Confounding in Educational Research: A Critical Overview of Research Approaches Investigating Virtual and Augmented Reality

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Highlights

(1) Media comparison studies are often confounded because relevant factors of the learning scenario are not considered.
(2) Media comparison studies would be more meaningful if the conditions during investigations were standardized, and additional moderator and mediator variables were incorporated into the experimental design.
(3) Other research approaches, e.g., value added studies, may offer insights relevant to educational practice.

Keywords: Virtual Reality, Augmented Reality, Media Comparison, Confounding, Research Approaches

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1 Introduction

Despite considerable evidence in research that Virtual and Augmented Reality (VR/AR) enhances learning (e.g., Arici et al., 2019; Radianti et al., 2020), an argument is presented that most of this research is confounded. Wherever VR and AR are used to deliver competencies and are at the same time compared to conventional educational presentation forms, any resulting change in learning or performance may be attributed to the uncontrolled effects, e.g., of different instructional methods or content, if these are not controlled systematically. Typically, those studies, known as media comparison studies (e.g., Mayer, 2019), are focusing on the question *if* learning with VR or AR works and *if* it is better compared other presentations, and do not examine *when* and *how* learning with VR and AR works (e.g., Buchner & Kerres, 2023; Makransky & Petersen, 2021).

Within this comment, the research question to be addressed is which research approaches are currently examining the effectiveness of VR/AR learning applications. Thus, the aim is to give an overview of different types of research approaches, including media comparison studies, and discuss their relevance for educational research. The comment concludes by summarizing the findings for future research with VR and AR and providing recommendations.

2 Types of Media Comparison Studies

Based on a theoretical background, the definition of research questions and hypotheses, and the operationalization of research constructs, educational researchers aim to use several research approaches to conduct investigations, collect, analyze, and synthesize data with reference back to their questions and hypotheses. Regardless of whether a researcher chooses qualitative or quantitative research methods, there are different research approaches in the field of educational technologies. Clark (2014) suggests four approaches to educational research. For VR and AR, further research approaches are distinguished (see Table 1).

3 Limitations of Media Comparison Studies

Media comparison studies are prevalent. A systematic review analyzing studies using AR from high-quality journals revealed that 80% of the studies compare AR to another medium or technology (Buchner & Kerres, 2023). However, in media comparison studies, there is often a risk that relevant parameters of the learning setting are not considered. Contrary, theoretical models that describe learning with AR and VR are complex in design and consider multicausal relationships (e.g., Dengel & Mägdefrau, 2020; Makransky & Petersen, 2021; Mulders et al., 2020). The effects of learning environments, teacher behavior, instruc-

Table 1. Overview of research approaches towards AR/VR.

Research approach	Description with an AR or VR example
Evaluative approach	VR/AR vs. no VR/AR: Students explore a VR/AR simulation and rate its efficacy (before and) after the exploration. There is no control group. *Example:* The effectiveness of a VR simulation on behavior in emergency situations (e.g., fire) is evaluated by aspiring paramedics.
Media comparison approach (type 1)	VR/AR vs. conventional presentation: Randomly assigned students learn something using either an VR/AR simulation or a conventional presentation form. *Example:* Aspiring paramedics learn how to behave in emergency situations (e.g., fire). Half of them receive a written manual, the other half use a VR simulation.
Media comparison approach (type 2)	VR/AR technology 1 vs. VR/AR technology 2: Randomly assigned students learn something using either the VR/AR technology form 1 or the VR/AR technology form 2. *Example:* Aspiring paramedics learn how to behave in emergency situations (e.g., fire). Half of them use the 360° application on a laptop, the other half use Head-Mounted Displays to explore a VR simulation.
Value added approach	VR/AR without generative learning activities vs. VR/AR with generative learning activities: Before, during or after a VR/AR experience, half of the randomly assigned students perform an additional learning activity, the other half perform no activity. *Example:* Half of the students will be given an assignment to create a to-do list after exploring a VR training for emergency situations, the other half will not be given an assignment.
Interactional approach	VR/AR target group 1 vs. VR/AR target group 2: A VR/AR simulation is used with different target groups. *Example:* VR training for emergency situations (e.g., fire) is explored by trainees either at the beginning or end of paramedic training.
Unique affordance approach	VR/AR vs. no VR/AR: Students explore a VR/AR simulation and rate its efficacy. There is no control group. Conventional presentation forms are not available. *Example:* The effectiveness of a VR simulation on behavior in emergency situations (e.g., fire) is evaluated by aspiring paramedics. Conventional teaching methods (e.g., a real large-scale fire in a controlled setting) cannot be used to present the situation, because it is too dangerous and expensive.

tional methods etc. are explained theoretically. However, media comparison studies fail to operationalize this complexity into an appropriate empirical design.

In addition, media comparison studies run the risk of confounding: To be able to clearly attribute learning effects to the manipulation of the media presentation, the other conditions must be kept equal during the investigation. Often, however, the conditions during an investigation differ not only with respect to the medial presentation, but also with respect to the instructional methods, the teacher, or the content. For example, a VR environment in which a single aspiring paramedic learns how to behave in case of fire differs from a group work of several trainees in which the behavioral steps in case of fire are to be put in the correct order, not only regarding the medial presentation, but obviously also regarding the social setting. Hence, differences in learning are not clearly caused by the manipulation of the media presentation but may also be due to the different social setting.

Laboratory studies make it easier to standardize conditions during an investigation and usually eliminate confounding variables, but they have limited generalizability and are not close to educational practice. Field studies are prevalent in educational research but make it nearly impossible to keep all conditions the same except for the manipulation of media presentation. Whether laboratory or field research, it is recommended that experimental conditions be standardized as much as possible in media comparison studies (Shaughnessy et al., 2000).

One way to reflect the complexity of learning scenarios more adequately than it happen in media comparison studies is to integrate moderator and mediator variables into the experimental design (as suggested in several theoretical models towards VR and AR, e.g., Makransky & Petersen, 2021). Regarding VR and AR, possible mediators are latent processes that happen during a VR or AR experience. One of these processes may be the feeling of presence (Mikropoulos, 2006), another one cognitive load (Makransky & Petersen, 2021). Moderating effects can be expected, for example, from the learners' prior knowledge (Taçgın, 2020). Figure 1 shows how experimental designs, known from media comparison studies, can be supplemented with moderating and mediating variables.

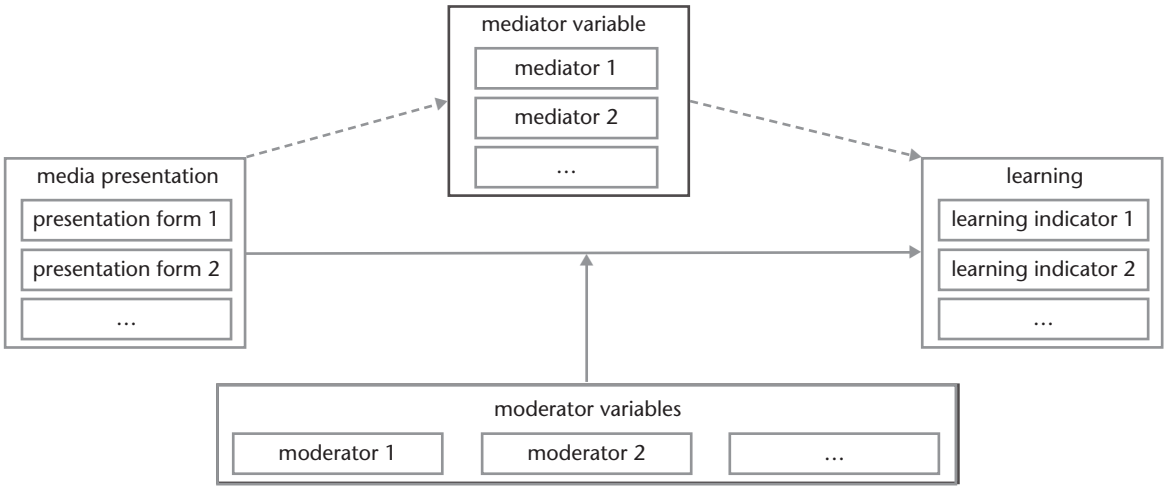

Figure 1. An experimental design beyond media comparisons (based on Mulders, 2023).

Due to the criticism of media comparison studies, other research approaches seem beneficial. Using value added and interactional approaches, further independent variables are integrated into the experimental design and are manipulated systematically (see Figure 2). Such approaches can provide recommendations relevant to educational practice. Klingenberg et al. (2022), for example, investigated the effectiveness of additional learning activities, as segmentation or summarization after a VR experience. Results indicated that, compared to the control condition, adding segmentation or summarization leads to better transfer, but not to acquiring more factual knowledge.

4 Conclusion

Taken together, VR and AR are two contemporary technologies arousing great interest in educational research and practice. However, a perspective focused solely on the technology fails to provide evidence of the effects of VR and AR. Hence, other research approaches are needed to test the potential and limits of the use of VR and AR in educational settings. More complex research approaches are indicated that go beyond the unidirectional effects of media presentation forms. For example, the studies by Parong and Mayer (2021), Petersen et al. (2022) as

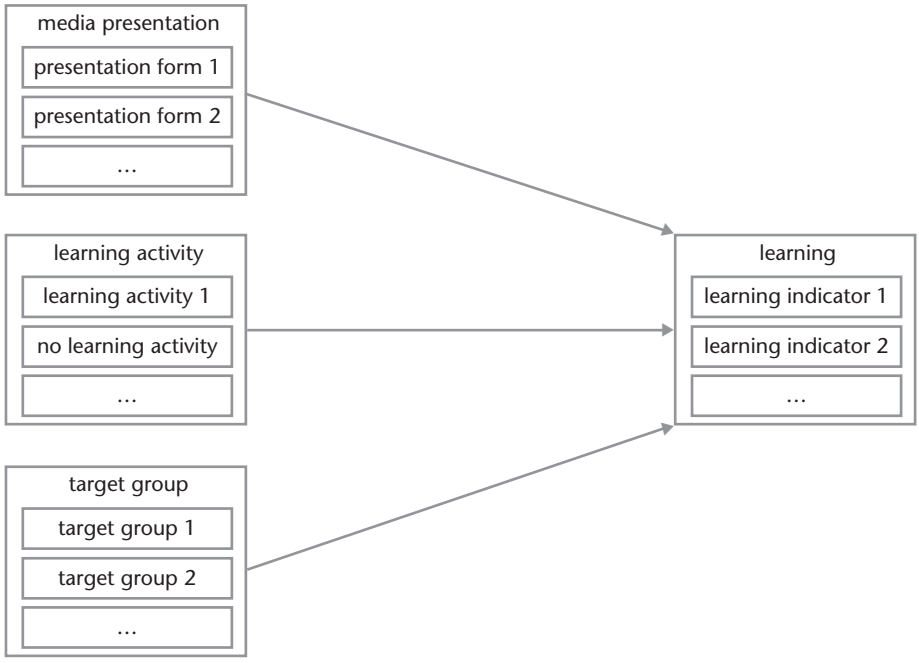

Figure 2. An experimental design beyond media comparisons.

Note. Interactions between the independent variables are not displayed in the presentation, nevertheless they are scientifically interesting to observe.

well as Johnson-Glenberg et al. (2021) exemplify how the integration of additional variables significantly enhances the validity of these studies. Such approaches make it possible to better describe the quality of learning experiences in VR and AR or to make practically relevant recommendations for the use of generative learning activities.

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