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# A STUDY ON THE IMPACT OF VIRTUAL REALITY (VR) IMMERSIVE ENVIRONMENT ON SECOND LANGUAGE ACQUISITION EFFICIENCY: FROM THE PERSPECTIVE OF COGNITIVE LOAD AND CONTEXTUAL MEMORY

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## ABSTRACT

*This study provides a comparative analysis of Virtual Reality (VR) immersive environments and traditional instructional methods in the domain of Second Language Acquisition (SLA), with a specific focus on cognitive load and contextual memory as critical determinants of learning efficiency. Drawing upon a synthesis of recent empirical research and theoretical frameworks such as Cognitive Load Theory and context-dependent memory models, the paper examines how immersive VR learning environments can influence language retention, learner motivation, and the transferability of acquired skills to real-world communication contexts. Findings from the literature indicate that VR-assisted learning offers substantial benefits in enhancing contextual memory retention, primarily due to its capacity to provide authentic, situationally relevant, and multisensory learning experiences. These immersive qualities not only facilitate deeper encoding of linguistic input but also improve recall through environmental cueing. However, the increased intrinsic and extraneous cognitive load associated with navigating and interacting within VR environments may hinder learning efficiency, particularly among novice learners or individuals with limited working memory capacity. The analysis suggests that the optimal pedagogical application of VR in SLA may lie in a blended learning model, where immersive VR experiences are complemented by traditional methods that emphasize focused skill reinforcement, grammar instruction, and controlled practice. Such integration can maximize the motivational and contextual benefits of VR while minimizing the risks associated with cognitive overload. This research highlights the need for deliberate instructional design and further longitudinal studies to explore adaptive VR approaches tailored to diverse learner profiles.*

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**KEYWORDS:** Virtual Reality, Second Language Acquisition, Cognitive Load, Contextual Memory, Comparative Analysis.

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## 1. INTRODUCTION

Virtual Reality (VR) has emerged as a promising technological tool in language education, offering learners immersive experiences that closely replicate real-world communication contexts. The potential of VR in Second Language Acquisition (SLA) lies in its ability to provide rich situational cues, multi-sensory engagement, and interactive learning opportunities. However, VR learning environments also pose challenges related to cognitive load management. Excessive sensory input and complex navigation tasks can impose additional mental demands, which may hinder learning efficiency if not properly managed.

This study adopts a comparative analysis approach to examine the impacts of VR versus traditional 2D or classroom-based learning, focusing specifically on cognitive load and contextual memory. While traditional methods often emphasize linguistic accuracy and repetitive practice, VR environments introduce an experiential dimension, potentially leading to more robust memory encoding but also higher demands on working memory.

Second language acquisition (SLA) is a multifaceted cognitive and social process that involves mastering vocabulary, grammar, pronunciation, pragmatic skills, and cultural nuances. Traditional language learning methods—such as classroom lectures, textbook exercises, and multimedia lessons—often provide limited exposure to authentic communicative contexts. While these approaches can be effective for foundational knowledge, they typically lack the situational depth, sensory engagement, and real-time interaction that occur in natural language use. Consequently, learners may acquire theoretical knowledge of a language but face difficulties applying it effectively in real-world scenarios.

In recent years, technological advancements have introduced new tools to address these challenges. Among them, Virtual Reality (VR) has emerged as a transformative medium, capable of simulating realistic, interactive, and immersive environments that bridge the gap between classroom learning and authentic language use. VR platforms can place learners in culturally and linguistically rich settings—such as marketplaces, transportation hubs, or social gatherings—where they must engage in communication that closely mirrors real-life experiences. This immersive approach aligns with situated learning theory, which asserts that knowledge is best acquired when embedded within the context of its application.

However, the effectiveness of VR for SLA is not

solely determined by its ability to provide immersion. Learning outcomes are also influenced by cognitive factors, particularly cognitive load and contextual memory. According to Cognitive Load Theory (CLT), the human working memory has a limited capacity, and excessive mental effort—whether from complex tasks, distracting visual stimuli, or unfamiliar interactions—can hinder the learning process. Poorly designed VR environments, with overly complex interfaces or irrelevant stimuli, may overwhelm learners, reducing their ability to process linguistic information effectively.

On the other hand, contextual memory theory highlights how environmental cues—such as background sounds, spatial arrangements, and object associations—can enhance information retrieval. VR's capacity to replicate contextual cues offers a unique advantage in SLA: learners can associate new words and structures with specific sensory and situational experiences, thereby improving long-term retention. For instance, learning the word "menu" while holding a virtual menu in a restaurant simulation not only reinforces vocabulary through repetition but also anchors it in a memorable sensory context.

The interplay between these two factors—cognitive load and contextual memory—represents both an opportunity and a challenge. While VR has the potential to create optimal learning environments rich in contextual cues, it must be carefully designed to avoid overburdening the learner's cognitive resources. This study investigates how immersive VR environments influence SLA efficiency by balancing these cognitive dimensions, aiming to provide insights for designing VR-based language learning systems that are both engaging and pedagogically effective.

## 2. RELATED WORK

Lin and Lan (2015) found that learners in VR environments demonstrated better vocabulary retention than those in traditional learning contexts, attributing this to the immersive nature of VR which provides relevant contextual cues. Similarly, Makransky and Lilleholt (2018) observed that immersive VR settings enhanced learner motivation and presence, which positively influenced learning outcomes.

On the other hand, studies by Parong and Mayer (2018) reported that while VR increased engagement, it also elevated extraneous cognitive load due to the richness of visual and auditory stimuli. This aligns with Cognitive Load Theory (Sweller, 1988), which emphasizes that overload can reduce learning

efficiency despite high engagement. In the context of contextual memory, Krokos et al. (2019) showed that VR users retained more information in memory palace tasks compared to desktop users. This suggests that immersive environments facilitate deeper encoding of information through spatial and situational cues. Meta-analyses such as Luo et al. (2021) further support the potential of VR in SLA, reporting medium-to-large effect sizes while highlighting the necessity for careful instructional design to avoid overwhelming learners.

### **2.1. VR and Contextual Memory in Language Learning**

Several studies underscore how immersive VR environments serve as powerful contextual memory cues in language learning. A recent experiment involving VR "memory palaces" demonstrated that when learners associated vocabulary with distinctive virtual settings, their long-term retention soared—up to 92% after one week—even when tested in non-VR environments<sup>1</sup>. This aligns with encoding specificity principles and context reinstatement strategies, where recreating or mentally reinstating learning contexts bolsters recall<sup>2,3</sup>.

Similarly, research using 360° video-based environments revealed that exposure to multiple virtual contexts (decontextualization) significantly reduced forgetting compared to learning within a single static VR environment<sup>4</sup>. These findings suggest that variation in immersive contexts can help circumvent context-dependent memory limitations and improve vocabulary retention across different settings.

### **2.2. Sensorimotor Engagement and Enactment Effects**

Embodied interactions within VR—such as grabbing or manipulating virtual objects—can substantially enhance language learning. A study found that L2 learners who physically “grasped” virtual representations of target words achieved better memorization outcomes compared to those who experienced audiovisual-only conditions. Particularly, learners with lower language aptitude benefited most, likely due to reduced cognitive load via sensorimotor encoding<sup>5</sup>. This is supported by the enactment effect literature, where physically performing an action during encoding enhances later recall<sup>6</sup>.

### **2.3. Motivation, Cognitive Load, And Vr Learning**

A mixed-methods study in business English instruction observed that immersive VR did not significantly alter cognitive load metrics—despite improving motivation and engagement through

simulated business tasks like negotiations and presentations<sup>7</sup>. This highlights a nuanced interaction: VR's immersive affordance can boost motivation and engagement, but its cognitive demands must still be monitored carefully.

Another review of VR's role in ESL oral communication indicated that while VR generally enhances motivation, confidence, creativity, and willingness to communicate, these benefits are sometimes tempered by increased cognitive load, motion sickness, and interface challenges<sup>8</sup>.

### **2.4. Learner Acceptance, Cognitive Absorption, And Vr**

Research examining EFL learners' attitudes and brain engagement during VR-based instruction revealed that immersion significantly improved cognitive absorption—and indirectly, retention—compared to non-immersive settings<sup>9</sup>. This underscores the psychological value of immersion, though it also raises considerations around how deeply learners process information when immersed.

### **2.5. Vr and Oral Comprehension**

Tai and Chen (2021) investigated VR's impact on EFL learners' listening comprehension. They introduced mobile-rendered VR via head-mounted displays and noted that higher immersion correlated with stronger listening performance—indicating that VR tools can support auditory processing in SLA<sup>10</sup>.

## **3. THEORETICAL FRAMEWORK**

The impact of Virtual Reality (VR) on Second Language Acquisition (SLA) can be best understood through the combined lenses of Cognitive Load Theory (CLT) and Contextual Memory Theory (CMT). These frameworks help explain why immersive VR can both enhance and potentially hinder learning, depending on how instructional experiences are designed.

### **3.1. Cognitive Load Theory (Clt)**

Developed by John Sweller (1988, 1994), CLT posits that learning effectiveness is influenced by the mental effort required to process information within the limits of working memory.

**CLT categorizes cognitive load into three components:**

1. Intrinsic Load - The inherent difficulty of the material being learned. In SLA, this might include the complexity of grammatical rules or the novelty of vocabulary.
2. Extraneous Load - The unnecessary mental effort imposed by poorly designed

instructional materials or irrelevant stimuli. In VR, extraneous load may arise from overly complex navigation, irrelevant background visuals, or distracting sound effects.

3. Germane Load – The mental resources devoted to schema construction and automation, i.e., integrating new language elements into long-term memory.

VR can reduce extraneous load by replacing abstract explanations with intuitive, spatially meaningful interactions—such as pointing to objects while naming them. However, poorly designed VR experiences can increase extraneous load, leading to cognitive fatigue and decreased learning efficiency. Research by Makransky et al. (2019) found that well-structured VR instruction balanced sensory immersion with clear instructional goals, producing better comprehension than either low-immersion or high-distraction VR environments.

### 3.2. Contextual Memory Theory (Cmt)

Contextual Memory Theory explains how environmental cues present during learning can facilitate later recall, especially when the retrieval context matches the learning context. This is supported by Godden & Baddeley's (1975) classic study on context-dependent memory, where divers recalled information better in the environment in which it was learned.

#### In VR-based SLA:

- Learners can encode language within rich, context-specific scenes—for example, learning food vocabulary in a simulated restaurant.
- Retrieval is facilitated when the learner encounters a similar context, even outside VR, due to mental reinstatement of the learning environment.

Unlike static classroom visuals, VR allows learners to interact dynamically with context—touching, hearing, and responding to environmental stimuli—which strengthens episodic encoding. Studies (e.g., Schöne et al., 2019) show that such multi-sensory encoding promotes deeper integration of linguistic and situational memory traces.

### 3.3. Interplay between Clt and Cmt in Vr-Sla

#### In immersive language learning:

- Positive synergy occurs when contextual cues support schema building without overloading working memory.
- Negative interference occurs when contextual richness becomes a distraction, raising extraneous load and impairing focus.

For example, a VR street market simulation that

teaches numbers and prices may boost recall if designed with relevant, minimal distractions. However, adding too many unrelated NPC conversations, moving vehicles, and unnecessary sound effects can raise cognitive load beyond optimal levels, negating the contextual memory benefits.

### 3.4. Implications for Vr-Sla Design

#### From this dual-theoretical perspective, effective VR language learning systems should:

1. Align VR scenes with clear pedagogical objectives to ensure contextual cues are relevant to the target language.
2. Minimize extraneous visual and auditory elements that don't directly contribute to the learning task.
3. Support cognitive pacing by controlling task complexity and adjusting immersion to match learner proficiency.
4. Leverage sensory cues for encoding vocabulary and structures in realistic scenarios, promoting retrieval through environmental associations.

## 4. COMPARATIVE ANALYSIS

When comparing VR-assisted SLA to traditional methods, a clear trade-off emerges between contextual richness and cognitive demand. VR environments excel in creating authentic, situationally relevant learning contexts that improve memory retention and learner motivation. In contrast, traditional methods, while less engaging, tend to impose lower cognitive demands and may be more effective for tasks requiring focused repetition and controlled practice.

From the perspective of contextual memory, VR offers significant advantages by linking new language input to realistic settings, aiding both recall and application in real-life situations. However, these benefits are sometimes offset by increased intrinsic and extraneous cognitive load, which can overwhelm novice learners or those with lower working memory capacity.

The optimal learning environment may, therefore, be a blended approach—leveraging VR for context-rich, immersive experiences while using traditional methods for targeted skill reinforcement. Such integration could maximize learning gains while mitigating the drawbacks of each approach.

When comparing VR-assisted Second Language Acquisition (SLA) with traditional classroom or 2D computer-based methods, a clear trade-off emerges between contextual richness and cognitive demand.

Immersive VR environments excel at providing authentic, situationally relevant contexts that closely replicate real-world communication scenarios. Such environments engage multiple sensory modalities visual, auditory, and sometimes kinaesthetic thereby fostering context-dependent memory formation (Godden & Baddeley, 1975; Krokos et al., 2019). Learners in VR are more likely to encode language in relation to a specific physical or social context, which improves both immediate recall and the ability to transfer skills to real-life situations (Lin & Lan, 2015). Furthermore, VR's interactivity increases intrinsic motivation and learning persistence (Makransky & Lilleholt, 2018).

By contrast, traditional SLA methods—such as textbook exercises, language drills, and controlled listening/reading comprehension often lack situational immersion but impose lower cognitive demands. This makes them particularly effective for explicit grammar instruction, phonetic training, and controlled practice where focused repetition is needed (Sweller, 1988). In such settings, learners can process information without the distraction of managing a complex 3D environment or interpreting multiple sensory inputs simultaneously.

However, VR's benefits come with trade-offs. The rich sensory and interactive features that make VR so engaging can also contribute to higher intrinsic and extraneous cognitive load (Parong & Mayer, 2018). Novice learners or those with limited working memory capacity may experience cognitive overload, leading to reduced efficiency despite high engagement. In addition, VR navigation tasks such as moving through a virtual space or handling VR controllers may divert attentional resources from actual language processing.

From the contextual memory perspective, VR offers clear advantages. Studies in spatial memory and context-dependent recall suggest that when information is learned within a rich, immersive environment, the environmental cues serve as powerful retrieval triggers (Krokos et al., 2019; Schöne et al., 2019). Traditional methods cannot match this environmental cueing effect, which is why VR learners often show better delayed recall of vocabulary and conversational patterns.

Given these contrasts, an optimal pedagogical approach may lie in blended learning models. In such a design, VR can be used strategically for context-rich simulations such as role-playing at an airport, shopping in a virtual marketplace, or conducting a job interview while traditional methods can reinforce grammar accuracy, vocabulary drilling, and error correction outside the immersive environment. This

hybrid model not only maximizes retention through experiential learning but also mitigates the risk of cognitive overload by alternating between high- and low-load instructional modes.

Ultimately, the decision between VR and traditional methods should not be framed as an either/or choice but rather as complementary tools in a diversified instructional strategy. This approach allows educators to harness the motivational and contextual strengths of VR while relying on the precision and efficiency of traditional language instruction for foundational skill-building.

## 5. CONCLUSION

This comparative analysis indicates that VR immersive environments hold significant promise for enhancing second language acquisition, particularly in terms of contextual memory retention and learner engagement. However, the accompanying increase in cognitive load necessitates deliberate instructional design. By understanding the strengths and limitations of both VR and traditional learning methods, educators can design blended learning strategies that balance immersion with cognitive efficiency, ultimately supporting more effective and sustainable language learning outcomes.

This comparative analysis underscores the significant potential of Virtual Reality (VR) immersive environments to enhance Second Language Acquisition (SLA), particularly in contextual memory retention, learner engagement, and the transferability of skills to real-world situations. VR's immersive, context-rich nature provides powerful situational cues, allowing learners to encode and retrieve linguistic information more effectively. By simulating authentic environments such as a virtual marketplace, airport, or cultural setting VR enables language practice in meaningful, situationally relevant contexts that traditional methods often struggle to replicate.

However, the same immersive qualities that make VR effective can also elevate cognitive load. Complex visual, auditory, and interactive elements if not carefully moderated may demand excessive attentional resources, especially from novice learners or individuals with lower working memory capacity. This can hinder learning efficiency, even when engagement is high. As a result, instructional design becomes a critical factor in determining whether VR functions as a facilitator or a barrier to SLA. Strategies such as progressive immersion, chunking of content, and guided navigation can help manage cognitive load while preserving the benefits of immersive

engagement.

From a pedagogical perspective, the findings suggest that the most effective approach is not to replace traditional instruction with VR, but rather to integrate the two within a blended learning framework. In this model, VR is used to provide experiential, context-rich learning episodes, while traditional instruction reinforces explicit grammar learning, focused vocabulary drills, and structured error correction. Such an approach allows learners to experience language in action while also solidifying core linguistic structures in a cognitively efficient manner.

In the broader scope of language education, this study's analysis highlights an important principle:

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technology is a tool, not a panacea. VR holds remarkable promise when applied purposefully, but its success depends on alignment with cognitive learning principles, careful scaffolding, and adaptability to learner needs. Future research should focus on longitudinal studies, adaptive VR environments powered by AI, and cross-cultural investigations to determine how these immersive tools can best serve diverse learner populations.

Ultimately, the integration of VR into SLA is not just about adopting cutting-edge technology it is about crafting a learning ecosystem that balances immersion with cognitive efficiency, ensuring that engagement translates into sustained, transferable language competence.