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MODALITY PRINCIPLE IN IMMERSIVE VIRTUAL REALITY: AN EYE-TRACKING STUDY

ABSTRACT

According to the modality principle of the Cognitive Theory of Multimedia Learning, learning is facilitated when visual content is accompanied by vocal narration compared to text explanation. However, the application of this principle in immersive virtual reality (IVR) remains unclear. In the present experiment involving 101 secondary school students, was compared the application of the modality principle in IVR and on desktop. Measurements of learning outcomes, eye movements behaviour, presence and cognitive load were carried out during a lesson about forest, in IVR or on desktop, with vocal narration or with text, involving four experimental groups. A modality effect was found for the desktop but not for the IVR condition, suggesting a reversed modality effect. The desktop condition was associated with less visual distraction, while the IVR condition led to higher presence. This study showed that the content of lessons in IVR should be adapted to avoid distractions.

Keywords

Eye tracking, Instructional design, Simulation-based learning, Cognitive skills and processes

EXTENDED SUMMARY

Theoretical background and aim

Immersive virtual reality (IVR) places learners in a 3 dimensional learning materiel, making them see and hear what could not be perceived in reality. However, learning in IVR is not always superior to conventional multimedia format, resulting in overall small effect sizes (Coban et al., 2022). Several factors may account for these differences in learning outcomes, such as the quantity of visual stimuli, the task control level, or the immersion degree (Makransky et al., 2019). In order to improve the efficiency of immersive virtual reality learning, recent researches suggest applying principles of multimedia learning (Albus et al., 2021, 2023; Makransky, 2021). These principles advocate for adapting lesson formats to align with the human cognitive system's limitations. Among these principles, the modality principle proposes that learning is enhanced when audio accompanies visual content compared to text (Mayer & Fiorella, 2021). Recent studies suggest a modality principle inversion effect in immersive virtual reality (Albus et al., 2023; Liberman & Dubovi, 2023). The substantial visual information load in immersive virtual reality may prioritize visual processing over auditory processing, as suggested by the Colavita effect (Sinnott et al., 2007). However, these previous studies did not compare a desktop setting with an IVR setting. In the present research, we conducted an experimental study to rigorously compare the modality effect in IVR and in desktop-based media to examine its impact on learning and eye movement. We aimed to investigate whether the modality effect was reversed in IVR and if this reversal could be attributed to a higher visual load in IVR.

Method

A sample of 101 7th-grade students participated in the study (M age = 12 years old; $SD = 0.06$). Two between-subject factors were tested in this study: the media on which a lesson was presented (IVR or desktop) and the modality through which the verbal information was delivered (audio narration or written text). The experimental design involved four groups of

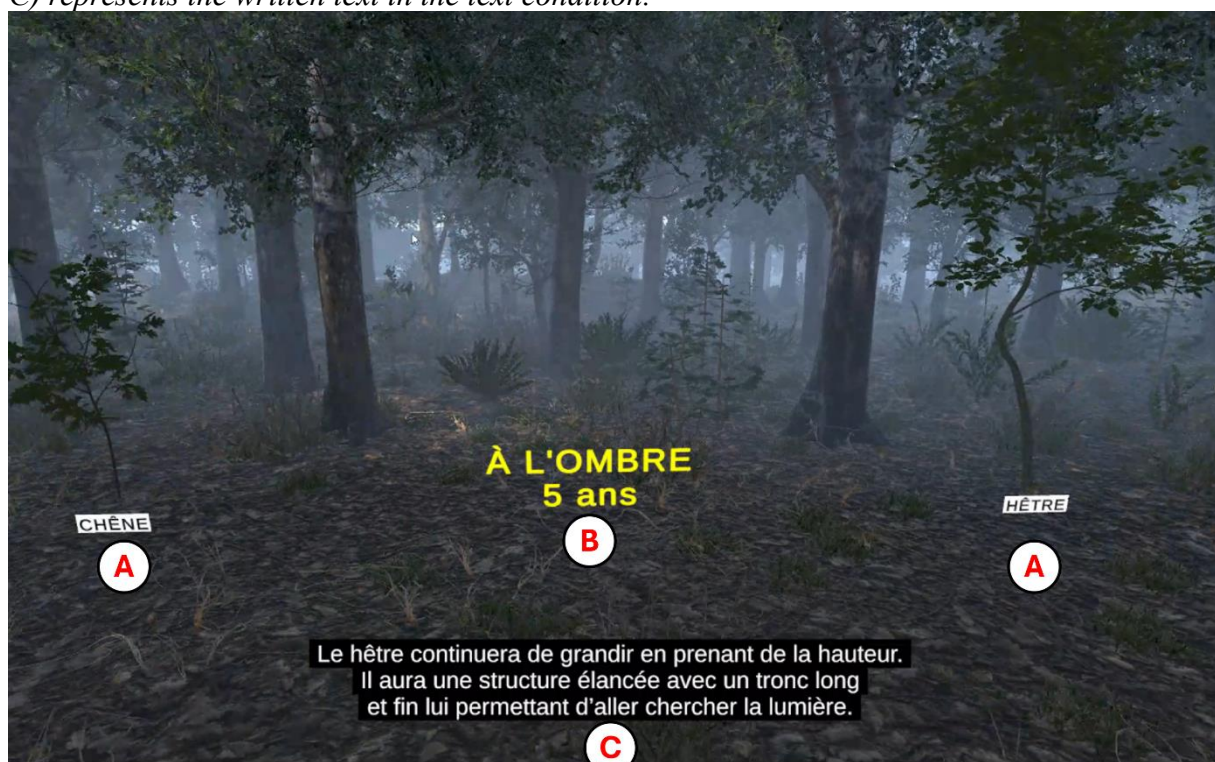
participants, corresponding to four experimental conditions: IVR media with audio, IVR media with text, desktop with audio, and desktop with text.

The material has been designed to provide as similar level of control and interactivity as possible between medias and words modalities. The learning material described the competition for light between beech and oak trees in a realistic and rich forest environment (see Figure 1). A virtual forest was depicted with the two target trees, an oak and a beech, positioned amidst the surrounding forest. Learners had the ability to move and to rotate their vision 360 degrees to observe the evolution of the trees. In the IVR conditions, movements (front-rear and right-left) were made naturally by walking or turning the head, while in the desktop condition, the same movements were controlled with the mouse. Additionally, auditory commentary accompanied the virtual environment in the auditory condition, whereas text was displayed similarly to subtitles in the text condition.

A first gathered measure concerned learning outcomes (MCQ on factual, conceptual and transfer knowledge). A second type of measure focused on eye-movements, especially the ratio of visual fixation time and number on relevant information (e.g., target trees and verbal information) compared to irrelevant information (e.g., background, surroundings, other forest areas). Thirdly, two questionnaires were completed, measuring presence (inspired by Makransky et al., 2017) and cognitive load (inspired by Klepsch et al., 2017).

Figure 1

Screenshot of the learning material, A) represents the target trees, B) describes the situation, C) represents the written text in the text condition.



Results

The media had an marginal effect on learning outcomes $F(1,101) = 3.59; p = 0.061; \eta^2p = 0.034$. The desktop groups performed better on MCQ questionnaire ($M = 6.92; SD = 2.33$) than the IVR groups ($M = 5.85; SD = 2.26$). The media and modality factors interacted on MCQ performance scores $F(1,101) = 7.15 p = 0.039; \eta^2p = 0.041$. The modality principle was found on desktop, with better learning in the audio condition than in the written text condition $t(101)$

= 2.82; $p = .029$; $d = 0.78$, but was not found in IVR ($p < .05$). Regarding the scores of presence, participants in the headset conditions rated higher than those in the desktop condition $F(1,101) = 28.85$ $p < .001$; $\eta^2p = 0.208$. An interaction between media and modality was observed on the germane cognitive load $F(1,101) = 7.52$ $p = 0.007$; $\eta^2p = 0.069$. In IVR written text conditions, germane load was higher than in the audio condition. In the desktop condition, desktop germane load was higher in the written text condition than in the audio condition. Regarding eye-tracking measures, results revealed that learners in the desktop condition did less numerous gazes at irrelevant areas compared to learners in the IVR condition $F(1,102) = 72.85$ $p < .001$; $\eta^2p = 0.417$. More detailed results on eye movements measures will be presented at the conference.

Theoretical and educational implications

Overall, our results indicate that the modality effect is expressed differently for IVR and for desktop environments. This is coherent with previous findings (Lieberman & Dubovi, 2023). On desktop, the modality principle effect was found with improved learning outcomes in the auditory condition compared to with the written text condition. In IVR, no differences were found in learning outcomes between auditory and written-text conditions. The higher interactivity and amount of visual information could have increased distraction, which is also supported by the eye-tracking measures. Although IVR can have positive effect on learning (Coban et al., 2022), the design of the virtual environment and lesson should be adapted to lead to less distraction and then better learning. The results on germane cognitive load showed that the written text was related to improved motivation on the IVR condition suggesting that it should be favoured over auditory comments. To reduce distraction and improve learning in IVR, other multimedia principles, such as signalling, could be applied. The use of annotations to guide attention to relevant areas can enhance learning in IVR (Albus et al., 2021) as well as visual signalling (Porte et al., in Press).

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