I. Introduction

This section introduces the research topic and agenda of this thesis. The first section A.I.1 motivates the thesis and highlights the relevance of the presented research. Next, the second section A.I.2 describes the research gaps and derives overarching research questions for this thesis. Following the third section A.I.3 which describes the structure of this thesis, the fourth section A.I.4 discusses the research positioning, design, and space. Lastly, this introduction is concluded by presenting anticipated contributions and implications of the thesis (A.I.5).

I.1 Motivation

"Experiment is the sole judge of scientific 'truth'"

(Richard Feynman)

From the earliest days of scientific inquiry, experiments have been instrumental in expanding the understanding of the world (Fink, 2022). The word experiment originates from the Latin verb "*experiri"* meaning *trying, testing, checking*. An experiment is a method used to investigate relationships between variables in controlled conditions, with the core objective of understanding causality (Benbasat, 1990). This method is widely applicable across various fields, from natural sciences to social sciences (Fink, 2022; M. Webster & Sell, 2014b).

After World War II, social scientists became more interested in phenomena that can be studied experimentally due to new topics and new technology (M. Webster & Sell, 2014b). Since then, advancements in technology have shaped experimental research in psychology and social sciences (Krantz & Dalal, 2000; M. Webster & Sell, 2014b). Gupta et al. (2018) attribute the rise of economic experiments in IS to advances in technology and conclude that the IS domain is lagging in the use of the methodology. This underlines the importance of understanding new technologies and their use for new ways to conduct experiments.

In recent years, VR technology has emerged as an affordable and consumer-grade technology (Wohlgenannt et al., 2020) since the barriers of high equipment cost and insufficient quality have been lowered (Valmaggia, 2017). According to Sherman & Craig (2018), a VR experience has five key elements. Participants (1) engage with the virtual world (3) created by the creators (2). The experience is characterized by immersion (4) and interactivity (5). As the experience is created in the mind of each individual, each participant has a unique experience based on their capabilities and background. The creators designed an application in order to enable the experience of the participants. A virtual world in the context of VR is an imaginary space that can be viewed and interacted with via the VR hardware so that the participants are physically immersed in it.

Due to its characteristics, VR enables concepts like a “Metaverse” in which physical reality and digital virtuality are blended in a multi-user environment that is continuous and interconnected (Mystakidis, 2022). Peukert et al. (2024) investigate the metaverse in the context of IS to discuss topics for future research. They also describe methodological opportunities for experiments in the metaverse utilizing the VR aspects of it.

Thus, VR might be the next technology that could advance experimental research, offering immersive experiences that can simulate real-world conditions or create entirely new environments for research.

Even though VR and the metaverse are significant topics for IS, the current knowledge base regarding VR remains underdeveloped (Peukert et al., 2024; Walsh & Pawlowski, 2002; Wohlgenannt et al., 2020). Especially rising questions like *“How can researchers harness the immersive and realistic qualities of the Metaverse to conduct experiments that would be challenging or impossible in physical settings?”* (Peukert et al., 2024, p. 8) motivate the need for this dissertation as it aims to explore the why, how, and when of utilizing VR in Information Systems research, focusing on application strategies.

This thesis adopts a problem-oriented perspective on the phenomenon of VR experiments in the IS domain. It addresses two primary aspects: the design of VR experiments and their use and application, particularly concerning validity issues and common challenges. The focus is on providing comprehensive guidance for conducting future VR experiments in both research and practice.

By examining the design and implementation of VR experiments, this thesis aims to identify and address potential pitfalls, ensuring the reliability and validity of experimental results. Furthermore, it highlights the practical applications of VR experiments, offering insights into how VR can be effectively utilized in various contexts such as product research, prototype testing, and UX studies. This thesis seeks to understand the promising yet underutilized medium of VR for experimental research. By bridging gaps in current methodologies and offering practical recommendations, it aims to encourage more widespread adoption of VR in the IS domain.

I.2 Research Gaps and Research Questions

This thesis aims to enhance the comprehension of VR experiments. The overarching goal is to motivate and understand VR experiments in a way that expands the toolkit of researchers, also giving operating instructions on how to use that tool. It will focus on three primary objectives with its respective research questions outlined below.

First, understanding new technology and its potential applications in research is essential for driving innovation and advancing scientific knowledge. Experimental research is a long-established method to conduct research (Weinmann et al., 2021). As there are different ways of doing experiments (for a more detailed description see section II.1) each way comes with its benefits and disadvantages. Understanding these is crucial for choosing the right method.

Online experiments are a prime example of how new technology can be leveraged in research (Arechar et al., 2018; Buso et al., 2021). These experiments utilize web-based platforms to collect data from a vast and diverse global audience, which is not feasible with traditional lab-based studies (Karahanna et al., 2018). With the advent of online communities in virtual worlds (2D screen-based), researchers explored experimentation within virtual worlds like "*second life"* or "*World of Warcraft"* (Bainbridge, 2007; Chesney et al., 2009).

Experimental tools like online experiments or virtual worlds come with their benefits, unique opportunities, and limitations (Arechar et al., 2018; Chesney et al., 2009; Karahanna et al., 2018). Thus, it is important to understand how a new technology might be beneficial for experimental research in IS. A current call of the *Journal of Information Technology* is called "Next-Generation Information Systems Research Methods" and is searching for new tools in the toolkit of IS research (Blohm et al., 2022). As digital IT becomes more and more widespread, also the scope of IS research is widening and thus in need of new methods to investigate phenomena. Recent discussions on the VR-driven metaverse raise the question of whether the metaverse might open new possibilities for immersive experiments in a "virtual lab" (Peukert et al., 2024). In line with these calls to action, the first research question aims to explore the potential benefits of VR experiments in IS.

> **RQ1:** *What benefits might Virtual Reality experiments offer compared to traditional approaches?*

Second, the design of an experiment is crucial for its success, especially concerning rigor and relevance (Arechar et al., 2018). This involves careful planning of the experimental setup, including the selection of appropriate variables, controls, and the environment in which the experiment is conducted. The unique capabilities of VR, such as immersive

environments and the ability to control and manipulate variables precisely, offer new opportunities for experimental design but also new challenges that need to be identified to be tackled. While the design of online experiments was broadly explored and different tools for creating them emerged (e.g., Bakshy et al., 2014), the design of VR experiments remains underexplored. Especially when VR experiments are conducted online, some design decisions could be crucial for the success of the experiment. While the opportunity to conduct VR experiments remotely has been discussed by previous research (Radiah et al., 2021) the studies also identify a need for further research on the design *"Therefore, researchers may need to develop additional tools to interact with participants or consider other ways to ensure smooth procedures."* (Radiah et al., 2021, p. 12). Thus, to design VR experiments, there is a need to conduct studies that create design knowledge. This leads to the following research question:

RQ2: *How should Virtual Reality experiments be designed?*

Third, leveraging the benefits of Virtual Reality in experimental research encompasses not only understanding its advantages but also implementing strategies to utilize these benefits fully. This involves exploring the potential of VR for enhancing the realism and engagement of experimental scenarios, improving data collection through more nuanced and complex interactions, and creating controlled yet flexible experimental conditions that were previously unattainable. This leads to the third research question:

RQ3: *How can the benefits of Virtual Reality experiments be leveraged?*

This research question is deconstructed into two sub-questions recognizing the multiple ways of leveraging different benefits. The first sub-question builds upon the integration of additional data streams, such as physiological measures, eye tracking, and real-time feedback, that could provide a richer understanding of participant responses and behaviors (Dimoka et al., 2012). New experimental methods enable new data streams that enable researchers to understand (actual) behavior in the respective environment (Williams et al., 2017), but also deepen their understanding of existing theories or even find new theories. For example, online/computer-based experiments enabled researchers to utilize mouse movement data (Hibbeln et al., 2017; Weinmann et al., 2022). The movements enabled them to understand emotions (Hibbeln et al., 2017) and fraud behavior (Weinmann et al., 2022). A possible problem in traditional research settings is time-synchronization of variables to draw reliable conclusions (Klumpp et al., 2022). Since the virtual environment is fully observable at all (discrete) times and measurement instruments can be seamlessly integrated and synchronized within it, time-synchronization issues are significantly reduced in VR experiments. Nevertheless, studies using this way of data collection are sparse. The first sub-question bridges this gap by presenting one approach of integrated data collection leveraging additional possible data streams:

RQ3.1: *How can additional data streams of Virtual Reality experiments be leveraged?*

The ability to create Virtual Environments offers unparalleled opportunities for experimental research. In the automotive industry, driving simulators are used for rapid prototyping and user testing (Kaptein et al., 1996; Morra et al., 2019; Riegler et al., 2019a). Furthermore, VR can be used to investigate Information Systems providing warnings for believable but still harmless "dangers" (Duarte et al., 2010). Even though VR can facilitate unique experimental conditions and simulate scenarios that are otherwise impossible or unethical to replicate in the real world and some IS researchers have harnessed this potential (Meißner et al., 2019; Peukert et al., 2019; Pfeiffer et al., 2020), studies leveraging VR for such purposes remain sparse. The second sub-question bridges this gap by presenting an inquiry into the applications and benefits of virtual environments in experimental research.

RQ3.2: *How can the possibility of creating Virtual Environments in Virtual Reality be leveraged?*

Figure 1 provides an overview of the research questions and their connections, which have been described in the chapter. The theoretical background to relevant topics is presented in section A.II.

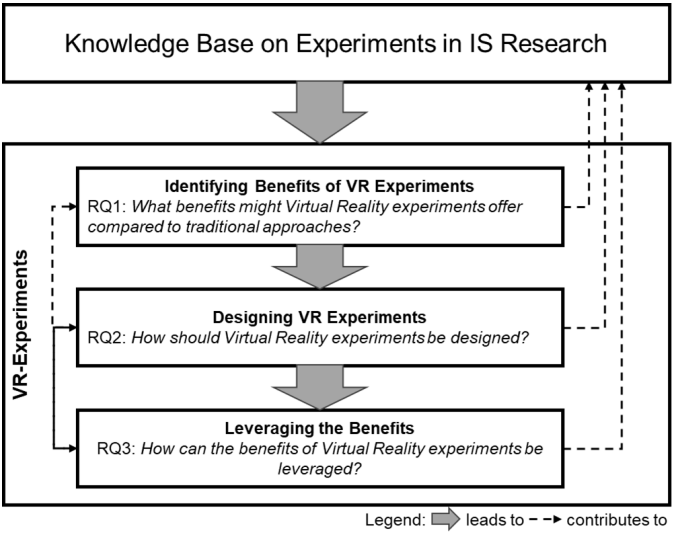

Figure 1 Research Overview

I.3 Structure of Thesis

This cumulative thesis includes four individual studies. It is structured in three main parts as shown in Figure 2.

Part A provides the foundation of this thesis by providing an introduction (A.I) and the research background (A.II). The introduction motivates the research by describing the evolution of experiments in human history and depicting VR as a new tool for IS research (A.I.1). Based on this, research questions investigating VR experiments are derived (A.I.2). Continuing from this, the structure of the thesis is presented (A.I.3), and the research is positioned (A.I.4). Lastly, the anticipated contributions are described (A.I.5). The background section introduces the most relevant concepts and research streams for this thesis while avoiding redundancies with the studies included in part B. First, experimental research is described (A.II.1). Next, Virtual Reality is presented from a technological and psychological perspective (A.II.2). Following this, the application of VR in research contexts is detailed (A.II.3). Lastly, a synthesis of the understanding of VR as a tool for experimental research in IS is presented (A.II.4). Part B includes the four studies as the core of this thesis. The studies provide a multi-perspective view of VR experiments in IS, shedding light on potential benefits, experiment design and application areas, while contributing to closing the research gaps (Table 1). Finally, part C concludes the thesis by providing a comprehensive overview of its contributions (C.I), which involves presenting and synthesizing the findings from the individual studies. The following chapter sets out the implications and limitations of these findings (C.II). The thesis concludes with final remarks that summarize the essentials and contributions of the study (C.III).

Table 1 Overview of the Studies Included in this Thesis

No.	Outlet	Status	Ranking[1]	Section	RQ	Main Contribution
1	Proceedings of the International Conference on Information Systems (2023)	Published	A	B.I.1	1	Showing that realism can be higher in VR-Experiments compared to traditional text-based experiments.
2	Proceedings of the 56th Hawaii International Conference on System Sciences (2023)	Published	C	B.II.1	2	Generating design knowledge on VR-Experiments.
3	Proceedings of the International Conference on Information Systems (2023)	Published	A	B.III.1	3	Utilizing new data of VR-Experiments.
4	Proceedings of the International Conference on Information Systems (2022)	Published	A	B.III.2	3	Example for the use of a virtual environment as an experimental environment

1 According to VHB-JOURQUAL 3 (valid at the time of publication)

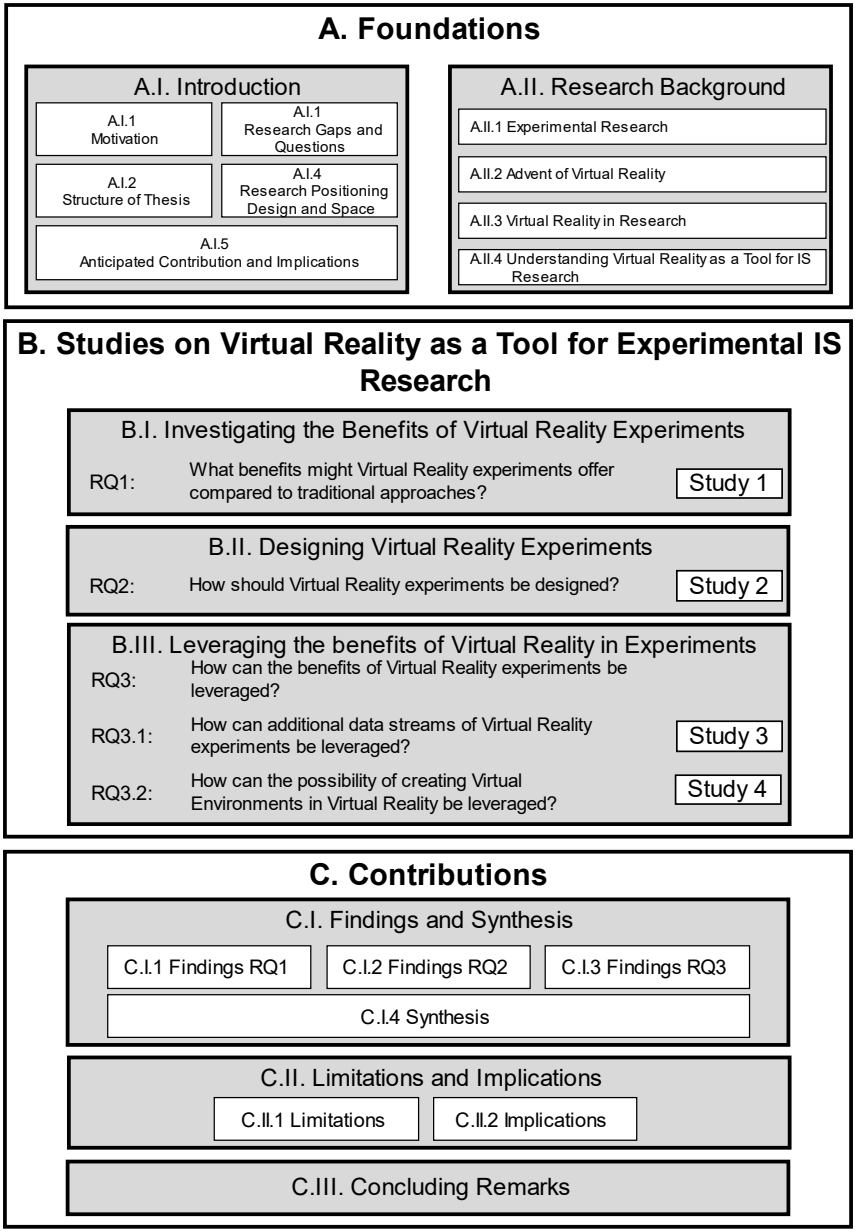

Figure 2 Structure of this Thesis

I.4 Research Positioning and Design

"We believe that the purpose of research is to advance knowledge and the scientific process." (Dennis & Valacich, 2001)

According to the Oxford Dictionary[2], research is *"a careful study of a subject, especially in order to discover new facts or information about it"*. In IS research the subject usually is an Information System or the effects of an Information System (Banker & Kauffman, 2004). The works of Gregor (2006) and (Banker & Kauffman, 2004) allow to position research within the IS domain concerning theory (Gregor, 2006) and research streams (Banker & Kauffman, 2004). In the following subsections, this thesis is positioned in the IS landscape (I.4.1) and the research design of the individual studies is presented (I.4.2).

I.4.1 Research Positioning

Table 2 presents the key criteria for positioning research in the field of Information Systems. The criteria will be further explained and examined, focusing on their application to this thesis and the studies it includes.

Table 2 Positioning Criteria in the IS Discipline

Epistemology	Positivism	Interpretivism	Critical Realism		Pragmatism
	Study #1. #3, #4				Study #2
Paradigm	Behavior-Oriented			Design-Oriented	
	Study #1. #3, #4			Study #2	
Theory Type	I. Analysis	II. Explanation	III. Prediction	IV. Explanation and Prediction	V. Design and Action
				Study #1. #3, #4	Study #2
Research Stream	Decision Support and Design Science	Value of Information	Human-Computer Systems Design	IS Organization and Strategy	Economics of IS and IT
	All Studies				
Research Method	Case Study	Conceptual Model	Mathematical Model	Literature Analysis	Survey
	Secondary Data	Design Science	Interview	Experimental Research	Content Analysis
	Study #2			Study #1, #3, #4	

First, research can be classified based on the epistemology. The word *epistemology* originates from epistēmē (knowledge) and logos (reason). Epistemology is the theory of knowledge and its "creation"(Steup & Neta, 2024). In the IS domain, four perspectives are generally considered: Orlikowski & Baroudi (1991) introduced Positivism, Interpretivism, as well as Critical Realism and Goldkuhl (2012) added the Pragmatism perspective. The epistemological perspective describes how a researcher perceives the world. Generally, experiments follow the positivist perspective since they test theories and seek generalizable results by verifying or falsifying results (Chen & Hirschheim, 2004). A causal

[2] https://www.oxfordlearnersdictionaries.com/definition/english/research_1

relationship is usually presented with an explanation, a prediction and a control (Orlikowski & Baroudi, 1991). The focus is on an objective reality with testable relationships behind the subjective human perception (Gregor, 2006).

In contrast to positivism, interpretivism focuses on phenomena in subjective contexts. Understanding human actions in a context requires an interpretation of those actions. Instead of having a fixed set of variables (like in a positivist study), interpretative studies seek a holistic understanding of a phenomenon.

Critical realism accepts the positivist stance of an objective world but seeks previously unobserved differences from the status quo(Orlikowski & Baroudi, 1991). It thus demands a comprehensive critique of accepted knowledge and allows to discover structural contradictions in social systems(Orlikowski & Baroudi, 1991).

Lastly, pragmatism combines action and change. It assumes that “Knowledge is constructed in order to better manage existence and taking part in the world” (Goldkuhl, 2012, p. 140). An artifact can be created (action) to influence human behavior (change). In IS research, this perspective is operationalized through the Design Science Research (DSR) paradigm, facilitating a pragmatic approach to inquiry (Ågerfalk, 2010).

Overall, this dissertation embraces a pragmatic stance, with the goal of advancing experimental methodologies by exploring the use of VR as an innovative experimental tool. Concurrently, this work acknowledges the value of a positivist perspective, especially in the development and execution of experiments that rely on empirical evidence and observable facts.

Two paradigms can be used to further classify IS research: behavior-oriented and design-oriented research (Arnott & Pervan, 2012; Hevner et al., 2004). Design-oriented research focuses on creating knowledge (e.g., with developing design theories) regarding how to design IS artifacts (Gregor, 2006; Gregor et al., 2020; Gregor & Jones, 2007). Behavior-oriented research seeks to explore and explain human or organizational behavior by developing or verifying theories (Hevner et al., 2004). Nevertheless, behavior-oriented theories paradigms can be integrated as a kernel theory in design-oriented research (Hevner et al., 2004).

While the core of the included studies (Studies 1, 3, and 4) aligns with the behavior-oriented research paradigm, this thesis, together with the insights from Study 2, takes a shift towards the design-oriented paradigm. It achieves this by communicating how the potential of VR experiments to refine and advance behavior-oriented research can be leveraged.

The five different types of theory presented by Gregor (2006) offer another framework to position the research of this thesis. This thesis aims for a type V theory “Design and Action” by giving explicit prescriptions for constructing VR experiments like study 2. The

other included studies build on different theory types. Studies 1, 3 and 4 follow an experimental design providing an explanation and prediction (theory type IV). Nevertheless, all studies contribute to the overarching goal of this thesis: the understanding of how, when and why to use VR experiments (type V).

Research in IS can additionally be classified by the research stream. Banker & Kauffman (2004) identified five different research streams in the history of IS research. This thesis mainly contributes to the research stream of Human-Computer Systems Design by having a user (experiment participant)-focused level of analysis, utilizing cognitive theories, and using experimental research. In other words, this thesis fits in the participant (human) – VR experiment (computer system) design research stream. Concerning research methods, experimental research and design science were used in the individual studies.

I.4.2 Research Design

In the following, the research design of the included studies is described, including methodology, data collection, and data analysis (see Table 3)

Table 3 Research Design of Studies

No.	Methodology	Data Collection	Data Analysis
1	Experiment with a 2x1 design (Dennis & Valacich, 2001)	Survey	PLS-SEM
2	Design Science Research (Hevner et al., 2004)	Literature Review, Expert Workshop	Coding
3	VR-Experiment with a 2x1 design (Dennis & Valacich, 2001)	Movement recording and survey	Machine Learning (Support Vector Machine)
4	Multiexperimental Study each with a 2x1 design (Dennis & Valacich, 2001)	Time measurements	Survival analysis

Studies 1, 3 and 4 build upon empirical research (Dennis & Valacich, 2001) to conduct an experimental study. They address the research gaps identified in section I.2 to deepen the understanding of VR experiments.

Specifically, Study 1 utilizes a 2x1 between-subjects design to explore different presentation modes of an artificial experimental context. Participants were divided into two groups: the first group experienced the scenario via a textual vignette, while the second group engaged with the scenario through an interactive VR simulation. This research was designed to explore the relationship between the effects of different presentation modes and their impact on perceived realism, motivated by the assumption that perceived realism is a precursor to realistic behavior (Slater et al., 2009). Data collection was conducted via a survey following exposure to the experimental conditions, and analysis was performed using Partial Least Squares Structural Equation Modeling (PLS-SEM). Study 3 also had a 2x1 between-subject design for an experimental group comparison with machine learning prediction analysis. Movements of participants were recorded following the manipulation to capture potential differences induced by the experimental conditions. The