation and reading engagement. But it can also disturb understanding through environment stimulation, interaction burden and extra information. This double character is especially obvious for high-cognitive-load texts with high meaning density, complex logic and unclear understanding paths. Because such reading needs continuous, stable and low-interruption cognitive processing.

From existing research, the focus of IVR reading research has gradually changed from technical usability and stronger immersion to task fitting and experience optimization. Based on related studies, this paper divides IVR reading experience for high-cognitive-load texts into three connected levels: text interface level, interaction control level and virtual environment level. Among them, text interface level decides whether reading can be clear and low-burden. Interaction control level influences reading rhythm, operation smoothness and understanding continuity. Virtual environment level decides whether environment supports reading or competes for attention with the text. What really affects reading quality is not the number of immersive elements. It is whether these design elements work together to support text understanding.

Therefore, IVR reading design for high-cognitive-load texts should not take "stronger immersion" as the only goal. It should take "supporting deep reading" as the core direction. It should balance clear interface, simple interaction and quiet environment. Future studies should further observe different text types, reading stages and user differences. They should use process measurement to show the dynamic mechanism of reading experience. Only on this basis can IVR reading change from a new immersive display to a real reading medium for understanding complex texts.

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