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Examining the impact of immersion, graphic detail, and habituation on preschoolers' learning outcomes with virtual reality

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Abstract

In a previous study (Dall'Olio et al., 2024), we observed that preschool children who viewed a presentation in immersive virtual reality (IVR) had significantly poorer learning outcomes than those who viewed the presentation in a less immersive desktop virtual reality (D-VR) condition. One possible explanation is that IVR may cause too much cognitive load therefore impairing learning. The two follow-up studies discussed in this paper once again compared IVR and D-VR, but this time with a view of two factors that may reduce the cognitive load of IVR: the level of detail of the presentation (high detail/low detail) and the viewer's habituation to the medium (habituated/not habituated). In the first study, we investigated whether the learning outcomes of a presentation delivered to 155 preschool children aged four to six years differed based on the levels of detail and immersion (IVR/D-VR). Contrary to our hypotheses, we observed no significant impact of detail or immersion, nor was there any significant interaction between these two features. In the second study, we compared the learning outcomes of 72 preschool children with different levels of habituation to the medium used. Again, contrary to our hypotheses, we found no significant impact of medium habituation and immersion and no interaction between these two variables. We report inconclusive evidence here and suggest that further research is needed. Specifically, future studies should examine additional factors that may influence learning outcomes, as well as the effects of different IVR methods in varied learning situations, and with children of different ages.

Keywords: Virtual reality; Level of graphic detail; Habituation; Memory; Preschool children.

Highlights

- We study the impact of detail, habituation, and immersion on preschool children's recall.
- We report inconclusive evidence (non-significant results).
- Future research is needed on whether and why IVR impairs/enhances learning.

Examining the impact of immersion, graphic detail, and habituation on preschoolers' learning outcomes with virtual reality

With the continuous arrival on the market of new virtual reality (VR) headsets (HTC VIVE, Meta Quest, etc.), many studies have looked into the use of immersive VR (IVR) in learning (see Won et al., 2023 for a review). Nevertheless, despite such interest, findings from these studies have been inconsistent, with IVR sometimes promoting learning (e.g., Makransky & Mayer, 2022; Olmos-Raya et al., 2018), sometimes having no effect (e.g., Leder et al., 2019), and sometimes having a negative effect on learning (e.g., Dall'Olio et al., 2024; Makransky et al., 2019). In view of these divergent results, it seems clear that the question is not whether IVR can promote learning, but rather under what conditions and according to what characteristics IVR can facilitate learning. In this paper, we report on our attempt to investigate some of these possible characteristics by conducting two follow-up studies to our previous work (Dall'Olio et al., 2024), in which we found that children aged four to six years had worse learning outcomes following an IVR presentation about China compared to the same tablet-based presentation delivered in a medium known as desktop VR (D-VR). We proposed two possible explanations for these findings. First, the high level of graphic detail in the VR environment might have led to extraneous processing, especially in IVR, where the higher resolution and surrounding environment could have been distracting. Second, the novelty of IVR might have induced excessive cognitive processing, as the children were likely less familiar with VR headsets than tablets. In the present paper, we report the results of our two follow-up studies aimed at investigating these possible explanations. Before providing the details of the two studies, we review the existing literature on VR and learning, with a focus on notions such as immersion, interaction, level of graphic detail, and habituation. It should be noted that this review is mainly centered on research conducted with adults, as studies investigating the use of VR in preschool children remain rare.

VR and learning

VR can be defined as a computer-generated environment that simulates and/or replicates different aspects of the physical world (Ifanov et al., 2023; Won et al., 2023). New technologies, including VR, are coming to occupy an increasingly important place in learning environments. Several theories have attempted to explain how VR can be used as a learning medium. Among these is the cognitive theory of multimedia learning (CTML) proposed by Mayer et al. (2009). This theory emphasizes the different cognitive processes involved in multimedia learning, and the challenge it poses to the limited resources of the human brain. In this particular study, the authors highlight three types of cognitive processes that a person has to deal with when learning with multimedia material: (1) the cognitive processes essential to obtaining a proper mental representation of the learning material, also known as *essential processing*; (2) the processes that help one understand the learning material and promote its integration, also known as *generative processing*; and (3) the processes that do not support learning as such or may even distract the person from learning, also known as *extraneous processing*. To optimize learning outcomes, it therefore seems essential that the learning material be structured to encourage generative processing and thus avoids those elements that can provoke extraneous processing, especially as our cognitive resources are limited.

In the case of VR learning, two elements are important vectors of generative processing: the sense of presence and its interactive nature. These two features have been shown to play a major role in facilitating the psychological aspects of learning, such as situational interest, intrinsic motivation, self-efficacy, embodiment, and self-regulation (Makransky & Petersen, 2021). *Sense of presence* is the subjective feeling of “being there” in the virtual environment (Ijsselsteijn & Riva, 2003). It should not be mistaken for the notion of immersion, which is the objective capacity of a tool to immerse us in an environment. For example, a VR headset like the Meta Quest 2 is highly immersive (IVR), whereas a computer is a low-immersion medium (D-VR). Nevertheless, several studies have demonstrated a significant correlation between the level of immersion and the sense of presence (Makransky & Mayer, 2022). In other words, the greater the immersion, the greater the sense of presence. Users of VR headsets are therefore likely to have a strong sense of presence in the virtual environment, thanks to the highly immersive characteristics of the medium.

The *interactive nature* of VR refers to the ability to interact directly with the virtual environment. Different levels of interaction can be distinguished depending on the medium used to interact with the virtual environment. While we most often use a mouse and keyboard to interact with a virtual environment in D-VR, IVR allows us to interact with the environment more directly with our bodies, for example, by moving our heads and eyes to choose what to look at. Some features and peripherals even allow us to use our hands to interact with the scenery and our feet to move around in it. The new possibilities for interaction offered by IVR have been shown to facilitate learning by promoting agency (Petersen et al., 2022). This is even more important when it comes to procedural learning with complex motor skills. In fact, several studies have demonstrated the effectiveness of using IVR in learning a variety of procedures that require the activation of our motor skills (for a review, see Jongbloed et al., 2024). In addition, the use of a physical controller as an intermediary to interact with the virtual environment could be a source of increased cognitive load and extraneous processing (Makransky & Petersen, 2021). Interacting without intermediaries and directly with our bodies would therefore reduce extraneous processing and allow for a better learning experience.

Nevertheless, if IVR learning material can promote generative processing, it can also promote extraneous processing, which is detrimental to learning. Among these extraneous processing aspects are two features that can overload the cognitive processes of the person experiencing the virtual environment: the *level of graphic detail* of the environment and *habituation to the VR headset* and the environment encountered.

Level of graphic detail

In their Cognitive Affective Model of Immersive Learning (CAMIL), Makransky and Petersen (2021) highlight that a potential drawback of IVR for learning may be the excessive graphic detail of virtual presentations and virtual learning tools. The risk is that in an attempt to increase the graphic detail of the virtual environment for the sake of fidelity, immersion, and realism, we end up adding graphic details, also known as seductive details, that distract the learner from the learning objectives (Moreno & Mayer, 2002). Distraction is especially likely to occur when these graphic details are not directly related to the learning objectives. Removing irrelevant elements can thus improve learning outcomes (Parong & Mayer, 2021), a principle known as *coherence*, that is also applicable in cases of multimedia learning unrelated to IVR (Mayer et al., 2001; Moreno & Mayer, 2000).

Nevertheless, reducing superfluous details in a virtual environment to maintain the principle of coherence can prove problematic in the case of IVR learning. Indeed, immersion depends on realism and the level of graphic detail, which are essential for creating a sense of presence in the virtual environment (Huang et al., 2020; Sylaiou et al., 2010). Therefore, we should also maintain a certain level of fidelity and graphical representation in IVR learning material. One of the fundamental objectives when designing learning material with IVR, therefore, is to sustain immersion in the virtual environment while ensuring that excessive graphic detail does not compromise coherence and, consequently, learning effectiveness. Designers, educational psychologists, and all of those involved in creating virtual material for education must find a balance between preventing distractions and maintaining a focus on the learning objectives.

Habituation with immersive VR and the novelty effect

Another possibility that could explain the cognitive load causing extraneous processing could be habituation, or rather non-habituation, to the medium of IVR in children. Indeed, children may learn less effectively with VR headsets because they are simply not accustomed to using them. In a previous study (Dall'Olio et al., 2024), we observed that only 11.3% of the children we tested had ever used a VR headset, and only 3% had done so on more than one occasion. This is problematic, given that in many studies, researchers evaluate the effectiveness of VR headsets in learning by directly comparing them to the use of other learning media, such as tablets and desktop computers (e.g., Olmos-Raya et al., 2018; Smith et al., 2018). Indeed, the latter are much more widely available in households than VR headsets. In Switzerland, for example, 79% of households are equipped with at least one tablet (Bernath et al., 2020). Nevertheless, this effect of the medium's novelty on learning is still poorly understood, and further exploration in this regard is needed. Thus far, researchers have speculated that this novelty effect of the medium could either hinder learning by adding extraneous processing (Makransky et al., 2019; Parong & Mayer, 2021) or, on the contrary, help learning by increasing motivation (Huang et al., 2023; Makransky & Mayer, 2022; Makransky & Petersen, 2021). In addition to the cognitive overload involved in learning to use a new tool, such as a VR headset, new users of this method would also be more likely to explore the virtual environment, specifically by testing the different interactions and limitations it offers, rather than focusing on the learning task (Miguel-Alonso et al., 2024). To reduce this novelty effect, one proposal advanced by researchers has been to add a pre-training session, a tutorial period, or simply more informal time to explore the virtual environment before assessing the participants' learning capacity (Huang et al., 2023; Miguel-Alonso et al., 2023). In fact, the novelty effect is short-lived and should diminish as the device is used more often (Koch et al., 2018). Accordingly, such a time period would give participants the chance to familiarize themselves with the technology and explore the virtual environments without the added pressure of learning. This period of familiarization would help to reduce the novelty effect, whether in terms of its effect on motivation, the increase in cognitive load, or the fact that it may distract the participant from the learning task. By reducing this novelty effect, we could then obtain a more objective view of the effectiveness of IVR in learning. Recently, it should be noted that pre-training sessions and short tutorials have proven to be useful for reducing the negative impact of the novelty effect (Miguel-Alonso et al., 2023, 2024), even if the extent of our understanding of the phenomenon remains limited.

Present study

In this paper, we aimed to answer two of the questions raised by our previous study (Dall'Olio et al., 2024) by investigating the different parameters that could influence preschool children's learning from a VR presentation. To maintain consistency with our prior research, we closely followed its methodology and used similar test materials, with adjustments being made to the experimental variables to address our new hypotheses. These adjustments will be detailed in the description of each part of the study below. In our previous study, we investigated how the immersive nature of a virtual presentation could influence preschool children's (aged four to six years) learning outcomes. The children followed a virtual presentation, either with a VR headset in a highly immersive condition (IVR) or with a tablet in a low immersive condition (D-VR). After the presentation, the participants were asked to complete two recall tasks: a new/old recognition task and a quiz task. We expected that the highly immersive nature of the presentation with the VR headset would lead to better recall in the IVR condition than in the D-VR condition. Nevertheless, we found that children in the D-VR condition had significantly better recall on both the new/old recognition task and the quiz. One possible explanation might be that, instead of promoting generative processing, presentation in the IVR condition would have called for extraneous processing and therefore increased the cognitive load of learning. We identified two possible reasons for this increase in extraneous processing: the level of detail in the virtual presentation's graphical environment and a lack of habituation to the IVR medium. In this paper, we investigated these two possible key characteristics through two follow-up studies.

In the first study, we used a between design to investigate the impact of immersion (IVR/D-VR) and the level of detail of a virtual presentation (high/low) on the learning outcomes of preschool children. We hypothesized that children would learn more easily from a less detailed presentation, particularly in the IVR condition, where seductive detail may have a particularly strong impact on cognitive load. In the second study, using a mixed design, we explored the impact of immersion level (IVR/D-VR) and medium habituation (habituated/non-habituated) on preschool children's learning outcomes. In this case, we hypothesized that children habituated to the medium would perform significantly better than those not so habituated, particularly in the IVR condition, where the child has the most to gain expertise with the medium. With these two follow-up studies, we hope to gain a better understanding of the role that the level of detail and media habituation play in determining the success of VR learning for preschool children. Achieving such an understanding would allow us to highlight the essential points to consider when creating VR learning material for young children.

Study 1

In this study, we investigated the impact of the level of graphic detail and the immersive nature of a virtual presentation on the learning outcomes of preschool children. We manipulated the level of graphic detail of the presentation by altering elements such as background content (present/absent), the presence of 3D elements (high/low quantity), and the texture quality (high/low). The immersive nature of the presentation was manipulated according to the medium used by the children to view it. In the IVR condition, the children followed the presentation with a VR headset, while in the D-VR condition, they followed the same presentation on a tablet. To assess learning outcomes, the children were asked to perform two tasks, a new/old recognition task and a quiz task, directly after the presentation. In addition, we controlled for verbal abilities, theory of mind abilities, age, and gender. We hypothesized that reducing the level of graphic detail in the virtual presentation would lead to improved learning outcomes. Specifically, we anticipated that the children would perform better when presented with low detail graphics compared to high detail graphics. In addition, we expected to observe a significant interaction between the level of graphic detail and the level of immersion, with the impact of graphic detail being more pronounced in the IVR condition than in the D-VR condition.

Method

Design

In this study, we manipulated the level of immersion (between-subjects factor) with the IVR and D-VR conditions, and the level of graphic detail of the presentation (between-subjects factor) with the high and low graphic detail conditions. This resulted in a 2 × 2 design comprising the following conditions: a high graphic detail presentation in IVR, a high graphic detail presentation in D-VR, a low graphic detail presentation in IVR, and a low graphic detail presentation in D-VR. Data for the two high graphic detail conditions were obtained from our previous study (Dall'Olio et al., 2024), while data for the low graphic detail conditions were collected specifically for the present study.

Learning outcomes were measured using two tasks: an old/new recognition task and a quiz task. Given the importance of the children's verbal skills in comprehending the verbal aspects of the presentation, we controlled for their verbal abilities. In addition, we controlled for theory of mind abilities. Theory of mind refers to the understanding of one's own and others' mental states, including beliefs and intentions (Gopnik & Wellman, 1992). This control was implemented to account for potential differences in cognitive development that could influence learning outcomes. Furthermore, we evaluated children's knowledge about China and excluded those with prior knowledge of the subject (see preregistered exclusion criteria on OSF: https://osf.io/jt7zy). Additionally, to maintain consistency with our previous study, other variables were also included. Indeed, given that we wanted to use the data from this previous study, it was important that the study duration and workload remained the same. However, these variables will not be considered further in this paper, as they were not included in the analysis due to the fact that they were not directly relevant to the research question under investigation here.

Participants

The required sample size was preregistered on OSF (https://osf.io/jt7zy). An a-priori G*Power analysis revealed that we needed a sample of at least 128 participants to detect a medium effect for interaction (2 × 2 between-subjects analysis of variance; parameters: $f = 0.25$, $\alpha = 0.05$, $1-\beta = 0.80$; Faul et al., 2007). We increased the sample size to around 40 children per group (N = 155, 84 female, mean age = 5.33, ranging from 4–6 years) to ensure that there were enough participating children after data exclusion.

We collected the first set of data from 83 children (41 female, mean age = 5.45) as part of a previous study from March to June 2021 (Dall'Olio et al., 2024). These data pertained to conditions with a high level of graphic detail. Subsequently, data from the remaining 72 children (43 female, mean age = 5.20) were specifically collected for this study from November 2021 to May 2023, during which we focused on conditions with a low level of graphic detail. All children were recruited from different preschools across Switzerland and were semi-randomly assigned to one of our four different conditions, which included a high graphic detail presentation in IVR (N = 47, 24 female, mean age = 5.34), a high graphic detail presentation in D-VR (N = 36, 17 female, mean age = 5.58), a low graphic detail presentation in IVR (N = 39, 24 female, mean age = 5.26), and a low graphic detail presentation in D-VR (N = 33, 19 female, mean age = 5.15). As Switzerland is a country with several national languages, 133 children were tested in French and 22 in German. The different tools and tests were adapted accordingly, either with the official translation or an adaptation by a native speaker. We obtained ethical approval for the study from the local ethics committee of UniDistance Suisse, and written parental consent was obtained for each child.

Materials

Virtual presentation and environment

To design the virtual environment, we used the game engine Unity (version 2019.4.32). We created 3D models using Blender software (www.blender.org) in versions 2.82 to 2.93. The textures used in the virtual presentation came from the open-source database "TextureHaven" (www.TextureHaven.com) and were edited with Photoshop (Adobe Creative Cloud, 2019). The different sounds and music used were taken from a license-free database (www.freesound.org). Apart from the resolution (1833 × 1920 for each eye in IVR and 1080 × 1920 in D-VR) and the field of view (89° ± 4 in IVR and 87.1° in D-VR), the virtual environment was identical in the IVR and D-VR conditions. The VR headset used during the presentation was a Meta Quest 2, and the tablet used was a Samsung Galaxy Tab A7. A video of the virtual presentation is available online on OSF (https://osf.io/r4s8c/).

The learning objectives of the virtual presentation consisted of different cultural and geographical information (visual and auditive) about China. This information was presented by a homemade avatar (a young Chinese girl). The virtual environment consisted of a representation of a Chinese temple. The virtual presentation had either a high or a low level of graphic detail, according to the testing condition (see Figure 1). The main differences between the high vs.

low graphic detail conditions were the absence of the forest background in favor of a neutral background (blue sky) and a complex texture replaced by the simple application of color. These changes did not directly concern the presentation's learning objectives, in contrast to the different visual and auditive items used in the memory tasks.

Figure 1.

High graphic detail presentation (left) and low graphic detail presentation (right)

The presentation began with a short two-minute tutorial to familiarize the children with the virtual environment and the VR headset and to make sure they understood that they could control where they were looking by moving their heads and eyes. Then, the actual presentation began, and the avatar shared various pieces of visual and auditory information about China (e.g., presentation of the Chinese flag) and about herself (e.g., the meaning of her first name). Finally, 12 visual stimuli (the integrality of the test material is available on the OSF at https://osf.io/r4s8c/) were presented to the child. Of these stimuli, the first six were 3D models related to Chinese food (i.e., lotus root, dragon fruit, bao, durian, zongzi, and chopsticks), three others were images of typical places to visit in China (i.e., a Chinese temple, Huangshan, and the Great Wall of China), and three images of activities to do in China (i.e., flying a kite, karaoke, and tai chi). For each of these stimuli, the avatar provided additional information or commentary to clarify what the child was seeing. The visual stimuli were either obtained from a copyright-free database (www.pixabay.com) or created by one of the authors. Every piece of auditive information was completely dubbed with the voiceover of two native speakers for our two different versions—one in German and one in French.

Assessment of previous knowledge of China

To assess the extent of the children's familiarity with China, we used a task including three questions: two concerning the flag of China (with inquiries about its color and shape) and one regarding the location of China on the world map. Before each question, to help the children understand the task, an example was given with the same question concerning the country in which the testing was taking place (Switzerland). More concretely, we showed the Swiss flag, accompanied by the question, "Do you know what this is?" This was followed by a brief description of the flag (i.e., its shape and color), and then the avatar asked the children about the Chinese flag. The maximum score the child could achieve on this task was four: one point for each question plus an extra point if the child could represent the Chinese flag perfectly. As the results of this task were part of our exclusion criteria, participants with a score higher than two were not included in the analyses.

Learning outcomes

In this study, we used two different tasks to measure children's learning outcomes after viewing the virtual presentation: a new/old recognition task and a quiz task.

New/old recognition task. The new/old recognition task consisted of two sets of 12 trials (Sets A and B). Half of the participants were tested with Set A and the other half with Set B. During each trial, a stimulus was presented to the child (for a total of 12 stimuli per set). Stimuli were presented in random order, and the child was asked to rate them as new or old items. Between each trial, a fixation cross was presented for 800 ms. In each of the two sets, six stimuli were old, and six were new. An old stimulus consisted of an image or 3D model of an object presented in the virtual presentation. A new stimulus, on the other hand, was an image or 3D model absent from the virtual presentation. We had a total of 12 new stimuli. Six were 3D models related to food (i.e., broth, kiwano, empanadas, sushi, cabbage, and cake), three others were images of landscape and monuments (i.e., mountain landscape, Tamil Nadu, and Taj-Mahal), and the last three visual stimuli were images of activities (i.e., dance, boating, and polo). The child had no time limit to complete each trial. To indicate her/his answer, the child had to press the "Q" key (symbolized on the keyboard by a red sticker) if she/he thought it was an old item, and the "P" key (symbolized on the keyboard by a blue sticker) if she/he thought it was a new item. The precise instruction given to the children was to press the red button when they thought they had seen the image presented in the trial during the presentation, or to press the blue button if they thought they had not seen the image during the presentation. The new/old recognition task was designed on PsychoPy (version 2020.2.10; Peirce et al., 2019) and had to be completed on a laptop computer.

Quiz task. The quiz task consisted of eight questions related to information that the child had just seen or heard during the virtual presentation on China. Of these eight questions, four were related to information conveyed auditorily during the presentation (e.g., What was the name of the character in the story?), and the other four were related to information conveyed visually (e.g., How do you write the character's name in Chinese?). The experimenter read the various questions aloud to them. For each question, the child could initially try to answer freely. If they were unable to give the correct answer, the experimenter presented them with four different options (one correct and three wrong). When the question was about visual information, the experimenter directly presented the child with a selection of images from which to choose (one correct and three wrong). Each question answered correctly earned the child one point (for a total of eight possible points). The complete questionnaire can be found on OSF (https://osf.io/r4s8c/).

Control task

Verbal abilities. To measure verbal abilities, we used two different subtests of the Wechsler Preschool and Primary Scale of Intelligence IV (WPPSI-IV): the picture naming subtest measuring active language skills and the receptive vocabulary subtest measuring passive language skills. Our participants were of different native languages, and we used the German and French versions of these tests accordingly. As the number of items differed between the German and French versions, we used the percentage of correct answers as a scoring system instead of the original score. The scores of these two tasks were then averaged to obtain a single verbal ability score.

Theory of mind. To measure the children's theory of mind ability, we used the same four tasks as in our previous study. These included the classic false belief stories "Maxi and the Chocolate" (Wimmer & Perner, 1983) and "The Mouse and the Cheese" (Clements & Perner, 1994), as well as the two false belief situations that consisted of "The Pencil Box" and "The Smarties Box" (Perner et al., 1987). For each task completed correctly, the child was awarded one point, for a total of four possible points. For a task to be counted as correct, the child had to answer all corresponding questions correctly. The child had to answer three questions for the two classic false belief story tasks and four questions for the two false belief situation tasks. The complete script of the four tasks with the different questions can be found on OSF (https://osf.io/r4s8c/).

Procedure

The children were tested individually in their respective schools, in a separate room, and in a quiet environment to ensure that they were not disturbed. First, they were asked to answer a general knowledge questionnaire about China. After this, the experimenter presented the VR headset or tablet to the child, depending on the experimental condition, and explained how it worked. The children could then begin to follow the virtual presentation on the corresponding medium. Depending on the experimental condition, the child followed the presentation on a tablet or a VR headset in high or low graphic detail conditions. After the presentation, the children had to answer the quiz task, as well as the new/old recognition task, to assess what they had retained from the encoding phase. They were then asked to complete the first part of the theory of mind task (two stories). These tasks were carried out in a fixed order, as listed above. To avoid overloading the children, the second part of the theory of mind task (two stories) and the two tasks measuring verbal skills were carried out a week later during a second meeting.

Results

Following our preregistration on OSF (https://osf.io/jt7zy), we conducted two analyses of covariance, with the fixed-effects *level of immersion* (IVR and D-VR) and *graphic detail* (low and high), while controlling for the covariates age, gender, verbal abilities, and theory of mind abilities. These analyses were conducted with two outcome variables, which consisted of the child's performance on the new/old recognition task and the quiz task. We excluded outliers that had three standard deviations above/below the mean and/or children who obtained a score higher than two points on the assessment of previous knowledge of China. Some participants were also excluded due to technical problems or because they did not have time to complete the parts required for their full participation in the study. Given that compliance with these criteria could vary from task to task, and in order to keep as many participants as possible in our analyses, we followed these exclusion criteria in a way that was specific to each analysis. Details of these exclusions are presented before each analysis below.

New old recognition task

For the analysis of the *new/old recognition task*, we used the sensitivity index d', as in our previous study (Dall'Olio et al., 2024). We computed d' using the following formula (Macmillan & Creelman, 1991):

$$d' = z^{-1}(\text{Hit}) - z^{-1}(\text{False Alarms}).$$

As we obtained extreme values for the hit and false alarm rates (0 and 1, respectively), we adjusted these values according to the method used in our previous study (Dall'Olio et., 2024). We added 1 to the number of signal trials and the number of noise trials and 0.5 to the number of hits and the number of false alarms.

A two-way analysis of covariance was performed to compare d' among our four experimental conditions depending on the levels of immersion (IVR and D-VR) and graphic detail (low and high) as the main independent variables, with age, gender, verbal abilities, and theory of mind abilities serving as covariates. We had to exclude one child for technical reasons, one for not having the time to complete the tasks and two because they had previous knowledge about China. In the end, we carried out the analysis on 151 children, including 46 in the IVR high graphic detail presentation group, 38 in the IVR low graphic detail presentation group, 34 in the D-VR high graphic detail presentation group, and 33 in the D-VR low graphic detail presentation group.

We did not find a significant impact of immersion on the results for the new/old recognition task ($F(1, 134) = 2.034$; $p = .156$, $\eta_p^2 = .015$). Children in the IVR conditions ($M = 1.787$, $SEM = .090$) performed as well as children in the D-VR conditions ($M = 1.977$, $SEM = .099$). We also observed no significant effect of the level of graphic detail ($F(1, 134) = .0199$; $p = .888$, $\eta_p^2 < .001$). Children performed as well in the low graphic detail conditions ($M = 1.872$, $SEM = .100$) as in the high graphic detail conditions ($M = 1.891$, $SEM = .090$). Moreover, we found no significant interaction between graphic detail and immersion ($F(1, 134) = .266$; $p = .607$, $\eta_p^2 = .002$). Children performed equally as well in all four conditions ($M = 1.812$ in low detail IVR, $M = 1.761$ in high detail IVR, $M = 1.932$ in low detail D-VR, and $M = 2.021$ in high detail D-VR). As for covariates, gender ($F(1, 134) = 1.465$; $p = .228$, $\eta_p^2 = .011$) and theory of mind abilities ($F(1, 134) = 1.070$; $p = .303$, $\eta_p^2 = .008$) had no significant impact on the results. On the contrary, we did find a significant impact of the covariates of age ($F(1, 134) = 17.046$; $p < .001$, $\eta_p^2 = .113$) and verbal abilities ($F(1, 134) = 6.916$; $p = .010$, $\eta_p^2 = .049$). It is worth noting that carrying out the same analysis without including the covariates did not change the outcome in terms of accepting or rejecting the null hypothesis.

Quiz task

For the *quiz task*, we carried out the same two-way analysis of covariance to compare the quiz task scores among our four experimental conditions, depending on the level of immersion and graphic details as the main independent variables, while controlling for age, gender, verbal abilities, and theory of mind abilities. We had to exclude one participant because he scored three standard deviations under the mean and two because they had previous knowledge about China. In the end, we carried out the analysis on 152 participants, including 46 in the IVR high graphic detail presentation group, 39 in the IVR low graphic detail presentation group, 34 in the D-VR high graphic detail presentation group, and 33 in the D-VR low graphic detail presentation group.

We found no significant impact of immersion on the results of the quiz task ($F(1, 133) = .787$; $p = .377$, $\eta_p^2 = .006$). As with the previous task, participants in the IVR conditions ($M = 5.957$ $SEM = .146$) performed as well as those in the D-VR conditions ($M = 6.150$, $SEM = .161$). We also did not find any significant impact of the level of graphic detail on the children's performances ($F(1, 133) = .898$; $p = .345$, $\eta_p^2 = .007$). Participants in the low graphic detail conditions ($M = 6.158$, $SEM = .162$) performed just as well as those in the high graphic detail conditions ($M = 5.949$, $SEM = .148$). Once again, we found no significant interaction between level of immersion and graphic details (F(1, 133 = .357; $p = .551$, $\eta_p^2 = .003$). Children performed equally as well in the four conditions ($M = 6.127$ in low detail IVR, $M = 5.787$ in high detail IVR, $M = 6.189$ in low detail D-VR, and $M = 6.111$ in high detail D-VR). Concerning the covariates, we did not find a significant impact of gender ($F(1, 133) = 1.208$; $p = .274$, $\eta_p^2 = .009$). However, we did find a significant impact for the covariates of age ($F(1, 133) = 6.226$; $p = .014$, $\eta_p^2 = .045$), verbal abilities ($F(1, 133) = 11.153$; $p < .001$, $\eta_p^2 = .077$), and theory of mind abilities ($F(1, 133) = 4.645$; $p = .033$, $\eta_p^2 = .034$). Again, carrying out the same analysis without including the covariates did not change the outcome in terms of accepting or rejecting the null hypothesis.

Discussion

In this first study, we investigated the impact that the level of detail (high/low detail) and immersion (IVR/D-VR) of a VR presentation had on children's learning. We observed no significant differences in learning outcomes based on the level of detail of the presentation. According to the CAMIL model (Makransky & Petersen, 2021), removing or diminishing seductive details that are not necessary for learning should reduce cognitive load and thereby promote learning. The fact that this was not the case in our study could indicate that the manipulation of the level of detail did not work properly. In other words, either the seductive details were not correctly identified and removed, or the manipulation carried out between the two presentations affected parameters other than the level of detail, which counterbalanced the benefits of a less detailed virtual presentation. It is possible that by attempting to reduce these seductive details, we also diminished the sense of presence provided by the virtual environment. Indeed, the graphical aspect of the virtual environment plays a major role in establishing a sense of presence (Sylaiou et al., 2010), and presence is closely linked to one of the primary advantages of IVR in education, namely its motivational aspect (Huang et al., 2023). Thus, modifying the graphical aspect of the virtual environment may have unintentionally undermined the potential of IVR as an effective learning medium. To further investigate the impact of level of detail on multimedia learning, it seems important to study in greater depth the impact of certain graphic modifications, such as level of detail, on the sense of presence and cognitive load of the participants during the learning task. To keep the test time short for our young participants (aged four to six) and to stay as close as possible to the design of our previous study (Dall'Olio et al., 2024), we were unable to implement these variables in the present study.

In addition, we did not observe any significant differences in the children's performances on the quiz and new/old recognition tasks based on the immersion level of the virtual presentation. The children learned equally well with the tablet (D-VR) and the VR headset (IVR). Given that many factors must come into play for immersion to promote learning, it is perhaps not surprising that immersion alone did not have a significant impact in our study.

Contrary to our predictions, we did not observe a significant interaction between the level of detail and the degree of immersion of the virtual presentation. We hypothesized that reducing detail would have a significantly greater impact when learning with a VR headset, as children might be more distracted by seductive details unnecessary for learning when immersed in the virtual environment. However, the data indicated that children did not benefit any more from the level of detail in IVR than in D-VR. In the context of the learning experience we designed for the children, it appears that the level of detail, as manipulated, had no significant impact on performance in either the D-VR and IVR conditions. As mentioned earlier, our manipulation of the virtual presentation's level of detail may not have been sufficient to produce the intended effects.

Study 2

In this second study, we aimed to investigate the impact of immersion on preschool children's learning from a virtual presentation based on their habituation to the medium. As in the previous study, the immersive nature of the presentation was manipulated via the medium type, which in this case consisted of headsets for IVR conditions and tablets for D-VR conditions. To evaluate the impact of habituation, the children watched the same presentation with the same medium one week later and performed a second series of tests. We expected that children would show better learning outcomes after a second exposure to the presentation, and this effect would be more pronounced in the IVR condition.

Methods

Design

In the second study, we manipulated the level of immersion (between-subjects factor) with the IVR and D-VR conditions and the degree of habituation to the medium (within-subjects factor) with habituated and non-habituated conditions. This gave us a 2 × 2 design (mixed) with the conditions of non-habituated children receiving the IVR presentation, non-habituated children receiving the D-VR presentation, habituated children receiving the IVR presentation, and habituated children receiving the D-VR presentation. Data from the non-habituated conditions were the same as those collected under the low graphic detail conditions of the first study. Data from the habituated conditions were collected one week later with the same sample of children. Indeed, unlike the first study, and given that we were investigating the effect of the repeated use of VR, the data were collected on two different occasions. Again, we measured learning outcomes (new/old recognition task and quiz task) and controlled for age, gender, verbal abilities, and theory of mind abilities, as in Study 1.

Participants

The required sample size was preregistered on OSF (https://osf.io/jt7zy). An a-priori G*Power analysis revealed that we needed a sample of at least 66 participants to detect a medium effect for interaction (2 × 2 mixed design analysis of variance; parameters: $f = 0.25$, $\alpha = 0.05$, $1-\beta = 0.80$; Faul et al., 2007). We increased the sample size to around 36 children per group ($N = 72$, 43 female, $M = 5.6$, ranging from 4–6 years) to ensure that we had enough participants after data exclusion and to remain consistent with the number of participants per group in the first study. The same exclusion criteria were used in the second study as in the first. A detailed breakdown of the number of participants excluded is presented before each analysis below. Once again, children were recruited from different preschools across Switzerland and were semi-randomly assigned to one of our two between conditions, which included an IVR presentation ($N = 86$, 48 female, mean age = 5.256) and a D-VR presentation ($N = 69$, 36 female, mean age = 5.152). The children were tested only in French. We obtained ethical approval for the study from the local ethics committee of UniDistance Suisse, and written parental consent was obtained for each child.

Procedure

The procedure was very similar to that of Study 1. The main difference was that, one week after the first test session, the children were once again asked to attend the same virtual presentation (same medium condition) as the week before. The children were then again asked to perform the two memory tasks, which included the quiz task and the new/old recognition task, to assess learning outcomes after medium habituation. For the new/old recognition task, participants were tested on a different set of images in the non-habituated and habituated testing conditions. Indeed, as explained in the first study, we had two sets of 12 different items (Set A and Set B). Participants could then be tested on one set during the non-habituated phase and on the other during the habituated phase. The order of the set on which the child was tested first was counterbalanced. For the quiz task, due to the limited number of items, participants were tested on the same questions during both the non-habituated condition immediately after the first presentation and after the implementation of the habituated condition one week later.

Materials

The VR presentation was the same as that used in Study 1 in the low graphic detail condition. Otherwise, the test material was the same as in Study 1.

Results

Following our preregistration on OSF (https://osf.io/jt7zy), we computed two analyses of covariance, with the fixed-effects *level of immersion* (IVR and D-VR, between-subjects factor) and *habituation* (non-habituated and habituated, within-subjects factor), while controlling for age, gender, verbal abilities, and theory of mind abilities as covariates. The two outcome variables consisted of performance on the new/old recognition task and performance on the quiz task. Exclusion criteria were the same as in Study 1. Once again, given that compliance with these criteria could vary from task to task, and in order to keep as many participants as possible in our analyses, we followed these exclusion criteria in a way that was specific to each analysis. Details of these exclusions are presented before each analysis below.

New old recognition task

For the *new/old recognition task*, we again used signal detection theory (Macmillan & Creelman, 1991) to calculate d' as in Study 1. We had to exclude two participants for technical reasons and four other participants because they were absent on the second day. In the end, we carried out the analysis on 66 children, including 36 in the IVR condition and 30 in the D-VR condition, for two different measurements (non-habituated and habituated). We did not find a significant impact of immersion on the results for the new/old recognition task ($F(1, 51) = .121$; $p = .729$, $\eta_p^2 = .002$). Children in the IVR conditions ($M = 1.859$, $SEM = .124$) performed as well as children in the D-VR conditions ($M = 1.922$, $SEM = .127$). We also did not observe a significant effect of habituation ($F(1, 51) = .590$; $p = .446$, $\eta_p^2 = .011$). Specifically, children performed as well on the first day ($M = 1.771$, $SEM = .113$) as they did on the second day ($M = 2.09$, $SEM = .106$). Contrary to our expectations, we found no significant interaction between immersion and habituation ($F(1, 51) = .059$; $p = .810$, $\eta_p^2 = .001$), as the children performed just as well in all four conditions ($M = 1.756$ in non-habituated IVR, $M = 1.962$ in habituated IVR, $M = 1.787$ in non-habituated D-VR, and $M = 2.057$ in habituated D-VR). We did not find a significant impact for the covariates of gender ($F(1, 51) = .015$; $p = .904$, $\eta_p^2 < .001$), age ($F(1, 51) = 1.143$; p

= .290, η_p^2 = .022), and theory of mind abilities (F(1, 51) = 1.828; p = .182, η_p^2 = .035). However, we did find a significant impact of the verbal abilities of the children on their performance (F(1, 58) = 13.833; p < .001, η_p^2 = .213). Conducting the same analysis without including covariates did not change the outcome in terms of accepting or rejecting the null hypothesis.

Quiz task

We performed a two-way mixed analysis of covariance to compare the scores of the *quiz task* among our four experimental conditions depending on the level of immersion (between-subjects factor) and habituation to the medium (within-subjects factor) as main independent variables, and age, gender, verbal abilities, and theory of mind abilities as covariates. We had to exclude four children because they were absent on the second day. In the end, we carried out the analysis on 68 children, including 38 in the IVR condition and 30 in the D-VR condition, for two different measurements. Again, we found no significant impact of immersion on the results of the quiz task (F(1, 58) = .525; p = .472, η_p^2 = .009). As in the previous task, children in the IVR conditions (M = 6.598, SEM = .162) performed as well as those in the D-VR conditions (M = 6.429, SEM = .168). We also did not find any significant impact of habituation (F(1, 58) = .148; p = .702, η_p^2 = .003). As for the results of the new/old recognition task, participants in the habituated conditions (M = 6.865, SEM = .142) performed as well as those in the non-habituated conditions (M = 6.162, SEM = .146). Once again, we found no significant interaction between habituation and immersion in the virtual presentation (F(1, 58 = 1.124; p = .294, η_p^2 = .019), as the children performed as well in all four conditions (M = 6.156 in non-habituated IVR, M = 7.041 in habituated IVR, M = 6.168 in non-habituated D-VR, and M = 6.690 in habituated D-VR). Furthermore, we did not find a significant impact of the covariates of gender (F(1, 58) = 0.168; p = .683, η_p^2 = .003, age (F(1, 58) = 3.929; p = .124, η_p^2 = .040) and theory of mind abilities (F(1, 58) = .581; p = .549, η_p^2 = .010). However, there was a significant impact of the verbal abilities of the children (F(1, 58) = 4.296; p = .043, η_p^2 = .069). Again, conducting the same analysis without including the covariates did not change the outcome in terms of accepting or rejecting the null hypothesis.

Discussion

In this second study, we examined the effects of habituation (habituated/unhabituated) and immersion (IVR/D-VR) with respect to a VR presentation on children's learning. Contrary to our hypothesis, habituation did not significantly influence the children's learning outcomes in either the new/old recognition task or the quiz. One possible explanation is that the participants did not have sufficient time to habituate to the two mediums. Specifically, they interacted with the tablet and VR headset only twice (versus once), which may have been insufficient to develop expertise with these tools. Another explanation is related to our methodology: we tested habituation by having children experience the same presentation in both the unhabituated and habituated conditions. Future studies could explore habituation using different presentations in the two conditions. This is because using the same presentation may not only test habituation to the VR headset and tablet, but also habituation to the content itself. Additionally, repeating the same presentation could affect children's motivation to learn. Motivation, as noted in the literature, plays a key role in media-based learning (Makransky & Petersen, 2021). Providing a different presentation in the habituated condition might therefore enhance the participants' interest and motivation, thereby improving learning outcomes.

As in the first study, we found no significant impact of immersion on the children's performance. Since some participants were involved in both studies, it is unsurprising that similar results were observed. Contrary to our hypothesis, we observed no significant interaction between immersion and habituation in either the new/old recognition task or the quiz. We hypothesized that children who are more familiar with tablets than VR headsets would benefit more from habituation in the IVR condition than in the D-VR condition. However, this was not the case. Habituation did not significantly improve performance in either condition. Therefore, further research could explore the effects of IVR and habituation using a different approach to habituation, such as varying the content (e.g., different virtual presentations between sessions) and extending the duration (e.g., more sessions and increased exposure to the medium). Since young children are generally more accustomed to tablets than VR headsets (Bernath et al., 2020), two five-minute VR sessions may not suffice for them to reach the same level of habituation with the VR headset as they have with the tablet.

General Discussion

The aim of this research was to further investigate the impact of immersion on the learning abilities of preschool children. More precisely, after observing in our previous study that preschool children learned significantly more poorly in IVR than in D-VR, we wondered what characteristics could influence the effectiveness of IVR learning. Indeed, in the literature, we observed a wide variety of results when using IVR, particularly in comparison with D-VR learning. In some studies, the highly immersive capacity of IVR offered a significant learning advantage (Makransky & Mayer, 2022; Martarelli et al., 2024; Olmos-Raya et al., 2018), while in others, it had no effect (Leder et al., 2019) and even hindered learning in some cases (Dall'Olio et al., 2024; Makransky et al., 2019). One way of explaining these differing results might be that other factors come into play and influence the way immersion impacts learning abilities (Makransky & Petersen, 2021). These factors are said to be a source of extraneous processing and to be detrimental to learning (Mayer et al., 2023). In this article, we set out to investigate two of these possible extraneous processing factors: the level of detail of the learning material and habituation to the IVR medium.

In our first study, we investigated the impact of the level of detail of the virtual environment and immersion on the learning outcomes of preschool children. To our knowledge, no other studies have manipulated the level of detail of a virtual presentation to observe its impact on IVR learning. Many authors maintain that reducing the seductive details of a virtual environment should reduce extraneous processing and enhance learning (Mayer et al., 2023; Parong & Mayer, 2021). Nevertheless, we did not observe any significant effect of the level of detail, immersion, or any interaction between the two variables on the children's recall. One reason for this lack of effect might be that by reducing the level of detail, we also reduced the sense of presence offered by the virtual presentation (Huang et al., 2020). Even if we had reduced extraneous processing by reducing graphical detail, we were also likely to have reduced generative processing by reducing the sense of presence. We therefore believe that it is essential for future studies to control for the sense of presence and cognitive load when manipulating the graphics of the virtual environment. This will make it easier to target the manipulations of various variables correctly.

In our second study, we investigated the impact of medium habituation and immersion on preschool children's learning. We found no significant effect of habituation or immersion, and no significant interaction between the two variables. This lack of effect can be attributed to the fact that the children did not have enough time to get used to IVR. In our study, we compared the learning outcomes of children who had used VR headsets for five minutes with those who had used them for ten minutes. This was probably too little time for them to have gained any expertise with this medium, even though we proposed a short habituation phase at the start of each presentation. In adults, Miguel-Alonso et al. (2024) observed that their participants learned better with a VR headset after a three-to-six-minute tutorial with IVR and an explanation of its features. However, exposure time is not the only factor that facilitates habituation to this medium. In another study, Lawson and Mayer (2024) observed that a 10-minute period of habituation to the VR headset did not significantly improve their learning. Whereas in the Miguel-Alonso et al. study (2024) the habituation phase was purposely designed for the study to acclimatize participants to the VR headset and reduce cognitive load, the habituation phase in the Lawson and Mayer study (2024) was a short session of a commercial game. For familiarization with the medium to be effective, not only should the habituation phase be of sufficient duration, but it should also follow guidelines that promote an understanding of the virtual environment and the medium and reduce cognitive load.

Another explanation for our results is that we used the same virtual presentation in both test phases. The children would then have become as accustomed to the presentation itself as they had to the medium. For this reason, the second viewing of the presentation might have been less motivating for the children. Motivation is one of IVR's main assets in promoting learning (Koch et al., 2018). It is therefore important not to manipulate and increase habituation to the medium to the detriment of the participant's motivation to learn. Gamification of the learning experience and well-designed tutorials would be a way of familiarizing a person with IVR while maintaining a high level of motivation (Huang et al., 2021; Miguel-Alonso et al., 2023). Future studies should investigate the effects of longer habituation periods, thereby enabling children to become more accustomed to IVR. Beyond the duration, particular attention must be paid to these habituation phases to ensure that they follow pedagogical guidelines and do not undermine motivation.

In the studies presented here, we chose to focus on preschool children because there is a lack of research exploring the effectiveness of IVR in this age group, and as immersive technologies become increasingly accessible, understanding their potential impact on younger children is crucial for future educational applications. However, the children in our studies may not have been able to take advantage of the different benefits of IVR. Indeed, the Meta Quest 2 VR headsets used in our studies were not built with such young children in mind. In fact, Meta recommends the use of these devices from the age of 10. Although we did not receive any complaints at the time of testing, the fact that the headset was heavy (503 gr) and difficult to adjust for small heads could have been a drawback to learning. Nevertheless, even if they could not take full advantage of the VR headsets, the children were still able to successfully complete the learning process. Across the two studies, we observed that, on average, the children had more than 74% correct answers to the two different memory tasks after learning with IVR. IVR, therefore, remains a learning medium that children can successfully use. Nevertheless, today's VR headsets may not be suitable for preschoolers, such as those interviewed in our studies, who may have difficulty taking advantage of their immersive properties.

There are other limitations to our study, especially regarding the sample sizes, which, despite the power analyses, were relatively small. Our decision regarding sample sizes was based on both power analyses and feasibility considerations. Furthermore, while our results were inconclusive, we wish to highlight the importance of publishing non-significant results. In the field of IVR in education, non-significant results contribute to a more balanced understanding of the conditions under which these tools succeed or fail. More generally, publishing null results helps mitigate publication bias and allows for a more complete picture of the complexities involved in IVR environments. Our findings regarding immersion, level of detail, and habituation underscore the necessity for further investigation in this area, including with older children and across different VR environments.

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