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АЙТРЕКІНГ ТА ІМЕРСИВНІ ІНСТРУМЕНТИ: ОЦІНЮВАННЯ УВАГИ СТУДЕНТІВ І КОГНІТИВНОГО НАВАНТАЖЕННЯ У ВІРТУАЛЬНИХ КЛАСАХ З АНГЛІЙСЬКОЇ МОВИ

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Масштабна цифрова трансформація вищої освіти суттєво змінила педагогічні практики та навчальні середовища, зокрема у сфері викладання англійської мови. Зростання інтеграції імерсивних технологій, включно з віртуальною та доповненою реальністю, а також інтерактивними мультимедійними платформами, зумовила появу віртуальних класів з англійської мови, які характеризуються насиченим візуальним контентом, мультимодальною взаємодією та динамічною залученістю здобувачів освіти. Водночас такі середовища, попри значні педагогічні переваги, порушують важливі питання, пов’язані з розподілом уваги студентів, обробленням інформації та когнітивним навантаженням.

У статті подано розширене теоретико-аналітичне дослідження технології айтрекінгу як об’єктивного методологічного інструменту оцінювання уваги здобувачів освіти та їх когнітивного навантаження у віртуальних класах з англійської мови. Дослідження ґрунтується на теорії когнітивного навантаження та спирається на сучасні міждисциплінарні напрацювання з прикладної лінгвістики, освітньої психології та цифрової педагогіки, опубліковані у 2022–2026 роках. Особливу увагу приділено розмежуванню внутрішнього, зовнішнього та релевантного (герменного) когнітивного навантаження в контексті навчання іноземних мов.

Аналіз показує, що педагогічно оптимізовані імерсивні середовища сприяють стійкій візуальній увазі, підвищенню мотивації здобувачів освіти та глибшому мовному обробленню. Натомість погано структуровані віртуальні інтерфейси, надмірна візуальна стимуляція та фрагментований дизайн завдань істотно збільшують зовнішнє когнітивне навантаження і знижують ефективність навчання. Показники айтрекінгу, зокрема тривалість фіксацій, саккадичні рухи, траєкторії сканування та зони інтересу, надають цінну інформацію про когнітивні процеси здобувачів освіти під час виконання віртуальних завдань з англійської мови. У статті обґрунтовується доцільність системної інтеграції даних айтрекінгу в інструкційний дизайн і педагогічне ухвалення рішень з метою створення студентоцентрованих і когнітивно сталих віртуальних класів з англійської мови.

Ключові слова: *айтрекінг, імерсивні технології, віртуальні класи, викладання англійської мови, когнітивне навантаження, увага студентів.*

Martseniuk Olena, Shlikhtenko Yulia. Eye-tracking and immersive tools: evaluating students’ attention and cognitive load in virtual English classrooms

The large-scale digital transformation of higher education has profoundly reshaped pedagogical practices and learning environments, particularly in the field of English language teaching. The increasing integration of immersive technologies, including virtual reality, augmented reality, and interactive multimedia platforms, has led to the emergence of virtual English classrooms characterized by rich visual input, multimodal interaction,

and dynamic learner engagement. While such environments offer significant pedagogical advantages, they also raise critical concerns regarding students' attention distribution, information processing, and cognitive load. This article presents an extended theoretical and analytical investigation of eye-tracking technology as an objective methodological tool for evaluating students' attention and cognitive load in virtual English classrooms. The study is grounded in cognitive load theory and draws on recent interdisciplinary research in applied linguistics, educational psychology, and digital pedagogy published between 2022 and 2026. Particular emphasis is placed on the differentiation between intrinsic, extraneous, and germane cognitive load in foreign language learning contexts. The analysis demonstrates that pedagogically optimized immersive environments contribute to sustained visual attention, enhanced learner motivation, and deeper language processing. Conversely, poorly structured virtual interfaces, excessive visual stimulation, and fragmented task design significantly increase extraneous cognitive load and hinder learning effectiveness. Eye-tracking indicators such as fixation duration, saccadic movements, scan paths, and areas of interest provide valuable insights into learners' cognitive processes during virtual English language activities. The article argues for the systematic integration of eye-tracking data into instructional design and pedagogical decision-making in order to develop learner-centered and cognitively sustainable virtual English classrooms.

Key words: *eye-tracking, immersive technologies, virtual classrooms, English language teaching, cognitive load, student attention.*

Introduction. The ongoing digitalization of higher education has fundamentally transformed the organization, delivery, and evaluation of teaching and learning processes. English language teaching has been particularly affected by the rapid expansion of virtual learning environments, online platforms, and immersive technologies that enable flexible, interactive, and context-rich language instruction. Virtual English classrooms transcend spatial constraints and provide learners with access to authentic language input, collaborative tasks, and multimodal resources that support communicative competence development. At the same time, the increased reliance on visually complex and information-dense digital environments necessitates a reconsideration of learners' cognitive capacities and attentional resources. From a cognitive perspective, excessive multimedia input may overwhelm working memory, disrupt attention allocation, and reduce learning efficiency. Consequently, the evaluation of students' attention and cognitive load has become a key research priority in contemporary digital pedagogy.

Purpose of the Article. The purpose of this article is to conduct an in-depth theoretical analysis of eye-tracking technology as a research instrument for evaluating students' attention distribution and cognitive load in virtual English classrooms. Beyond outlining the methodological potential of eye-tracking, the study aims to conceptualize its role within the framework of modern philological and applied linguistic research, where language learning is increasingly understood as a cognitively and multimodally mediated process.

More specifically, the article seeks to examine how eye-tracking data can contribute to a more nuanced understanding of learners' interaction with linguistic input in immersive digital environments, including virtual reality–based classrooms and multimodal online platforms. Particular attention is paid to the ways in which visual attention patterns reflect underlying cognitive processes involved in foreign language comprehension, processing, and meaning construction.

Another important objective of the article is to identify pedagogical conditions under which immersive technologies facilitate meaningful language learning while minimizing extraneous cognitive load. Drawing on cognitive load theory, the study explores the balance between intrinsic, extraneous, and germane cognitive load in virtual English classrooms and highlights instructional design principles that support sustainable learner engagement rather than superficial interaction with digital content.

Finally, the article aims to bridge the gap between theoretical models of cognition and practical instructional design by demonstrating how eye-tracking indicators may inform evidence-based pedagogical decision-making. In this regard, the study positions eye-tracking not merely as a technical measurement tool but as a methodological resource capable of enhancing the cognitive, pedagogical, and philological grounding of virtual English language education.

Analysis of Recent Research. Recent scholarly research published between 2022 and 2026 demonstrates a steadily growing interest in the application of eye-tracking

methodologies within educational, linguistic, and interdisciplinary studies. This trend reflects a broader methodological shift toward empirically grounded approaches that allow researchers to investigate cognitive processes underlying language learning with a high degree of precision. In applied linguistics, eye-tracking has been extensively employed to explore reading comprehension, vocabulary acquisition, grammatical processing, and learners' interaction with multimodal texts, providing objective data on attention allocation and processing strategies.

A substantial body of research indicates that eye-movement measures, such as fixation duration, fixation frequency, and saccadic patterns, serve as reliable indicators of cognitive effort and depth of processing during language tasks. Studies focusing on second and foreign language reading have demonstrated that longer fixations and increased regression rates often correspond to lexical difficulty, syntactic complexity, or unfamiliar discourse structures. Similarly, research on vocabulary learning suggests that sustained visual attention to target lexical items is associated with improved retention and form–meaning mapping. These findings underscore the value of eye-tracking as a methodological tool capable of revealing implicit cognitive processes that remain inaccessible through traditional assessment methods. In parallel, recent research has increasingly examined learner interaction with multimodal and digital texts, emphasizing the role of visual and spatial cues in language comprehension. Eye-tracking studies in this domain highlight how learners navigate complex instructional materials that combine written text, images, audio input, and interactive elements. Such research demonstrates that learners' gaze behavior reflects not only linguistic processing but also strategic decision-making related to task demands and interface design. As a result, eye-tracking has become particularly relevant for the analysis of learning processes in virtual and immersive environments.

At the same time, a growing number of studies focus on the pedagogical potential of immersive technologies, including virtual reality, augmented reality, and simulation-based learning environments. Research in this area consistently reports positive effects of immersive tools on learner motivation, engagement, and perceived authenticity of language input. By enabling learners to interact with simulated real-world contexts, immersive environments support experiential and situated language learning, which is widely regarded as conducive to communicative competence development.

However, recent meta-analyses and systematic reviews caution against overly optimistic interpretations of these findings. Scholars emphasize that the pedagogical effectiveness of immersive technologies depends less on technological sophistication and more on instructional design quality and cognitive load management. Poorly designed immersive environments may overwhelm learners with excessive visual and interactive stimuli, leading to increased extraneous cognitive load and reduced learning efficiency. Consequently, several researchers argue for the integration of cognitive load theory as an analytical framework for evaluating immersive language learning environments.

Despite the growing body of research on eye-tracking and immersive technologies, a notable gap remains in studies that systematically combine these two lines of inquiry within the context of English language teaching. While eye-tracking has been widely applied to traditional language learning tasks, its potential for evaluating attention distribution and cognitive load in immersive virtual classrooms remains underexplored. This gap highlights the need for theoretically informed analyses that integrate eye-tracking methodology with cognitive load theory in order to better understand how learners process language in complex digital environments.

In addressing this gap, the present article builds on recent interdisciplinary research and contributes to the emerging field of cognitively oriented digital philology. By synthesizing findings from applied linguistics, educational psychology, and immersive learning research, the study provides a conceptual foundation for using eye-tracking data to inform pedagogical decision-making and instructional design in virtual English classrooms.

Main Research Material. Cognitive load theory provides a robust and widely accepted theoretical framework for analyzing learning processes in digitally mediated environments, particularly in contexts characterized by high levels of multimodal input and learner interaction. Originating from cognitive

psychology, the theory is grounded in the assumption that human working memory has limited capacity, whereas long-term memory is virtually unlimited. Effective learning, therefore, depends on instructional conditions that optimize the use of working memory resources while facilitating the construction and automation of cognitive schemas.

Within this framework, cognitive load is traditionally divided into three interrelated components: intrinsic, extraneous, and germane. Intrinsic cognitive load is determined by the inherent complexity of the learning task and the degree of element interactivity required for task completion. In foreign language learning, intrinsic load is influenced by factors such as linguistic complexity, learners' proficiency level, prior knowledge, and the cognitive demands of processing new grammatical structures, vocabulary, and discourse patterns. Tasks involving authentic language use or communicative interaction typically impose higher intrinsic load due to the need to integrate multiple linguistic and pragmatic elements simultaneously.

Extraneous cognitive load, by contrast, is not inherent to the learning task itself but results from suboptimal instructional design and poorly structured learning environments. In virtual and immersive classrooms, extraneous load may arise from excessive visual stimulation, fragmented task presentation, unclear navigation, or the presence of irrelevant multimedia elements that compete for learners' attention. From a pedagogical perspective, extraneous cognitive load is particularly problematic because it consumes limited working memory resources without contributing to learning. Consequently, reducing extraneous load through coherent task sequencing, visual clarity, and instructional simplicity is a central objective of effective digital pedagogy.

Germane cognitive load refers to the cognitive resources devoted to schema construction, abstraction, and automation. Unlike extraneous load, germane load is considered beneficial, as it directly supports meaningful learning and long-term retention. In foreign language education, germane load is associated with processes such as pattern recognition, form–meaning mapping, and the development of communicative competence. Instructional designs that encourage reflection, hypothesis testing, and active engagement with linguistic input can foster germane cognitive load, thereby enhancing learning outcomes.

Immersive learning environments inherently increase intrinsic cognitive load due to the complexity of multimodal input and interactive task structures. Virtual English classrooms often require learners to simultaneously process linguistic information, visual cues, spatial orientation, and interactive feedback. While such environments offer rich opportunities for experiential and situated learning, they also risk overwhelming learners' cognitive capacities if not carefully designed. Cognitive load theory thus provides a critical lens for evaluating the pedagogical effectiveness of immersive technologies in language education.

From a theoretical perspective, managing cognitive load in immersive environments involves not only minimizing extraneous load but also aligning intrinsic load with learners' cognitive readiness and promoting germane load through purposeful task design. Clear visual hierarchies, consistent interface layouts, and explicit instructional guidance can support attention allocation and reduce unnecessary cognitive demands. At the same time, tasks that gradually increase in complexity and encourage meaningful interaction with language input can facilitate schema construction and deeper processing.

In the context of this study, cognitive load theory serves as the conceptual foundation for interpreting eye-tracking data as indicators of learners' cognitive processing. Eye-movement measures such as fixation duration, saccadic transitions, and gaze dispersion can be understood as observable manifestations of cognitive load distribution during interaction with immersive learning environments. By linking eye-tracking indicators to the theoretical constructs of intrinsic, extraneous, and germane cognitive load, the study contributes to a more nuanced and empirically grounded understanding of learning processes in virtual English classrooms.

The methodological framework of the study is grounded in the principles of cognitive load theory and eye-movement analysis. Although the present article adopts a theoretical and analytical approach, it outlines a potential empirical research design suitable for higher education contexts. Such a design would involve English language learners participating in virtual

classroom activities supported by immersive technologies.

Eye-tracking devices would be used to collect data on fixation duration, saccadic movements, gaze transitions, and areas of interest. These indicators enable researchers to assess learners' attentional focus, identify sources of extraneous cognitive load, and evaluate the effectiveness of instructional design elements within virtual English classrooms.

Eye-tracking technology offers precise and objective measures of learners' visual attention and cognitive processing during virtual English language activities, making it a valuable methodological tool for investigating learning processes in digitally mediated environments. Unlike traditional observational methods or self-report questionnaires, eye-tracking enables the real-time registration of learners' gaze behavior, thereby providing direct evidence of how visual attention is distributed across instructional elements in virtual English classrooms.

The analysis of eye-movement patterns, including fixation duration, fixation frequency, saccadic movements, and scan paths, allows researchers to identify which components of a virtual learning environment attract sustained attention and which elements contribute to cognitive overload or learner disorientation. Extended fixations on specific linguistic or visual elements may indicate deep cognitive processing, increased task difficulty, or heightened instructional relevance, whereas rapid gaze shifts and scattered scan paths often signal excessive extraneous cognitive load or poorly structured instructional design.

In the context of virtual English language learning, eye-tracking data make it possible to examine learners' interaction with multimodal input, such as written text, audiovisual materials, visual prompts, and interactive tasks. These data reveal how learners prioritize linguistic information in relation to visual and spatial cues and how attention is allocated during complex language activities. Such insights are particularly important in immersive environments, where learners are required to process multiple streams of information simultaneously.

From a pedagogical perspective, eye-tracking data provide a foundation for evidence-based instructional design decisions. By analyzing learners' gaze behavior, educators can evaluate the effectiveness of interface layout, task sequencing, and visual scaffolding in virtual English classrooms. Instructional elements that consistently attract excessive or fragmented attention may indicate sources of extraneous cognitive load, whereas elements associated with sustained and focused gaze patterns are more likely to support germane cognitive load and meaningful language processing.

Furthermore, eye-tracking analysis allows for the identification of individual differences in attention allocation and cognitive processing strategies among language learners. Such differences may be related to learners' proficiency level, prior knowledge, or familiarity with immersive technologies. Recognizing these variations enables educators to design adaptive learning environments that accommodate diverse cognitive profiles and support differentiated instruction.

By integrating eye-tracking findings into the instructional design process, virtual English classrooms can be optimized to reduce unnecessary visual stimuli, enhance instructional clarity, and promote deeper engagement with linguistic input. In this way, eye-tracking technology functions not only as an analytical research instrument but also as a pedagogical resource that supports cognitively sustainable and learner-centered English language education.

The integration of eye-tracking technology into English language teaching has significant pedagogical implications. Eye-tracking data enable educators to move beyond subjective assumptions about learner engagement and obtain objective insights into students' attentional behavior. This information can support the development of learner-centered instructional strategies and adaptive learning environments.

In immersive English classrooms, pedagogical decisions informed by eye-tracking data may include task simplification, visual scaffolding, and the gradual introduction of multimodal elements in accordance with learners' proficiency levels and cognitive capacities. The discussion underscores the importance of aligning immersive technologies with pedagogical objectives and learners' cognitive capacities. While immersive tools offer considerable potential for enriching English language instruction, their effectiveness depends on thoughtful instructional design and continuous evaluation of learner interaction.

Eye-tracking technology serves as a critical link between theoretical models of cognitive

processing and practical instructional strategies, enabling data-driven optimization of virtual learning environments.

Conclusions and Prospects for Further Research. The article concludes that eye-tracking technology constitutes a valuable and methodologically robust instrument for evaluating students' attention distribution and cognitive load in virtual English classrooms. By providing objective and real-time data on learners' visual attention, eye-tracking makes it possible to move beyond subjective interpretations of learner engagement and gain deeper insight into the cognitive processes underlying foreign language learning in immersive digital environments.

The theoretical analysis demonstrates that eye-tracking indicators, such as fixation duration, saccadic movements, and gaze patterns, can be meaningfully interpreted within the framework of cognitive load theory. In particular, these indicators offer empirical evidence of how intrinsic, extraneous, and germane cognitive load are distributed during interaction with multimodal instructional content. As a result, eye-tracking data enable a more precise evaluation of instructional design quality in virtual English classrooms and highlight specific elements that either support or hinder meaningful language processing.

From a pedagogical perspective, the integration of eye-tracking data into instructional design processes can significantly enhance the effectiveness of immersive English language instruction. Evidence-based insights into learners' attentional behavior allow educators to optimize interface layout, task sequencing, and visual scaffolding, thereby reducing extraneous cognitive load and fostering conditions conducive to deeper linguistic processing and sustained learner engagement. In this regard, eye-tracking technology should be viewed not merely as a research tool but as a pedagogically relevant resource that supports learner-centered and cognitively sustainable digital education.

In addition, the study contributes to modern philological research by reinforcing the interdisciplinary connection between applied linguistics, cognitive psychology, and digital pedagogy. The use of eye-tracking methodology expands the analytical scope of contemporary philology by enabling the empirical investigation of language perception and processing in multimodal and immersive contexts, which increasingly characterize modern communication and language learning environments.

Prospects for further research include large-scale empirical validation of the theoretical assumptions outlined in this article through experimental and quasi-experimental designs involving diverse learner populations. Longitudinal studies are particularly needed to examine how sustained exposure to immersive learning environments influences cognitive load regulation, attentional strategies, and long-term language learning outcomes. Furthermore, cross-cultural and cross-institutional comparisons may provide valuable insights into how contextual factors, such as educational traditions and technological infrastructure, shape learners' interaction with virtual English classrooms.

Finally, future research may explore the integration of eye-tracking data with other learning analytics methods, such as neurophysiological measures or interaction logs, in order to develop more comprehensive models of learner cognition in immersive language learning environments. Such interdisciplinary approaches hold considerable potential for advancing both theoretical understanding and pedagogical practice in the field of English language education.

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