

## HABILITATION THESIS REVIEWER'S REPORT

### Masaryk University

**Applicant**

Mgr. Vojtěch Juřík, Ph.D.

**Habilitation thesis**

Virtual Simulations in Psychology: Evaluating Current Trends of Immersive Virtual Simulations Use in Psychological Research and Follow-up Applications

**Reviewer**

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Immersive Virtual Reality (IVR) is defined as a technological system that uses a computer and display to create a rich sensory environment that blocks out the physical world, enabling users to feel psychologically present in a simulated setting. It employs technologies such as Cave Automatic Virtual Environments (CAVEs) and head-mounted displays (HMDs) to enhance the sense of presence through features like tracking and stereoscopic vision. The aim of the thesis was to analyse the potential of human-centred simulations, specifically those using immersive virtual reality, across various disciplines, with particular emphasis on its integration into psychological research and applications. The first part of the thesis is a review of the field of immersive virtual simulation (IVS), while the second part provides insight into psychological research and practice through the efficient and informative application of IVS in different psychological disciplines.

The structure of the thesis is clear and logical. The author begins with the theoretical and historical background, providing a precise definition of simulation, specifically in psychology, and a clear distinction between the meanings of simulation and model. The specificities of mental, physical, and virtual simulations are then concisely explained.

In each chapter, the author critically reflects on the theoretical meaning and significance of each type of simulation. When discussing the adoption of virtual simulations in psychology, proper emphasis is given to the balance between control of conditions in the use of IVS and the (mainly ecological) validity of the results obtained in studies using IVS, especially in Human-in-the-Loop situations. In the empirical part of the thesis, the emphasis is first on current experimental studies from the virtual simulations laboratory at the Department of Psychology, Masaryk University, all of which were reported in prominent psychological scientific journals with corresponding impact, namely: (i) as an economical way to replicate the results of prior studies (through studying false memories), (ii) in education (comparing traditional learning with learning in IVR environments in two types of schools), (iii) as a psychotherapeutic tool (studying the effect of virtual reality exposure in acrophobia with or without psychological guidance), and (iv) in engineering applications (testing the retracing evacuation strategy in a virtual reality game-based investigation into the influence of a building's spatial configuration in an emergency). Second, the thesis addresses follow-up spatiotemporal movement analysis using virtual simulation – spatiotemporal virtual movement analysis – using AI in decision-making or agent-based modelling (in the study of evacuation paths in logistically complicated buildings). This follow-up spatiotemporal analysis of evacuation behaviour offers a comprehensive understanding of how navigation during emergencies can be predicted with a higher level of

ecological validity. These insights can be valuable for improving methodologies for researching evacuation strategies and understanding human crisis behaviour.

In presenting each completed and ongoing study, the author provides thorough and comprehensible reflections on the use, benefits, and shortcomings of the virtual simulation approaches employed. The thesis concludes appropriately with commentary on limitations and future directions. The author demonstrates experience in balanced evaluation of the advantages and disadvantages of each theoretical approach presented. The findings from the studies show that IVR is not only a viable tool for psychological experiments but also offers innovative and economical possibilities for addressing key methodological and theoretical challenges in the field. The thesis, as the author himself concludes, is valuable, instructive, and useful for several reasons: (i) it creates a theoretical framework for human-centred simulations, including immersive virtual simulations; (ii) it connects current cognitive psychology perspectives with human interactions with the environment; (iii) it establishes a basis for using virtual simulations as a foundation for effective, safe, controlled, and ecologically valid research and application in psychology; (iv) it summarises and critically comments on several of the author's studies on the use of virtual reality within psychological research and applications to reassess future research directions; and (v) it demonstrates new research insights in the field of evacuation modelling by linking virtual simulations and agent-based modelling, considering the human-in-the-loop principle.

**Relevance of the topic within the academic field:** The thesis addresses an exceptionally relevant and timely topic within contemporary psychology. As emphasised in the conclusions, psychology – like many scientific disciplines – is undergoing a methodological transformation driven by advanced technologies, with immersive virtual reality (IVR) emerging as one of the most promising tools for both research and application. The thesis convincingly situates immersive virtual simulations at the centre of this transformation, particularly in relation to long-standing challenges such as the control–validity trade-off, replicability, ethical constraints, and ecological validity. By framing IVR as a human-centred simulation technology, the work aligns strongly with current international research trends in cognitive psychology, social psychology, clinical psychology, and human–computer interaction, underscoring its high disciplinary relevance.

**Precision, clarity, and formulation of the topic:** The topic is formulated broadly yet coherently, with the concept of human-centred simulation serving as the central organising principle throughout the thesis. The conclusions further clarify this concept by explicitly defining human-centred simulations as those focused on human behaviour, cognition, and decision-making within interactive environments. The progression from theoretical foundations to empirical applications and future-oriented discussion is logical and well-structured. Nevertheless, as reflected in the main text, the conceptual density and extensive scope occasionally reduce clarity. While the conclusions successfully synthesise the aims and findings, earlier and more explicit delimitation of key concepts – such as distinctions between IVR, immersive virtual simulations, and broader simulation paradigms – would further improve comprehensibility. The language is very clear in defining the crucial phenomena and in differentiating the related concepts. The author leaves no room for alternative interpretations or understandings of the key terms. For example, the typology of simulations relevant in the framework of psychological research (p. 33 of the thesis), distinguishing between different simulation types – external and internal, computational mathematical and computer-based, physical (virtual and live), and mental (conscious and subconscious), constructive and human-centred – is crystal clear and very welcome. The author is well acquainted with recent concepts and theoretical approaches, such as dual-process theories, embodied cognition, connectionism and neural networks, the extended mind theory, and especially the Bayesian brain hypothesis, from which the predictive processing theory derives.

**Contribution to the field and comparison with existing research:** The thesis makes several substantial contributions to psychological science and related interdisciplinary domains. First, it develops a comprehensive theoretical framework for human-centred simulations, positioning immersive virtual simulations as a bridge between traditional mental simulations and physical, real-world experimentation. This contribution is reinforced in the conclusions by linking the framework to contemporary cognitive theories, particularly predictive processing, thereby grounding the work in established psychological discourse. Second, the thesis distinguishes itself from many foreign and domestic works by systematically integrating empirical evidence derived from the author's own research practice. Rather than merely presenting results, the thesis critically reassesses these studies, identifies their limitations, and outlines future research directions. This reflective approach is comparatively rare in the literature and adds notable scholarly value. Third, the interdisciplinary linkage between IVR, machine learning, and agent-based evacuation modelling represents a significant advancement beyond conventional psychological applications of virtual reality. The conclusions clearly articulate how the human-in-the-loop (HITL) principle, combined with immersive simulations, enables adaptive, data-rich experimental designs. Compared to existing international research, which often focuses on either VR applications or computational modelling in isolation, this thesis offers an integrative perspective that meaningfully advances both domains. Within the domestic context, the scope, analytical depth, and methodological innovation of the work place it among the most comprehensive contributions in this area.

The illustration of virtual simulation as a replication booster in replicating the results of prior studies through the study of false memories is a particularly valuable example of the utility of IVS in replication studies. Here, the author refers to the last ten years of efforts by the Open Science Collaboration, arguing that proving the validity of research conclusions through blind replication of phenomena is not the only, or even the best, way to verify ecological validity, as it is well known that reproducibility of results (examining the original data by repeating the same method) is not the same as replicability, which is of at least two kinds: exact or blind replicability (testing data obtained from different samples with the same method) and conceptual replicability, where different methods, approaches, and analyses are used on different samples. It has been shown frequently in recent years that the latter group of methods is much more efficient, and the author's example in the thesis can be considered one of the more promising ways to perform a replication.

Virtual Reality Exposure Therapy (VRET), an advanced form of cognitive-behavioural therapy, has shown considerable efficacy in reducing symptoms of PTSD and specific phobias, and offers an effective alternative or complement to traditional exposure therapies. Similarly, the integration of biofeedback mechanisms into IVR environments (which remains quite underdeveloped), machine learning (as an autonomous system for combining data from virtual simulations), and the "human-in-the-loop" (HITL) method, a fundamental aspect of machine learning that emphasises ongoing interaction between humans and machines throughout the AI development process, all appear to be promising tools for improving the predictive validity of psychological models.

**Methodology and level of analysis:** The methodological approach – combining theoretical analysis, synthesis, and critical reassessment of empirical studies – is well suited to the research objectives. The thesis is primarily a review; its structure is clear, focused, and comprehensible. The conclusions demonstrate that each stated objective has been systematically addressed, from establishing the theoretical framework to empirically validating IVR's potential in psychological experimentation, therapy, and modelling. The empirical analyses presented in PART III, particularly the spatiotemporal trajectory analysis of evacuation behaviour using Gaussian distributions and KL-divergence, reflect a high level of methodological rigour and originality. The integration of real-world data, VR-based simulations, and artificial agent simulations enables meaningful comparative analysis, moving beyond simplistic performance metrics such as total evacuation time. This depth of analysis

strengthens the thesis's contribution to both psychology and simulation science. At the same time, the conclusions appropriately acknowledge limitations, including the need for further research into cognitive equivalence between IVR and real-world behaviour, as well as the necessity for longitudinal and cross-cultural studies. The author could explore solutions to methodological sampling problems in cases – common in this type of research, as the author himself notes – where there is sample attrition and missing values due to cybersickness, poor understanding of the research situation, or other reasons (for example, in the fourth study presented, 9 participants out of 82 dropped out of the experiment), or when dealing with samples exhibiting lower variability in interpersonal differences in the phenomenon under study (overly homogeneous groups, such as samples from the student population).

**Formal standards and academic quality:** The thesis meets high formal and academic standards. The language is scholarly, precise, and consistent with advanced academic writing, and the conclusions demonstrate a strong command of the relevant literature. Citations are used extensively and appropriately to support both theoretical claims and empirical interpretations. The concluding sections are particularly strong in synthesising complex material and articulating future research directions. While the writing is generally clear, sentence complexity and length occasionally affect readability. However, this does not significantly detract from the overall academic quality. Structurally, the thesis is well organised, with the final summary and conclusion effectively integrating theoretical discussion, empirical findings, ethical considerations, and future perspectives into a coherent whole. The terminology is clear, unambiguous, and understandable. The list of references is impressive, including relevant works from the last twenty years or so of research in the fields covered by the thesis.

**Ethical considerations and future orientation:** A notable strength of the thesis, clearly articulated in the conclusions, is its explicit engagement with ethical issues related to immersive virtual simulations. The discussion of participant well-being, emotional impact, data privacy, and informed consent demonstrates methodological maturity and awareness of emerging challenges in IVR research. The author is well aware of the most significant risks in research using IVR methods and techniques. In addition to important questions about data privacy and confidentiality, processing data such as biometric information, behavioural patterns, and interaction metrics, there are serious psychological issues that must be addressed in this type of research. Immersion can evoke intense emotional and physiological reactions. Participants may experience distress, anxiety, or other unintended psychological consequences, especially in scenarios involving emotionally charged or traumatic content, so ensuring participants' emotional safety and well-being is paramount in developing and applying IVR technologies. As IVR becomes increasingly integrated with artificial intelligence and machine learning, new questions arise about informed consent and how participants are made aware of how their data will be used during and after the research. Transparent and robust ethical guidelines should govern the design, implementation, and evaluation of IVR systems, ensuring participants are fully informed about potential risks and benefits and have the option to withdraw without negative consequences. Safeguards must include risk assessments to evaluate the psychological impact of IVR scenarios, participant screening to identify those who may be particularly vulnerable, debriefing procedures to help participants process their experiences, and robust data security measures to protect sensitive information. The call for robust ethical frameworks and ongoing evaluation is well justified and adds depth to the thesis's contribution. The future-oriented perspective is also a strong point. By outlining directions for adaptive IVR–ML systems, longitudinal research, cross-cultural studies, and interdisciplinary collaboration, the thesis positions itself not only as a contribution to current knowledge but also as a foundation for future research agendas.

**Overall assessment:** We agree with the author that the methods presented, which integrate virtual simulations and machine learning, represent a significant advancement in psychological research. By

combining these technologies, researchers can develop more accurate models, design better experiments, and gain deeper insights into human behaviour, cognition, and other complex psychological phenomena. In this way, they can contribute to the development of more effective interventions and treatments. The methods and approaches presented in this thesis show promise for wider application not only in psychology, but also in other fields such as medicine, industry, architecture and engineering, sport, arts, and tourism. Overall, the thesis represents a theoretically well-grounded, highly relevant, methodologically robust, and conceptually ambitious contribution to psychology and interdisciplinary simulation research. The integrated conclusions reinforce the originality and coherence of the work, demonstrating that the stated aims have been successfully achieved. Through its theoretical framework, empirical rigour, interdisciplinary integration, and ethical awareness, the thesis compares very favourably with both domestic and international research and makes a significant contribution to the advancement of immersive virtual simulations in psychological science. The thesis, based on broad theoretical discussion and empirical evidence, presents novel findings, showcasing data processing from IVS with potential applications in agent-based modelling.

Based on the above, it can be concluded that the habilitation thesis entitled *Virtual Simulations in Psychology: Evaluating Current Trends of Immersive Virtual Simulations Use in Psychological Research and Follow-up Applications* by Mgr. Vojtěch Juřík, Ph.D., in every respect fulfils the requirements expected of a habilitation thesis in the field of psychology.

**Reviewer's questions for the habilitation thesis defence** (number of questions up to the reviewer)

- The mention of IVS as a replication booster in the thesis (using the example of the study of false memories) is intriguing. It is well established that »exact replication is not a silver bullet«. What are the advantages and disadvantages of so-called conceptual replication (examining results obtained from different samples with different methods, approaches, and analyses) using IVS compared to classical approaches to assessing the ecological validity of results from previous studies?
- The issue of changes in sample structure due to the dropout of a significant number of participants is highly relevant in IVS studies. Could the author explore in more detail the solutions to these sampling problems, such as sample attrition and missing values due to cybersickness, poor understanding of the research situation, or when dealing with samples that exhibit lower variability in interpersonal differences in the phenomenon under study (for example, overly homogeneous groups such as student samples)?
- The author mentions in the thesis the use of the IVR approach as an aid in training to combat neurodegenerative diseases. Could he be more specific in describing these possibilities? Is there any recent empirical evidence in the form of concrete studies available in this area?

**Conclusion**

The habilitation thesis entitled *Virtual Simulations in Psychology: Evaluating Current Trends of Immersive Virtual Simulations Use in Psychological Research and Follow-up Applications* by Mgr. Vojtěch Juřík, Ph.D., **fulfils** requirements expected of a habilitation thesis in the field of Psychology.

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Signature: