Orchestrating Virtual Reality Exposure Therapy

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Abstract

Systems for Virtual Reality Exposure Therapy (VRET) are shaping the future of therapy of anxiety disorders, especially at a time when we are seeing an increase in virtual meetings in almost every context in life. Exposure therapy is an established therapy method in the treatment of anxiety disorders. In the context of exposure therapy, a rich set of tools are available for helping therapists conduct therapy tailored to a patient's needs. Typically, the therapist guides the patient through a feared experience in a real context and/or with an object

In-virtuo exposure has several benefits compared to in-vivo exposures, for example, the possibility of controlling the stimuli and context of the exposure. To be able to conduct in-virtuo exposure, therapists need effective, versatile, and usable VRET systems.

My research aims to investigate the use of virtual reality in exposure therapy in order to explore, identify and propose how the design of VRET systems can be improved to better support in-virtuo exposure therapy in therapeutic practice outside of research. Many VRET systems are designed and built explicitly for research settings and purposes. Therefore, the systems do not fulfill needs for real therapeutic practice where most patients are being treated.

Four strands of research emerged in this thesis work. First, the understanding of the full therapy process beyond the exposure sessions, where VRET systems have the potential to be used beyond exposures. Second, I see therapists playing a critical role during the therapy process, which should be reflected in the design. Third, emerging from the central role of therapists, I studied VRET systems that empower therapists to prepare and orchestrate exposure sessions. Fourth, I examined the role of designers and Human-Computer Interaction (HCI) in creating these systems, which I see as important and underrepresented.

Unlike other research, my work is mainly therapist-oriented with empha-

sis on the potential needs in therapeutic practice, which led to conclusions regarding further possible applications and implications for the design of VRET systems. By investigating different aspects of exposure therapy, my work has resulted in a new view on VRET systems.

Sammanfattning

Exponeringsterapi men hjälp av system baserade på virtuell verklighet (VRET) kan vara en viktig komponent i framtidens terapi av ångestsyndrom. Inom den etablera metoden exponeringsterapi finns en rik uppsättning verktyg tillgängliga för att hjälpa terapeuter att skräddarsy terapi efter en patients behov. Typiskt vägleder terapeuten patienten genom en fruktad upplevelse i ett verkligt sammanhang. Det handlar ofta om att patienten har problem i olika miljöer eller situationer.

Virtuell exponering har flera fördelar jämfört med så kallad in-vivo exponering, till exempel genom att det möjliggör att kontrollera stimuli och sammanhang, men också att det kan genomföras på klinik. Men för att faktiskt kunna bedriva virtuell exponering behöver terapeuter effektiva, mångsidiga och användbara virtuella exponeringsbehandlingssystem. Under mina studier har jag mött terapeuter som uttryckte oro angående den upplevda användbarheten av virtuella exponeringsbehandlingssystem. Trots dessa farhågor tyder mina resultat på att terapeuter har en övergripande positiv inställning till virtuell exponeringsbehandling.

Min forskning syftar till att undersöka användningen av virtuell verklighet i exponeringsterapi för att utforska, identifiera och föreslå hur utformningen av virtuella exponeringsbehandlingssystem kan förbättras för att stödja användning i terapeutisk praktik. Många virtuella exponeringsbehandlingssystem är idag designade och byggda explicit för forskningssyften. Därför uppfyller inte dessa system de behov som faktiskt föreligger i terapeutisk praktik, där patienter behandlas.

Inom ramen för den här avhandlingen ser jag fyra olika bidrag. För det första har jag bidragit till ökad förståelsen för hur virtuella exponeringsbehandlingssystem kan behöva användas och designas för användning inom hela terapiprocessen. För det andra har jag belyst viktiga detaljer i terapeutens roll under terapiprocessen, vilket på olika sätt bör stödjas av systemet. För det tredje, med utgångspunkt från terapeuternas centrala roll, pekar jag på att terapeuten måste kunna förbereda och orkestrera exponeringssessioner. För det fjärde, pekar jag på designers och forskares (inom främst människa-datorinteraktion) viktiga roll i att skapa dessa system. Dessa roller och professioner är idag underrepresenterade in VRET området.

Till skillnad från annan VRET forskning är mitt arbete huvudsakligen terapeutorienterat med tonvikt på de potentiella behoven i terapeutisk praktik, vilket ledde till slutsatser kring tillämpningar och implikationer för design

av virtuella exponeringsbehandlingssystem. Genom att undersöka olika aspekter av exponeringsterapi resulterade mitt arbete i en ny och bredare syn på virtuella exponeringsbehandlingssystem.

Acknowledgments

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During my time at the UniTyLab at Heilbronn University, I had the pleasure to meet and work with great people. In particular, I wish to thank my fellow PhD students Sebastian, Philip and Ketoma. Sharing time inside and outside of university was always a pleasure, thank you for making this time a remarkable period in my life.

My research was shaped by the project EVElyn. I would like to thank everyone who has been involved in the project. I wish to express special gratitude to Magdalena Sich and Julia Diemer, for always being open to discussing my ideas and helping me understand therapy.

During my time at KTH, I met lots of great people who always supported me as an external PhD student. Thank you for the opportunity to join courses remotely, even when that was not common in the time before the pandemic.

I would also like to thank my parents and my sister, who continuously supported me over the years. Your encouragement was an inspiration and kept me moving towards my goal. Thank you for understanding when I had work to do and my time was limited.

Finally, I cannot thank enough my wife Gabriela. You supported me all the way that led to this thesis, without your support it would this work would not be in its final shape. Thank you for all the small and big gestures that made me smile even in the most stressful moments.

Contents

Chapter 1

Introduction

The consequences of mental health conditions may be severe for the afflicted individuals, relatives and the society in general [155]. The widely accepted definition of mental health [88] by the Public Health Agency of Canada describes mental health as follows:

"Mental health is the capacity of each and all of us to feel, think, and act in ways that enhance our ability to enjoy life and deal with the challenges we face" [113]

The definition suggests that there are various influences that affect mental health, which originate from an almost infinite number of reasons and may lead to serious mental disorders. Anxiety disorders, which are considered one of the most common mental disorders [69], have a 12-month prevalence of 18.1% [155] and a lifetime prevalence of 28.8% [68]. Examples of anxiety disorders are acrophobia (fear of heights), glossophobia (public speaking anxiety), or arachnophobia (fear of spiders). Exposure therapy is regarded as highly effective in treating such phobias. It has its origins in cognitive behavior therapy (CBT) [87] and features response rates of 80%-90% [30, 68]. Despite such effective treatment options, only a fraction of patients are treated [60, 37, 10, 142].

Exposure therapy is built around the rationale that patients can change their dysfunctional assessment of a situation (i.e., assessing the situation wrongly), which leads to reduced conditioned anxiety [18]. In treatment, patients are exposed to their phobic stimulus [18], which may be a situation (e.g., public speaking or standing on a high building) or an animal (e.g., a spider or a dog), to experience and evaluate their anxiety causing assessments. Generally, there are two exposure types in contemporary therapeutic practice: the gold standard [18] is to expose the patient to the real stimulus, called in-vivo. Furthermore, therapists have the option of exposing the patients in their imagination, which is called in-sensu.

Virtual Reality Exposure Therapy (VRET) has been researched since the 1990s [121], and has received increasing attention [119, 87] in recent years. The general idea is to induce phobic stimulus using Virtual Reality (VR), referred to as in-virtuo exposure. Using in-virtuo exposure in VRET setups has been show in clinical studies to lead to similar response rates as traditional in-vivo exposure [30, 68, 21, 85]. The recent progress of VR-enabling technologies (e.g., displays and miniaturization) have made VR available in cheaper systems that can be used for a variety of use cases. Among these are various therapeutic uses [74, 18]. This growing body of research has also indicated a positive impact of the use of VR in the context of therapy of mental health in general [87, 60].

There are several advantages of in-virtuo exposures compared to the established practice of in-vivo exposures. First, increased efficiency by reducing logistics associated with in-vivo therapy [89]. For instance, in-virtuo exposure removes the need for traveling to specific locations, as is often necessary for in-vivo exposure. Second, in-virtuo exposure can be conducted in safe and controllable physical environments [120, 128], hence the patient can exercise in a safe space without distractions. Third, the virtual stimuli can be controlled and replicated by a therapist [128], which can be employed to precisely control the properties of the stimulus and the environment for better treatment. Lastly, research indicates that patients are more willing to start therapy using in-virtuo exposure as a first step [48, 85] since they are aware that they are "only" confronted in a simulation.

Furthermore, in-virtuo exposures provide several advantages over in-sensu exposures [18, 128]: therapists do not rely as much on the patient's imagination, they have no dependency on creating mental images, which patients may draw too disastrous in their mind, and therapists are not able to know or fully control what a patient is imagining.

Despite the advantages and positive indications for therapeutic practice suggested by clinical research, VRET therapy is not yet established in therapeutic use [18, 36]. Today, VRET research is mainly conducted within clinical research settings, which do not represent the uses in therapeutic practice

[98]. If VRET system are to be used within real therapeutic practice, research needs to look, as Lindner puts it, "beyond effectiveness" [75]. Ann Blandford characterizes the aim of clinical research as the question "Does it improve outcomes?" [16], which focuses on the patient and therapeutic practice and outcomes. She argues that one explanation for the research design may be the origin of the research, spanning from biological science to implementation science (i.e. research related to the deployment of the therapeutic interventions in clinical practice). The typical approach is to use randomized controlled trials (RCTs). Although it is indeed important to demonstrate the effectiveness of in-virtuo exposures using RCTs, the problem with most of the previous research is that the VRET system are not designed for primary care settings [119, 75]. One reason is that VRET system designed for focused randomized trials consequently are narrow in scope to create standardized settings for statistical analysis [152]. While this explores effectiveness (i.e. "does the intervention work?") [16], it does not corresponding with therapeutic practice [18, 97, 75] where each patient has individual needs [36]. Furthermore, these trials tend to focus solely on the patient outcomes and disregard the role of the therapist. Therapists have a wide range of tasks during therapy, using a VRET system, they need to orchestrate both the exposure and the therapy itself. Therefore, therapists must understand and be empowered to exploit the full capabilities of VRET system.

To enable VRET system to be used in therapeutic practice, the gap between research and practice must be bridged [97], which includes the design of the VRET system. For this task, Human-Computer Interaction (HCI) researchers must be involved in the early stages [39, 33, 16, 98] to create systems that reflect the needs of healthcare professionals, patients, and other stakeholders. Currently, there is a limited body of research focusing on HCI issues in healthcare technology [15]. Despite an apparent shift to more human-centered activities (e.g.[4, 23]), there remains an emphasis on VR itself [18], i.e. the patient's experience. In addition, topics such as measurements of patient physiology [7, 31] are proposed to support therapists during therapy. While designing for patients is one key to the success of this intervention, we lack therapist-oriented thinking and design of VRET system [23] to optimize them for use in real therapeutic practice. For VRET system to mature and provide therapeutic benefit, the designs of the VRET system should account for all user groups [15, 98], including besides patients therapists, which is one of the central aspects of this thesis.

In this thesis, I will synthesize and discuss the results from my work on the design and use of VRET system and challenges in introducing them in real therapeutic practice. My view on VRET developed over the course of my research from a technology-oriented account to a holistic, therapist-oriented view on therapy of anxiety disorders. I comprehend VRET system as one tool in an already rich toolbox, which therapists use to orchestrate individualized therapy. My focus was to investigate how VRET system could be designed to support real-world therapy, which should support the transition of VRET system into therapeutic practice.

I conclude that VRET system for therapeutic practice have different requirements compared to when used in research settings. My research is built around the idea that therapy must be individualized to a patient's specific needs, as also suggested by [36, 15, 87], which is a task therapists should be empowered to perform when using VRET system. My research suggests that such a VR-system can also support other stages of therapy beyond the actual exposure. Exposure therapy consists of more activities than a series of exposures, and VR could create substantial benefit for therapy. My results suggest that VRET system could contribute to preparing, conducing and reflecting on exposure sessions. In addition, a holistically designed VR-system could be employed in the context of other mental disorders that a therapist encounters in therapeutic practice.

1.1 Research Objective

The goal of my research is to understand the process of exposure therapy in relation to VRET applications and to propose implications for the design of such systems, considering use in therapeutic practice. This entails pursuit of detailed knowledge of the setting and the full therapy process. Since much VRET research has been done in isolated clinical studies, one important aim of my work was to look into how to make VRET systems feasible and usable in real therapeutic practices. For uses in therapeutic practice, it may be useful to view VRET systems from a holistic perspective, i.e., beyond the exposures aiming to leverage the potential of VR. This has led to the following research questions:

Research Question I:

What challenges underlie using VRET as a tool in therapeutic practice?

This thesis aims to explore the transition of VRET systems from their uses in clinical research to therapeutic practice. This transition needs to consider a variety of aspects that differentiate therapeutic practice from research. My studies aimed to first explore the general setting in therapeutic practices and differences from uses in research. Second, my studies addressed the differences by exploring potential designs that enable use in practices.

Research Question II:

In what ways can VRET systems be made more versatile for therapeutic practice?

One of the results of addressing Research Question I was that the systems could provide more benefit to psychotherapy than they currently do. This may be characterized as more versatile, which may allow a wider range of uses. I aimed to investigate the present and potential future uses of VRET systems in the therapy process beyond the established use in exposure sessions.

1.2 Structure of the Thesis

This compilation thesis is based on five research papers that were part of a Constructive Design Research (CDR) process. My methodological framework, CDR, allowed me to progress iteratively. The aim of the present cover paper ("Kappa") is to provide an overview of the work, to discuss it on a meta-level, and provide overall reflections. In Chapter 1, I describe the context of my research and described the aims. Chapter 2 aims to set the theoretical background for the research, and to provide an overview of the field. In Chapter 3, I give an overview of the methods employed. The systems and prototypes that were created and subject to my studies are presented in Chapter 4 along with a summary of the background, methods, and results of each of the papers. In Chapter 5 there follows a discussion of my results on a higher level, which includes major aspects that stood out over the course of my research. Chapter 6 concludes the thesis and provides answers to the research questions posed in this first Chapter.

1.3 Papers included in the Thesis

Paper A: P. Schäfer, M. Koller, J. Diemer, G. Meixner. Development and evaluation of a virtual reality-system with integrated tracking of extremities under the aspect of Acrophobia. *2015 SAI Intelligent Systems Conference (IntelliSys).* IEEE.

My contributions: I took part in the ideation, design, and implementation of the system. Philip Schäfer conducted the evaluation and data analysis with support from Julia Diemer. He also led the writing process with support from Gerrit Meixner.

Paper B: M. Koller, P. Schäfer, M. Sich, J. Diemer, M. Müller, G. Meixner. Next Generation Virtual Reality Exposure Therapy Systems - A Study exploring Design Implications. *2018 International Conference on Intelligent Systems (IS).* IEEE.

My contributions: I planned and conducted the qualitative study along with Philip Schäfer and Magdalena Sich. Magdalena Sich along with Julia Diemer and Mathias Müller designed the questionnaire and conducted the quantitative analysis. Magdalena Sich analyzed the data statistically. I was responsible for the main outcome and writing, with support from Gerrit Meixner and all the other authors.

Paper C: M. Koller, P. Schäfer, D. Lochner, G. Meixner. Rich Interactions in Virtual Reality Exposure Therapy: A Pilot-Study evaluating a System for Presentation Training. *Seventh IEEE International Conference on Healthcare Informatics (ICHI 2019).* IEEE.

My contributions: I contributed to the study plan and participated in conducting the study along with Daniel Lochner and Philip Schäfer. I was then responsible for the data analysis and main outcome. The system design was led by Philip Schäfer, supported by me, and implemented by Daniel Lochner with the support of Philip Schäfer. Philip Schäfer and Gerrit Meixner supported the writing process, which I led.

Paper D: M. Koller, S. F. Rauh, A. Lundström, C. Bogdan, G. Meixner. Continuous Interaction for a Virtual Reality Exposure Therapy System. *Eighth IEEE International Conference on Healthcare Informatics (ICHI 2020).* IEEE.

My contributions: I contributed to the ideation and implementation of the improvements of the user interface. I was then responsible for the study plan, and supported the study, the data analysis and the main outcome. Philip Schäfer and Sebastian Rauh supported the implementation and study. I led the writing process, and all the authors contributed to the writing process.

Paper E: M. Koller, S. F. Rauh, C. Bogdan, G. Meixner. New Perspectives on Virtual Reality Exposure Therapy: a qualitative Study exploring Orchestration in the Process of Exposure Therapy. *SUBMITTED to 12th Nordic Conference on Human-Computer Interaction (NordiCHI 2022).* ACM.

My contributions: I was responsible for the study design, conducted the study, and led the data analysis. Sebastian Rauh and Cristian Bogdan supported the data analysis. I led the writing process, and all the authors contributed to the writing process.

1.4 Affiliations of Co-Authors

Cristian Bogdan	Associate Professor at MID (Media Technology and Interaction Design), KTH – Royal Institute of Technology.
Gerrit Meixner	Professor at Heilbronn University and Affiliated Professor at MID (Media Technology and Interaction Design), KTH – Royal Institute of Technology.
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Sebastian Felix Rauh	PhD Student at MID (Media Technology and Interaction Design), KTH – Royal Institute of Technology and Researcher at University of Applied Sciences Technikum Wien.
Philip Schäfer	Research Associate at the Department for Ergonomics and Human-Machine Systems, RWTH Aachen University.
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Julia Diemer	Researcher at Munich Department of Psychology, Ludwig Maximilian University, and Psychotherapist and Health Service Research at kbo-Inn-Salzach-Klinikum
Daniel Lochner	Former Master's Student at UniTyLab, Heilbronn University.
Mathias Müller	Co-Founder and CEO of VTplus GmbH.

1.5 Papers not included in the Thesis

During the research, I took part in various other research activities that resulted in publications that are not part of this thesis. Some papers were related to my work on exposure therapy, while others had a different focus. They nevertheless helped me to learn and shaped my research.

S. F. Rauh, M. Koller, P. Schäfer, G. Meixner, C. Bogdan, O. Viberg. MR On-SeT: A Mixed Reality Occupational Health and Safety Training for World-Wide Distribution. *International Journal of Emerging Technologies in Learning (iJET)*, Volume 16, Issue 05. 2021.

M. Koller, S. F. Rauh, G. Meixner, A. Lundström, C. Bogdan. Designing for Orchestration in Mixed and Virtual Reality: Challenges and Best Practices. *11th Nordic Conference on Human-Computer Interaction: Shaping Experiences, Shaping Society*. 2020.

R. Erbach, S. Maurer, G. Meixner, M. Koller, M. Woide, M. Walch, M. Weber, M. Baumann, P. Grimm, T. Keber, J. Klink-Straub, J. M. Mönig, J. Landesberger, U. Ehrlich, V. Fischer. KoFFI - The New Driving Experience: How to Cooperate with Automated Driving Vehicles. *Smart Automotive Mobility: Reliable Technology for the Mobile Human.* 2020.

M. Lüönd, P. Schäfer, M. Koller, G. Meixner. New conceptual approaches to meet the spatial and user safety requirements of outpatients with anxiety disorders for virtual reality exposure therapy. Poster presentation at *Virtual Environments: Current Topics in Psychological Research (VECTOR) Workshop.* 2018.

D. Lochner, P. Schäfer, M. Koller, G. Meixner. Full upper body mapping of a therapist for controlling avatars in the treatment of social anxiety with virtual reality exposure therapy. Poster presentation at *Virtual Environments: Current Topics in Psychological Research (VECTOR) Workshop.* 2018.

M. Koller, C. Bogdan, G. Meixner. Collaborative Task Modeling: A first Prototype integrated in HAMSTERS. *6th International Working Conference on Human-Centred Software Engineering.* 2016.

Chapter 2

Background

In this chapter, I will describe relevant background to my research. First, I will provide a brief overview of the process of exposure therapy. This is followed by an introduction to VRET. The chapter continues with remarks on research in the context of mental health settings. I will then move on to a description of hybrid user interfaces. The chapter closes with remarks on orchestration.

2.1 The Process of Exposure Therapy

This section summarizes the current process of exposure therapy in practice. It is intended to provide an overview of the related activities, which are not limited to exposures.

The process of exposure therapy is in most cases defined by a therapy manual (for example [9] in Germany), which follows a clear structure. The following list explains the activities of a therapy that is conducted under the CBT approach based on the German guideline [9]:

- **Diagnosis**: Work with the patient in order to find out more about the condition and possible comorbidities.

- **Psychoeducation**: Explain to the patient psychological backgrounds such as natural fear.

- **Work on disorder model**: Explain to the patient what an anxiety disorder is and how it persists in a vicious circle of anxiety and avoidance.

- **Work out the rationale for exposure therapy**: Explore with the patient how exposure therapy can break the circle of anxiety.
- **The decision to conduct therapy**: Active decision of the patient to continue to participate in the exposure therapy.
- **Develop the individual fear hierarchy**: Therapist and patient explore situations that trigger the anxiety and rank them based on the patient's perceived anxiety level (e.g. using a subjective scale from 0 to 100, where 100 is the maximum).
- **Start exposure sessions**: Now, the actual exposures start where a patient is, for example, exposed in-vivo to the phobic stimulus.

Therapists follow this structure but have freedom within the activities. The choices therapists make are based on the patient's therapeutic needs [87, 18, 36]. This includes the choice of the exposure type (i.e. in-sensu, in-vivo, and in-virtuo if already available). During the early stages of therapy, therapists and patients work together on the rationale of exposure therapy and decide together to proceed [131, 9]. The choice of exercise is influenced by the individual characteristics of a patient, such as creativity and ability to imagine [18]. The latter may influence the effectiveness of in-sensu exposure, where the patients are exposed to the phobic stimulus in their imagination. Before an exposure session, the therapist and the patient discuss the contents and goals of the session.

The most important aspect for the success of the therapy is that patients are experiencing anxiety with the related symptoms [131] in order to experience the decrease in anxiety and learn strategies to cope with the anxiety. These experiences are achieved by exposing the patient to a phobic stimulus, which could be a situation or a being. In these exercises, the aim is that patients learn to not avoid the phobic stimulus but to endure it, which will lead to a decrease in the anxiety [63]. One concrete example is glossophobia (public speaking anxiety) where patients need to confront the situation and talk in public guided by a therapist [77]. The setting and exposure exercises change during the therapy as therapists mainly choose a gradual approach where they increase the difficulty for the patients over the course of the therapy [36].

As a further part of therapy, the patients are given homework where they have to complete a task that is related to therapy, for example catching a spider, to also apply and repeat the learned behavior outside the therapeutic space [58]. Furthermore, this should support transferability, which means that the patients must transfer the learned concepts and behaviors to the real world [82]. While this is already a challenge from the traditional therapy setting (i.e. using in-vivo and in-sensu exposure), introducing in-virtuo may add another level that demands a transfer from the virtual world to the in-vivo exercises with the therapist that are usually conducted in conjunction with in-virtuo exposures.

2.2 Virtual Reality Exposure Therapy

The history of Virtual Reality (VR) dates back to 1968, when Ivan Sutherland presented the first version of a head-mounted display (HMD) [137]. He had the vision to create a three-dimensional picture on the user's retina. Over time, the technology developed and matured. Especially with advances in VR-enabling technologies, for example in the miniaturization and computing power that are used in modern smartphones, the development of VR experienced a boost. Oculus in 2013 introduced the first developer version of their HMD Oculus Rift, which marked the beginning of the development of consumer VR hardware. This advance also led to more research in various use-cases of VR, ranging from education to clinical applications [119].

The experience a user has when using VR is mainly measured in two dimensions, presence and immersion [135]. While these terms are used synonymously in some contexts, they describe two distinct phenomena. Immersion is defined by Slater and Wilbur as more technological characteristics of a VR system [136] such as hardware, peripheral software and the used software. One critical factor according to them are the displays used. Two main factors are relevant: the *vividness* (factors such as resolution) and the degree to which the real world is concealed, termed inclusiveness by Slater and Wilbur [136]. A further central element of immersion is the representation of the user's body in VR, termed body mapping by Slater et al. [134]. For body mapping, it is central that the movements are mapped with the virtual avatar so that the user feels the sense of body ownership, one influencing factor of embodiment [70]. The underlying technology that influences immersion became more sophisticated over time and reached a high level. Present-day VR systems use high-resolution displays that provide high vividness. The peripheral systems that are used, for example, for body mapping have also become more sophisticated. They previously worked mainly using markers (e.g., [124]) and moved now towards markerless full-body tracking (e.g., [92]), which is available in dedicated systems (e.g., The Captury[1]) but also in consumer hardware (e.g. Microsoft Azure Kinect[2]).

The use of VR in clinical use-cases is increasing and gaining relevance in research and practice [45, 120]. Among these use-cases is exposure therapy using VRET systems to conduct in-virtuo exposures. This therapy is anchored in the paradigm of CBT, which is considered to be an effective tool to treat anxiety disorders [25]. In current therapy, exposures are conducted mainly in-vivo (i.e. visiting the real situation or exposing to the respective object or being) and in-sensu (i.e. therapists guide the patient's imagination). VRET systems add the exposure in-virtuo, which means that patients are exposed to the phobic stimulus in a virtual environment. The potential of in-virtuo exposures has been researched since the early 1990s, when a first study on the effectiveness of an acrophobia scenario was evaluated by Rothbaum et al. [121]. VRET systems are attracted increased interest with the advent of consumer-ready VR devices, which led to an increase in the number of systems used in research. Furthermore, the systems gained complexity in terms of technology, which enabled them to cover more anxieties in more complex VR scenarios. Multiple studies and meta-reviews indicate an effect in therapy and positive therapy outcomes [65] including when using standard consumer hardware [79, 77]. Multiple studies suggest that VRET is an effective therapy method and has similar response rates compared to traditional in-vivo therapy[30, 68, 21]. The application of VRET systems has advantages for therapists. Using these systems, they can provide treatment for anxieties that are hard to access and generate in-vivo, e.g. fear of flying or social interactions [87, 128]. A further advantage is that therapists can fully control and replicate exposures [128], which is hard to realize for traditional in-vivo exposures due to factors that are not controllable for therapists, like pedestrians or movements of animals. From the patient's standpoint, there are indications that they are more willing to engage with therapy when starting with in-virtuo exposures [47].

[1] https://captury.com/

[2] https://azure.microsoft.com/en-us/services/kinect-dk/

In general, there are two types of VRET- systems: therapist-led systems where a therapist actively guides therapy, and automated systems where a therapist does not directly participate in and guide the experience [8]. The therapist-led systems are mainly applied in practice settings where patients visit a therapist, while some research is conducted where therapy is applied remotely [56, 67, 141]. Systems that offer automated therapy range from self-help applications that are freely available in the app stores, which may be used in therapy and seem to have an effect [79], to systems that employ complex physiological measures to employ AI and affective computing to alter therapy [8]. Automated therapy as currently researched contains a complete therapeutic experience, which includes psychoeducation [144], instructions (by a virtual therapist) [95, 3], and gamified CBT exercises [1, 145, 94, 82]. Such systems can be used by many potential patients since they only require a VR-ready smartphone (which means almost all modern smartphones) and a headset the smartphone can be put in, for example cardboard.

Research is also investigating further directions, which include new ways of conducting therapy. The use of VR allows new concepts to be used that are not possible to conduct in a real-life setting. For instance, there is the possibility of employing concepts of gamification in the scenarios [145, 82] and other forms of gradual therapy, for example by altering the attention of an audience [99, 66]. There is also a need in research need for individualized or tailored therapy [75]. Lindner argues that there is still too little research to conclude to what extent individualization is needed. One opportunity may be presented by the use of Artificial Intelligence (AI) in these systems [54, 5, 109], which allows the simulation to adapt based on sensor information [108, 6, 7]. Further use of AI may be considered in the design of dialog systems, which allows an automated conversation between the patient and an avatar where the avatar's responses are generated based on the patient's statements [22]. Furthermore, the use of AI is researched in the context of agents patients interact with outside of therapy sessions [42].

Despite the various technological opportunities to drive the complexity of VRET systems further, it must be borne in mind that the need for additional resources of VRET systems should not outweigh the therapeutic benefit. To ensure that VRET systems are not "over-engineered", the design should be focused on therapeutic practice. This implies that research should be conducted that assesses and documents the real therapeutic practice.

2.3 Research in Mental Health

The research in the field of mental health usually focuses initially on the patient to evaluate the therapy's effectiveness for the condition to treat. These trials are predominantly performed using randomized controlled trials (RCTs), which aim to indicate relationships between interventions and outcomes [110]. This has also translated to the use of digital technology in therapeutic contexts. While these trials are important to investigate the implications of an intervention, they are time-consuming to conduct [16, 39] and, hence, may slow down iterative processes as conducted in HCI research where new concepts and technologies are tested in short iterative cycles [15].

Furthermore, mainly therapists are not involved during the development phase due to a previous lack of human-centered design practices where technology was applied to use-cases more in a proof-of-concept mindset [119]. Especially in the context where a therapist is actively taking part in delivering a digitalized therapy, as in VRET, they must be involved in the early designs of these systems [15, 39, 33, 98].

Coyle et al. proposed a two-phased model (see Figure 2.1) that should account for the iterative character of developing technology user-centered while still considering the clinical evaluations [33]. The first phase is led by HCI-researchers, aiming to conduct evaluations and research with healthy participants. This should allow shorter feedback loops and more flexibility, which is impossible during RCTs due to inaccessibility for HCI researchers and the time-consuming character. In the second stage, which is led by clinical researchers, interventions should already have been indicating a potential benefit for therapy. Coyle et al. propose to conduct clinical pilot studies, which may be slower than studies with healthy participants but provide important feedback before an RCT [33].

To overcome this and compensate for the lack of access to patients [39, 91], therapists may fulfill a double role when conducting research [91]. Besides representing their view as therapists, they may serve as a mediator between patients and HCI researchers and provide insights that are relevant for patients. Doherty et al. propose methods to design in collaboration with mental health professionals (MHP) [39]. The first step may be considered as an initial analysis, known as background information gathering in their approach, where HCI researchers review literature and possibly interview MHPs. Second, Doherty et al. propose future workshops where current practices are possibly critiqued, and the future is envisioned [39]. Their third method

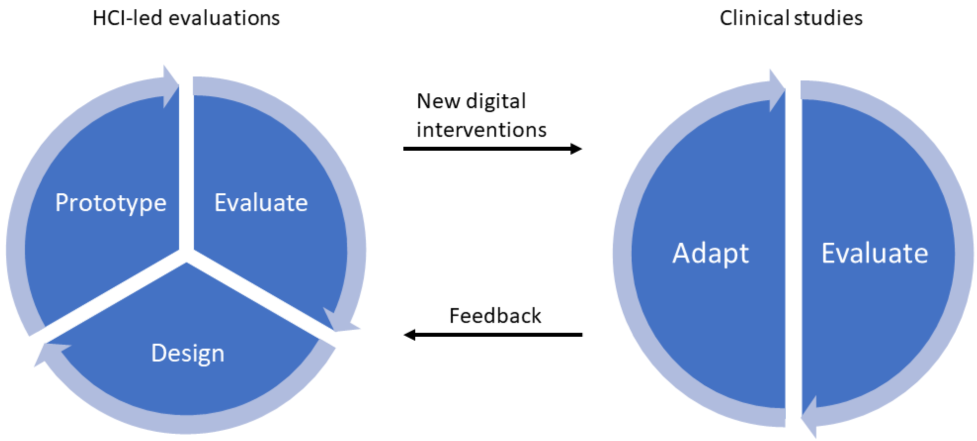


Figure 2.1: Two-phased development process of Mental Health Interventions. (adapted after [33])

is user-centered workshops, where designs are developed and evaluated. As a further method, they propose role-plays where therapy is enacted by the workshop participants. As some parts of the MHP's training contain role-plays, therapists who have completed the training should know the method and be able to participate in these plays. There, early ideas may be enacted and reviewed.

One of the main challenges outlined in the literature is the involvement of all stakeholders [129, 13, 147], including patients or clients who use the systems. This is mainly explained by the sensitivity of the setting to be analyzed. Coyle et al. state that participatory or ethnographic approaches are hard to conduct within these settings due to restrictions in access due to ethical concerns [33]. They argue that HCI-researchers rarely meet the requirements to directly interact with patients or observe therapy, which limits the perspectives and body of data relevant for the design of technical systems.

Despite the concerns raised by Coyle et al., there is a body of work that describes participatory design approaches used while developing interventions [33]. One way of integrating experiences of therapists and, more critically, patients may be to employ role-plays [91]. Flobak et al. report on also using this approach for the design of therapeutic content in VRET, which is the VR scenario itself [43]. The authors conducted workshops with healthy adolescents, which should represent the future target group (i.e., adolescents with a social anxiety disorder), creating scenarios. During the process, they used an iterative process containing ideation, story-boarding, live-action play, which was recorded by a 360°-camera, and experience-based evaluations. The results indicate that the workshop produced well-designed scenarios that may be used in VRET.

2.4 Hybrid User Interfaces

As systems use Extended Reality (XR) interactions, there is a need to integrate systems into reality environments [61, 149] where traditional interaction modalities can be chosen [130]. The ability to move seamlessly along the mixed reality continuum was implemented by Billinghurst et al. with the MagicBook where a user can transition into the augmented reality using a handheld device [12]. The term Hybrid User Interface (HUI) was proposed by Feiner and Shamash with the intention to enrich a heterogeneous environment with different devices to create rich interaction techniques [41]. In that way, HUIs aim to extend the capabilities of a single system [19] to create more powerful and meaningful interactions.

Especially in the fast-growing market of VR and AR, the integration of these new technologies in established modalities is key to usage [2, 61]. It may be noted that interactions should be performed in the respective modality [27], i.e., a user should not be forced to perform an interaction in 3D, which was designed for 2D, and vice versa. For example, it may not be suitable to create a navigation-task that is performed in 3D but using the established Windows-Menu-Icon-Pinter (WIMP) paradigm. On the other hand, a gestural input may be more suitable to fully control an avatar.

In general, it is possible to have hybrid interactions in two scenarios: parallel or serial [19]. In this context, parallel means that a user can, for example, use both 2D and 3D modalities during one single interaction. One concrete example would be to watch a 2D interface while interacting with 3D-gestures. In a serial hybrid interaction, the interactions are performed one after the other, as for example when activating a 3D interaction using a 2D interaction such as a button click.

Transitional interfaces challenge the designs because they combine different interaction modalities, technologies and spaces, which challenges users to be aware of the current status. Floris et al. propose three dimensions of continuous interaction that are a design should address: perceptive, cognitive, and functional continuity [44]. These are defined by the authors as follows:

- **Perceptive continuity**: The system's ability to present appropriate information in a perceptual environment [40].
- **Cognitive continuity**: The system's ability to ensure that a user is interpreting the perceived information correctly.
- **Functional continuity**: Related to the modality of the interaction and the adaptability of the system and users.

In order to account for the dimensions of continuity, designers should design systems that take into account not only the visual feedback of user's actions but also the physical dimension of an interactive component [28]. Furthermore, it may be noted that the underlying task of an interaction should be reflected in the design. For example, when a user wants to start gesture interaction out of a 2D environment, it may be designed in a way that the boundaries of the interactions are clear to the user.

2.5 Orchestration

The concept of orchestration of experiences was introduced by Koleva et al., and defines orchestrations as all activities that manage a user's experience [71]. Orchestration was exemplified in a variety of experiences, of which many stem from artistic experiences (e.g., [139]) or games (e.g., [11]). One early example is the "Desert Rain" system by Koleva et al. where a user's experience is orchestrated during the course of the experience, i.e., is live-orchestrated. This is done by individual user support, where multiple orchestrators manage digital and analog content that is presented to the user according to a story. This allows the orchestrators to individually design, pace, and tailor the experience to an individual user in a certain stage of the game [34]. There are examples for an orchestration that takes place in the same physical space [71] but there are also examples where the orchestration is done remotely [59], even decentralized [35] depending on the concept or story of the experience.

The concept of orchestration was also applied in the context of game design and game play [26, 53, 52]. In their study on a game where player cooperate, Graham et al. see four different roles an orchestrator could take [53]:

- *Orchestrator as game master*: Guides the story of a game and could be a player as well.
- *Orchestrator as stage manager*: Acts behind the scenes and stages the experience while being hidden from the players.
- *Orchestrator as a game designer*: Designs the game using mainly rapid prototyping to test them without long implementation times.
- *Purposeful orchestration*: Orchestrators want to manage an experience that is helpful for players (e.g. in therapy).

These four roles indicate that the work of orchestration is conducted in a spectrum ranging from a background as part of invisible work [102] to close cooperation between players, even with a participating orchestrator [53, 52].

Looking at these roles of orchestrators, we can conclude that there are two types of orchestration in general. First, there are the completely pre-scripted experiences that a user is following. One example is use in training where a user has to fulfill certain tasks in a pre-scripted order as in [115]. I call these systems pre-orchestrated, as the task of orchestration was performed during the design. Second, there are systems where the experiences are managed by an orchestrator in real-time, which I call live-orchestrated systems [84]. It may also be noted that the orchestrator (i.e., the manager) and actor (i.e., the person who is actually carrying out the actions) are distinguished [71].

In more complex and fully digital systems, it may be possible that the orchestrator is also acting and performing the action. The orchestration in these systems is conducted from outside the VR, i.e. in two distinguished states of the reality-virtuality continuum introduced by Milgram and Kishino [93], which can be termed XR [130].

Chapter 3

Method

VRET systems are complex systems that are used within a highly sensitive and cognitively complex context. This complexity is challenging both in terms of designing for system interactions (by patient and therapist) and related to the design of the VR content and environment. In the following chapter, I will introduce my research approach. I will start by introducing my general approach of Constructive Design Research, which deeply influenced my work and my methodological choices. My work has been iterative and formed from the initial outset throughout the research process. After the general approach description, I will provide an overview of my work, including a detailed description of my research process.

3.1 General approach

The general approach to this research is constructive design research (CDR), as described by Koskinen et al. [72]. CDR concerns the construction of designed artifacts as a central tool to generate knowledge. The designed artifact often refers to a prototype, but may also concern reconstructing an environment or space. In this thesis, this has relevance since the work is concerned with designing a complex system containing virtual environments where prototyping plays an important role in generating new knowledge.

In CDR, the research is typically conducted through an iterative process where the designed artifacts are reflected, modified, studied and evaluated, which leads to new knowledge. Based on the new knowledge, the process advances by modifying or creating new prototypes used in follow up studies. Generally, CDR includes – but strives to go beyond – concepts such as usability and user-centered design. The reason for this is that Koskinen et al. argue that by solely focusing on the user, a big part of the creativity that is an integral part of the design process does not reach its full potential. Commonly, CDR studies use a combination of methods that originate from different research disciplines, such as interviews or observations, to facilitate the iterative process by collecting data.

As a long-term research umbrella, I have used what is known as design research programs to formulate and progress the knowledge acquired. Research programs were originally introduced by the philosopher of science Imre Lakatos [72] and were introduced to the design research community by Johan Redström [117]. Design research programs clearly reflect the iterative character of CDR at a larger scale, as Redström defined them in three stages [117]:

1. Formulating the design research program
2. Design, implement and evaluate examples for designs
3. Reflect and refine the design research program

It is important to further emphasize that both Redström's and Koskinen's idea of research programs does not concern the iterative design of the individual prototypes and studies performed within the research program. Instead, it is concerned with the generation and advancement of knowledge as the program evolves as a result of the individual studies. In practice, and as an example, the results of an individual study may lead the researchers to realize that they need to reformulate or refine the initial research program, e.g. the problem investigated or the motivation of the program, as new knowledge has emerged. It is through this process, usually not fully covered by the individual research papers but rather happening in between the studies, that the research progresses and evolves as new understanding is gained within the research group. Using the notion of research programs, it is possible to capture, analyze and report on this type of knowledge attained. This is what will be done in this thesis as I will report on the lessons learned and progression within my particular research program focusing on VRET, also integrating knowledge I gained, which is not reported in the papers.

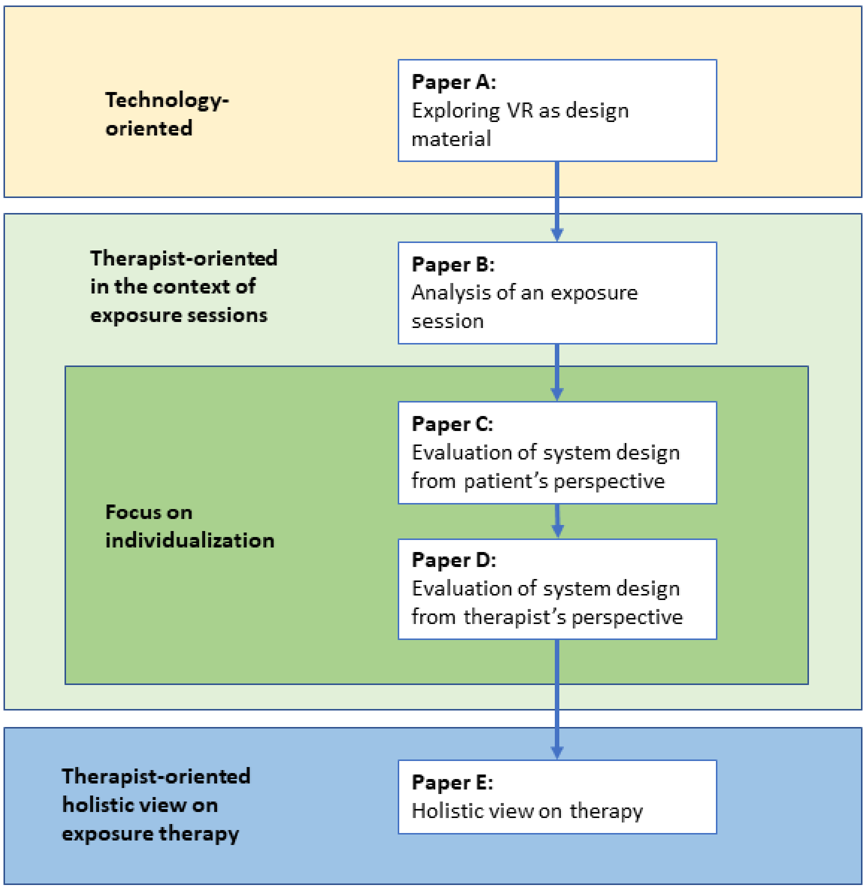


Figure 3.1: Overview over the course of my studies.

3.2 Overview of the Research Process

My research started with exploring Virtual Reality as a design material [116], which led me to focus on VRET from a design perspective. My progress is depicted in Figure 3.1, which illustrates the evolution of my research program from a technology-oriented research program towards a more holistic therapist-oriented view on exposure therapy.

My early explorations, within a technology-oriented research program formulation, aimed to evaluate the use of consumer VR hardware in the context of VRET. To do so, a VR-scenario for acrophobia was developed using the (at the time) recently released Oculus Rift Developer Kit 1[1]. In this system, an avatar for the patient was included, which aimed to increase the user's presence. The evaluation presented in Paper A was conducted in an in-lab study with healthy participants. The results indicated that the system provides a sufficient sense of presence and may therefore be used in serious use-cases such as the investigated use-case in VRET.

However, in the process of designing a prototype of a VRET system, I quickly shifted my attention towards the users of VRET systems since the aim of my research was to push the research a step closer to use in therapeutic practice. Therefore, starting from Paper B, I reformulated the research program to be therapist-oriented, in contrast to other research which is, in general, patient-oriented. I began researching exposure therapy from the perspective of the therapist in order to better pinpoint what therapy is about and how VR could facilitate exposure therapy. To achieve this, I conducted a field study where I explored the context of use and the activities carried out by a therapist during an exposure (Paper B). It may be noted that my focus during this study was particularly on the exposure session. The general process of exposure therapy (see Section 2.1) at that time was not the focus of my attention. The results of the study indicated that therapists individualize therapy to the patient's specific conditions. This implied that VRET systems need to support individualization.

During the first studies, I gained a deeper understanding of the surrounding context and the challenges involved in exposure therapy. As a result, the research program was yet again reformulated and narrowed down to focus on the individualization with which a therapist controls the VR content (i.e., the phobic stimulus) through orchestration. This orchestration takes place before (*preparing*) and during (*conducting*) exposure treatment sessions. This led to a prototype of a VRET system that allowed for orchestrating scenarios by preparing the scenario and allowed the therapist to embody (take over) an avatar (see Section 4.4). This idea of orchestration aimed to address the need for spontaneous interaction, in order to increase flexibility and versatility to support the therapist's work. This refinement of the research program led to Paper C and Paper D, which evaluate the prototype, first, from the view of a patient and, second, from the therapist's view. Live-orchestration, which is the main focus of Paper C, allows the orchestrator to embody an avatar for

[1] `https://web.archive.org/web/20120801212942/https://www.kickstarter.com/projects/1523379957/oculus-rift-step-into-the-game`

as long as the orchestrator wants to interact with the user inside VR. With the first evaluation from the patient's perspective, the VR-scenario was at the center of the study. The study evaluated the impact of orchestration and spontaneous interactions on the patient's experience. A major theme in the evaluation of the patient's experience was the measurement of presence [135], a central measurement of VR applications, as the VRET systems must provoke a high degree of presence.

The prototype was then evaluated from a therapist's perspective (Paper D) in order to understand the interactions necessary to support live-orchestration. This part of the PubVR system contains two different interaction modalities: 2D mouse and keyboard interaction (preparation of the scenario and avatar selection) and 3D gesture interaction (for the embodiment of an avatar). The main focus of this study was the therapist's experience in orchestrating the VR-scene while not being immersed.

In the aftermath of both these studies combined, I realized that VRET systems need to support more than the actual exposure (*conducting*), as is often done today within VRET research. This led me to expand my focus and evolve my research programs towards a more holistic – and broader – view of VRET systems. I included aspects of the complete exposure therapy process (i.e., beyond the exposure treatment session), which is presented in Paper E. While the former research program was focusing on the exposure, I broadened the research to go beyond the exposure treatment towards activities preparing an exposure treatment and sustaining the success. Furthermore, I investigated how technology, especially VR, may be able to bring a meaningful benefit to therapy for both therapists and patients. The goal was to investigate the current practice of exposure therapy, and I therefore asked the informants to speculate about how they envision exposure therapy in the future.

Chapter 4

Summary of appended papers

This section presents an overview of the five papers included in this compilation thesis, along with the systems I used in the evaluations. Each system is introduced briefly for a technical view at the particular place in the research process. For each paper, I will summarize the background, aims, method, and results. Furthermore, I will place the papers in context, with remarks that were not formulated in the papers but were important for the progression of my research program.

In my work, the design and creations of prototypes within the iterative CDR process allowed me to view and research the topic from multiple angles and explore potentials otherwise difficult to research, e.g., due to access limitations [33]. This also enables the progress of the research program. The designs also play an important role in communication, as it is difficult for therapists and patients to envision VR technology in their everyday practice without showing concrete prototypes that they can respond to and have opinions on. I have therefore used design methods such as ideation, sketching, and prototyping to explore VRET systems from a practical standpoint and created designs to use as vehicles for my studies. In the studies, I mainly used qualitative methods for data collection such as interviews, thinking-aloud, and observations. In addition to field studies that have informed my work, the evaluations of the developed designs have been conducted in lab settings. The focus on understanding practice and designing usable VRET systems is the main reason for leaning towards qualitative methods that better capture experiences and opinions, as well as providing rich descriptions of problems and opportunities important to progress the research program. I have also used surveys to capture quantitative data concerning general aspects of VRET systems, e.g. to measure presence and usability.

4.1 Activity: System for the therapy of acrophobia

The system was created for the prospective use in therapy of acrophobia, i.e. fear of heights. This implies that the design of the scenarios must contain locations that allow the immersed user (i.e. the patient in later versions) to experience exercises that represent heights. To provide the user with a realistic scenario, the VR designed for this study replicated an urban scenario. To simulate graduated therapy (i.e. increasing difficulty), the scenario consisted of three predefined locations, which represent three increasing levels of difficulty. The first location was intended for acclimatization, where the user is standing on a street surrounded by multi-story buildings. This was also designed to be able to collect baseline data. In the second location, we implemented a balcony on top of a multi-story building, which was accessible by the roof. The balcony was secured with handrails and had a metal grid on the floor (see Figure 4.1). The third location was an unsecured protrusion, which the user was to access from the roof. This was the highest difficulty of the scenario, as it was designed to provoke the highest level of anxiety. As a further feature, we implemented a system for full-body tracking, which gives the immersed user a body representation in VR. This was designed to potentially increase the user's sense of presence and by that provide a more realistic experience.

To immerse the users, we used the HMD Oculus Rift Developer Kit (DK) 1, which is considered to be the first consumer-ready version of a VR headset. In addition to the standard VR view without a user's body representation, we implemented full-body tracking, which gave us the opportunity to investigate the effect of a body representation on the user's behavior and presence. The motion tracking of the immersed user was implemented using the Microsoft Kinect 1[1] sensor. The locomotion was realized using a standard wireless game controller. During the exposures, a therapist would be able to set the immersed patient to one of the three pre-defined spots in order to conduct the graduated therapy. We also implemented a first-person view on a computer screen, which allows the person outside the VR (i.e. the therapist) to see the exact same picture as the immersed user.

[1] https://developer.microsoft.com/de-de/windows/kinect/

(a) A person experiencing our height scenario with enabled extremity tracking.

(b) First-person view while using our system with enabled extremity tracking.

Figure 4.1: Two views of our system with enabled extremity tracking.

4.2 Paper A: Development and evaluation of a virtual reality-system with integrated tracking of extremities under the aspect of Acrophobia

Full paper presented at 2015 SAI Intelligent Systems Conference (IntelliSys), London, UK.

Authors: Philip Schäfer, Marius Koller, Julia Diemer and Gerrit Meixner

Background and aims

This paper presents the first study and system we created in the context of VRET of acrophobia (fear of heights) with the purpose of opening and exploring the design material [116]. In contrast to other systems at the time, we aimed to use consumer-ready hardware to evaluate the feasibility of the cheaper and presumably non-expert hardware in the context of VRET systems. Research already indicated that there appears to be a link between presence and anxiety [38, 83], which led us to evaluate body-tracking as an influencing factor of presence [123] and possible consequences for the felt level of anxiety.

In the study, we investigated and evaluated the effect of a user's body representation (also called avatar) on presence and simulation sickness. A further aim was to assess the suitability of the used consumer hardware for use in therapeutic practice. In addition to a typical VR set-up that did not contain any form of avatar, our design used full-body tracking to allow the user to control the avatar in VR using regular body movements, which were presumed to have an influence on presence.

Methods

The study was conducted with 42 participants without diagnosed acrophobia, and they were allocated to two groups: a test group and a control group. The test group experienced the scenario with an avatar controlled by their body movements. The control group experienced the same scenario, but without an avatar and body tracking.

The experiment was designed using the following three stages during the testing phase:

- **Acclimatization**:
  The purpose was to accustom the participants to the virtual environment and collect a baseline measure of their heart rate.

- **Balcony task**:
  Participants were instructed to approach a balcony, which was secured by a railing and had metal grids on the floor so that the participants could see the ground. Here, the researcher focused on the participant's presence by observing and noting down the participant's movements and orally assessing the presence.

- **Protrusion task**:
  Continuing on the balcony, the participants were asked to enter an unsecured protrusion without a railing. When the participants reached the middle of the protrusion, they were asked to move one leg over the edge. This presumably had the highest phobic stimulus due to the small space without the securing railing. During this scene, the researcher also asked for the subjective level of presence.

The stages were visited in the same order and participants were teleported to the predefined locations. As a central measure of the quality of an immersive experience, we measured the participant's presence. We assessed the patient's presence using three dimensions: subjective (orally during the experience on a scale from 0-100 and a post-experience questionnaire), physiological (heart rate), and behavioral (participant's body language and reactions such as hesitation were noted by the researcher).

Results

The participants were on average immersed for 295 seconds to fulfill all tasks. The results indicated that the group with an avatar controlled using body-tracking tends to have a higher sense of presence and users have a higher degree of engagement with the virtual world. This indicates that the use of body representations may support therapy, e.g. because the participant's own body allows the user to estimate distances based on their own height [96]. For instance, they tried to walk instead of using the wireless controller for locomotion. Furthermore, the results indicate that participants, who are sensitive to heights, report a higher sense of presence, which suggested results similar to previous research [38, 83]. During the immersion, 6 participants reported symptoms of simulation sickness, which had a low impact on the overall experience. Furthermore, the comparably high degrees of presence indicated that the use of the system made up of consumer hardware may be feasible for therapy. With the VR technology maturing, the findings enabled us to use consumer hardware in future studies (see Section 4.4). We concluded that the design of the VR is a key component for the use of VR in therapy. We identified further topics that should be researched and implemented as, for example, implemented in system PubVR, to integrate auditory cues to provide a more realistic setting for the immersed user.

In the context of this study and in the aftermath, we also became aware that the therapists, who control the VR scene and exercises, have an underestimated and important role to play as an orchestrator of VRET systems. Hence, I concluded that we need to better account for this kind of orchestration by adapting my research program and more profoundly involvíng the therapists in the design process to better understand how this takes place. This was accomplished in the following papers.

4.3 Paper B: Next Generation Virtual Reality Exposure Therapy Systems - A Study exploring Design Implications

Full paper presented at 2018 International Conference on Intelligent Systems (IS), Funchal, Portugal.

Authors: Marius Koller, Philip Schäfer, Magdalena Sich, Julia Diemer, Mathias Müller and Gerrit Meixner

Background and aims

Following up on the previous study in Paper I, a new study was launched aiming to increase our understanding of the context of the use of VRET systems and current therapy practice. The aim was to understand the current therapeutic practice and to derive design implications. Due to a limited body of research, the study focused on therapists and their activities during the exposure sessions. Furthermore, we aimed to understand the therapist's expectations of VRET systems

Methods

This study was conducted using mixed methods. First, we conducted an online questionnaire, which aimed to provide data on therapists' expectations, fears, and possible desired characteristics of VRET systems. Secondly, we conducted observations of exposure sessions. In total, we observed 10 hours of therapy sessions in two different settings: in-vivo and in-virtuo. Thirdly, we conducted semi-structured interviews with therapists about their current practice.

Results

The main outcome of this study was the realization that exposure therapy is generally highly complex and based on the patient's individual process. We learned that the content of an exposure needs to be tailored to a patient's individual needs, possibly with on-the-fly adjustments. This was also reflected by the implication that therapists need flexibility in these systems to tailor the exposure. We also found that trust is central to the relationship between therapists and patients, hence the design of a VRET system should account for a trustful relationship. We also learned that the space available in the real context of typically small therapist offices is very limited; this indicates a general challenge to allow for locomotion in VRET systems. Hence, the design of scenarios and VRET systems should account for limited space and not assume by default that large spaces are available.

This study led us to realize that exposure therapy has an emphasis on the individuality of the patients and the exposures conducted. This reflection led to a change in my research program towards an even more therapist-oriented approach. Based on the transition towards the therapist-oriented approach, we aimed to achieve flexibility in the context of exposure therapy. Based on the experience we gained in the previous papers, we aimed to design a system that combines flexibility and the power of full-body tracking. Therefore, we decided to work with social interactions because within the social interactions there lies a high degree of individuality, partly expressed by the body. Based on research and discussions with therapists, we hypothesized that therapists need a high degree of flexibility in these scenarios.

4.4 PubVR: System for the therapy of Public Speaking Anxiety

This system was created for use in the therapy of public speaking anxiety (PSA). The system consists of two parts: the VR for immersed patients and the orchestration user interface for therapists. The system is designed so that the therapist is not immersed in the VR, but orchestrates it from outside the VR, as depicted in Figure 4.2.The virtual scene resembles a seminar room, which is populated with avatars that form a virtual audience (see Figure 4.3). The patient is immersed using an HMD and can walk freely in the room. Furthermore, there is the possibility of integrating a custom presentation (e.g., prepared by the patient), which is displayed on the front wall of the room. To interact with the presentation, the immersed user has a controller, which contains the functionality of a presenter (i.e., switch slides and laser pointer). The slides are also shown on a screen, which is placed on the speaker's desk to allow the presenter to see the content of the presentation without turning away from the audience. The avatars perform standardized animations, which should always reflect a positive attitude towards the presenter by attending and following the presentation.

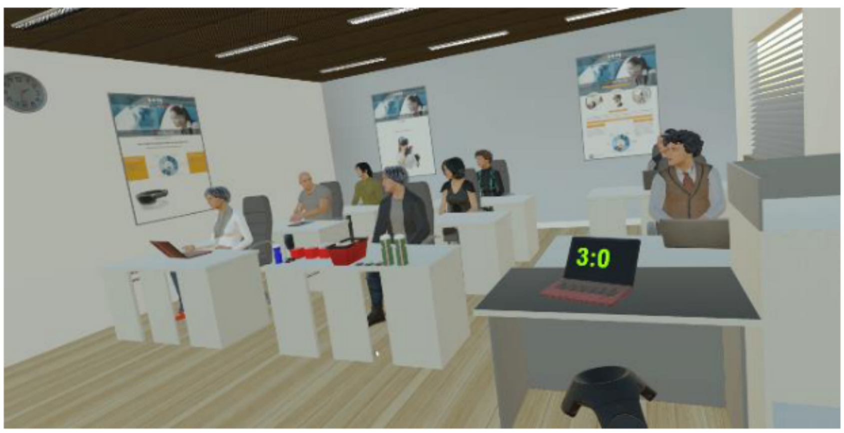
Figure 4.2: The envisioned setting with the immersed patient and therapist orchestrating the phobic stimulus.

The therapist's side of the system allows the orchestration of the simulation while not being immersed. First, we implemented a feature to set up the scenario, which provides the possibility of uploading their own presentations and populating the simulation by placing avatars at the desks. The orchestrators are able to choose whether an avatar is sitting at a desk or whether the desk should be empty, i.e. they cannot choose which avatar is placed at a desk. This may be used in gradual therapy where the difficulty of an exposure exercise is altered [36]. Second, we implemented live-orchestration, which allows the orchestrator to take over and embody an avatar to allow therapists to control the avatar during the exposure. This is done by a Microsoft Kinect 2[2] sensor, which mirrors the movements of the upper limbs of the orchestrator. Besides the non-verbal interactions, a verbal communication channel is open which allows the orchestrator to talk to the presenter, which appears as if the embodied avatar was talking.

For the interaction with the system, we used the approach of hybrid continuous interactions. This was chosen to account for the change in interaction modality and the need for a conscious change between both. We designed a graphical user interface (GUI), which allows interaction with the system by mouse (e.g. to select an avatar to embody), and keyboard (e.g. to change

[2]https://developer.microsoft.com/de-de/windows/kinect/

(a) The therapist's view from outside the VR.



(b) First-person view from the patient.

Figure 4.3: Two views of our system's virtual environment.

the therapist's perspective of the VR). To start embodying the avatar, the therapist must perform an activation gesture, which is recorded by the Microsoft Kinect 2 sensor. The activation gesture asks the orchestrator to close both fists at the same time and keep them closed for one second.

After the activation, the embodiment begins, which includes the non-verbal and verbal communication channels. Without the embodiment of an avatar, no verbal channel is open. When the orchestrator wants to terminate the embodiment, the same gesture as for activation must be performed to hand the avatar back to system-controlled behavior. We chose the unintu-

Figure 4.4: Gesture performed to start the embodiment.

itive gesture to have a dedicated break in the orchestrator's behavior, which should indicate the change of the interaction paradigm and keep the current paradigm present. At the same time, we designed the gesture in such a way that it could be performed in an unobtrusive way.

4.5 Paper C: Rich Interactions in Virtual Reality Exposure Therapy: A Pilot-Study evaluating a System for Presentation Training

Full paper presented at 2019 International Conference of Healthcare Informatics, Xi'an, China.

Authors: Marius Koller, Philip Schäfer, Daniel Lochner, and Gerrit Meixner

Background and aims

This study evaluated a VRET system designed for the therapy of public speaking anxiety (PSA). This study was designed as a response to the demand for flexibility and tailorable content learned from the previous study (Paper B). The system aims to provide flexibility by allowing the therapist to become an orchestrator by embodying an avatar through body-tracking. This allows the therapist to control an avatar from outside the virtual environment. In the study, we investigated the view of the presenter (equivalent to the patient) view, who stands in front of the virtual audience. The aim was to understand the presenter's experiences while presenting, focusing on the differences between the spontaneous and pre-scripted interactions.

Methods

We conducted a study with 24 healthy participants divided into two groups: one received the live interaction (i.e. real-time embodiment of an avatar), the other the pre-scripted (i.e. pre-recorded behaviors and statements played on a manual trigger) interactions. Both groups were tasked with presenting the same given presentation, and the interactions took place in defined stages of the presentation, e.g., after a certain statement in the presentation or before switching a slide. The interactions differed in the orchestrator's flexibility, which means that the orchestrator was able to react to the presenter's behavior spontaneously, which was not possible in the condition with the pre-recorded statements and behaviors because it was not possible to predict the participant's behavior to be able to pre-record statements. After the presentation, which lasted about 5 minutes, the participants were asked to fill out a questionnaire measuring social- and co-presence. The experiment ended with a semi-structured interview, which explored the participant's experiences during the immersion, focusing on the interactions and transitions from the avatar's behavior from "listening" to "interacting" to evaluate whether there were interruptions in the experience.

Results

The results indicated that allowing therapists to manipulate avatars by live interaction – i.e. live-orchestration – had a positive impact on the presenter's overall experience. This manifested itself for both the non-verbal and verbal interaction cues. The verbal channel had benefits when the presenter had follow-up questions to the currently embodied avatar. For the pre-orchestrated condition, there was no spontaneous interaction available and, hence, no response was possible. This led to silence and possibly repeated questions by the presenter before s/he went on. The live-orchestrated condition allowed the therapist to react spontaneously to the presenter's questions. The embodiment of an avatar also contained the movement of the upper body. Participants did not report any breaks in presence or other negative influences on the change of avatar's behavior. This indicates that the transition from pre-orchestrated standard behavior to live-embodied interactions is potentially usable for VRET systems in real therapy settings.

In the next step of evaluation, we focused on the therapist's side of the system, which is presented in the following paper. The initial focus should be the interactions with the system and the process of orchestration. As we have a hybrid user interface, the study should focus on basic characteristics such as usability and user experience. Due to the early experimental stage of the system and the basic non-clinical research question, the study could be conducted with non-therapist participants.

4.6 Paper D: Continuous Interaction for a Virtual Reality Exposure Therapy System

Full paper presented at 2020 International Conference of Healthcare Informatics, Oldenburg, Germany. This paper received the best paper award.

Authors: Marius Koller, Sebastian Felix Rauh, Anders Lundström, Cristian Bogdan, and Gerrit Meixner

Background and aims

This study aimed to evaluate the therapist's interactions with the system for the treatment of public speaking anxiety. The therapist's side of the system may be seen as a hybrid user interface, as it contains heterogeneous technologies (VR and traditional GUI) and interaction modalities (midair gestures and keyboard-mouse-interaction). The focus of the study was on the implemented concept of continuous interaction, which is defined as the ability to transition between interaction spaces and modalities [28]. By design, the therapists transition from a standard 2D mouse interaction (e.g., when choosing the avatar to embody on the GUI) to a 3D gestural interaction (starting from the activation of an avatar). To make the therapists always aware of the current space, we designed the transition by a dedicated gesture. The participant needs to close both hands to fists and hold them closed for one second (see section 4.4). To prevent unintentional hand-overs, we designed a gesture that is not present in a regular conversation. This study aimed to investigate the participant's perception of the transitional user interface and the influence of the concept of continuous interaction. We expected that the implementation of continuous interaction may increase the awareness of the current interaction modality (i.e., 2D or 3D interaction), which we saw as crucial for the use in a therapeutic context.

Methods

This study was conducted with a total of eight participants, who acted as therapists and twice performed the same tasks of a protocol testing two different design iterations of the GUI. The protocol contained the following steps, which aimed to perform various hand-overs that the participants experience in the continuous interaction:

- Arrange the seating of avatars (i.e. pre-orchestration of the exposure exercise)
- Choose an avatar (2D-interaction) and take-over (3D-interaction) an avatar and embody the avatar (i.e. live-orchestration)
- Hand the control (3D-interaction) of the avatar back to the system
- Repeat 2. and 3. for a different avatar
- Change the perspective to the first-person-view (2D-interaction)

During these tasks, we asked participants to conduct several hand-overs and embodiment phases to let them experience the hybrid user interface and the transition between the interaction modalities and virtual spaces. While the participants experienced the interaction and environment, we asked them to verbalize their thoughts and experiences using the thinking-aloud method. After the participants finished the tasks for each version of the GUI, they filled out the standard usability questionnaire ISONORM 9241-110 S [112]. Furthermore, we conducted semi-structured interviews assessing issues and experiences with the system and interactions.

Results

Our results suggest that the design of continuous interactions supported the participants to be aware of the interaction space they are in. Our results indicated that the participants learned the interaction and improved after the initial successful hand-over of the avatar control, regardless of the GUI. The participants felt that the gesture to activate the embodiment was too obtrusive. By design, we intended the obtrusive character in order to create a clear distinction between the interaction modalities and spaces, which should make the participants aware of the current interactions space. Furthermore, results indicate that perceptual and cognitive continuity are closely related. On the cognitive level, our results indicate that the icon-based representation seems to be beneficial in relation to the cognitive load, presuming the use of well-established icons. The interaction's learnability appeared to be good, indicated by the fast improvement (in accuracy and time) over a relatively small number of interactions. The study led us to realize two challenges for the design of VRET systems that are designed and used in therapeutic practice. First, the scalability of the phobic stimulus has implications for the design. Despite having a small scale system in the study, we already experienced a degree of complexity. When considering therapeutic practice, the stimuli and their complexity may increase. Integration of more realistic stimuli and deciding to which interaction space they would be counted towards should be done in close collaboration with therapists. Second, the design of the therapist's transition between the interaction spaces and modalities must be considered during the design. With more complex stimuli, there may be a need for combined stimuli, which may be triggered in different interaction spaces and by different modalities.

During the study and in discussions with therapists, we found strong indications towards a more complex set of stimuli in therapy. This posed a design challenge surrounding the scalability of the system, which suggested conducting a study where therapists are closely involved. Furthermore, after the initial two positive evaluations of the concept of live-orchestration implemented in the VR system, the stage was reached where therapists should be allowed to comment on and suggest changes to it. After this study, my research program changed towards the holistic view of exposure therapy because I saw indications of the potential a VRET system has outside the exposure sessions, which led me to the next study. The aim was to acquire knowledge about the full exposure therapy process and to identify options for a VRET system to fit in. Furthermore, we aimed to identify whether the design choices we made can be further informed and possibly extended.

4.7 Paper E: New Perspectives on Virtual Reality Exposure Therapy: a qualitative Study exploring Orchestration in the Process of Exposure Therapy

Full paper submitted to 2022 12th Nordic Conference on Human-Computer Interaction, Aarhus, Denmark.

Authors: Marius Koller, Sebastian Felix Rauh, Cristian Bogdan, and Gerrit Meixner

Background and aims

In the aftermath of the previous study, I saw indications of the potential of the concept of orchestration. There were hints that when looking at exposure therapy in a holistic way, there may be even more opportunities for VR to contribute to therapy of anxiety disorders. To investigate this potential, I planned a remote interview study with therapists evaluating their current therapy process, anticipating that individualization plays an important role in their work. Furthermore, the study aimed to investigate how therapists see the use of VR in their future workflows.

In addition to exploring the therapist's views, I wanted them to reflect on the concept of orchestration implemented in the system that was subject to evaluation during the previous studies.

Methods

This study was conducted using a semi-structured interview, which had three major parts: 1) current practice in therapy, 2) comments on the concept of live-orchestration, and 3) vision of VR in therapy. Due to practical considerations (e.g. restrictions related to the COVID-19 pandemic), I decided to conduct the interview remotely. In contrast to face-to-face interviews, the interviews conducted remotely allowed me to interview a geographically more diverse group of therapists. This has the advantage of interviewing therapists with different backgrounds as well as social and professional settings.

In total, I interviewed eight therapists with various levels of experience. All were familiar with VR, and four were already using it actively in therapeutic settings. The concept of orchestration was presented to the therapists by video clips that showed a person using the system (i.e., the full set of interactions) as well as a screencast that showed the actions the system performed upon interaction.

Results

The results suggest that therapists, in general, see the benefits that VRET systems may provide. However, there appears to be a gap between VRET systems used in research and needs in therapeutic practice. We found suggestions that VRET systems need to be designed to empower therapists to use the systems in their daily practice in a flexible way. Introducing orchestration into VRET systems that allows the therapist to shape the VR content of the systems may be one way to add flexibility to the systems.

We found design implications, which should be considered when designing VRET systems. First, the orchestration should allow the therapist to control the VR to a degree that still allows focus on the patient and therapy. Therefore, it may be fruitful to allow a therapist to pre-orchestrate the scene beforehand. However, the effort to prepare the sessions needs to be kept in mind when designing. Our results suggest that intelligent algorithms, or even AI, may be used in this context. It must be noted that the therapists want to remain in control, which has consequences for the supporting algorithms, as they need to keep the therapist in control. As a second implication, we found that besides the control of the preparation, therapists want to control the phobic stimulus, which may be achieved by introducing live orchestration. We found there are differences in the level of detail on which therapists want to live-orchestrate the scenario, which should be reflected in the design (e.g., by allowing to trigger behaviors instead of embodying an avatar). As a third implication, we found that there is a demand for a broad variety of scenarios that can be used for therapy, which also contains a tension. VRET systems should ensure that therapists are able to find scenarios that match the patient's needs. It may be noted that the more individual scenarios are created, the more difficult it becomes for therapists to oversee and choose the proper scenario. The tension is to create enough scenarios that a therapist can choose from, but also to have a number such that therapists can oversee them. This could be achieved by creating orchestrateable scenarios that empower therapists to individualize to a patient, both while preparing and conducting therapy.

Chapter 5

Discussion

Through a Constructive Design Research (CDR) process with the purpose of expanding the use of VRET systems and learning more about how these systems can be designed and implemented to support therapeutic processes, I have been able to extract some key lessons learned. I will open the discussion with general challenges I faced and found during my research. In the following subsections I will discuss key lessons learned at an overarching level focusing on 1) therapist's roles during therapy, 2) VR as a tool in Exposure therapy, 3), Orchestrating individualized therapy and 4) Design implications. I will end the chapter with methodological reflections.

5.1 Challenges surrounding VRET

First, we will look at challenges I found during my research that are not all part of my papers, but contributed to the progression of my CDR process and understanding of therapy. The challenges we will discuss contribute to the understanding of why I see VRET systems as not yet being ready for therapeutic practice.

Overall, my studies suggest that VRET is perceived positively by therapists (Paper B and Paper E), which research also proposes [81, 118]. However, during my research I identified a number of challenges surrounding VRET: 1) readiness for use in therapeutic practice, 2) experimental character of the VRET systems, 3) accessibility of VRET systems, and 4) therapist being replaced by a VRET system that reduces the work that a human therapist does.

The first challenge I found is a lack of readiness of VRET systems for use in real therapeutic practice. In contrast to Rizzo and Koenig's statement that clinical VR is ready for prime-time [119], I believe VRET systems are not yet designed for use in clinical practice. Unlike the authors, I approach the system's readiness not from the clinical standpoint (i.e., based on therapy outcome) but from the more practical, therapist-oriented view. There is plenty of research indicating that VR may be useful and effective in various therapeutic use-cases [119, 87]. However, all systems are currently designed as stand-alone systems, which may not be practical from various standpoints such as costs [87].

My results suggest that most therapists conduct therapy for various mental disorders and conditions in their practices, which is not represented in present-day VRET systems, as they focus on single disorders and uses. This may call for a re-conceptualization of VRET systems in therapeutic settings away from the focus on single disorders and use-cases towards a more general and holistic view of VR that supports therapeutic practice in all stages. VR-systems should combine approaches and use cases into one flexible system.

The opportunities for therapy provided by the technology appear to be not wide spread outside of research, which may limit the creativity of using VRET systems [81]. For example, advances in VR [18] and Machine Learning [87, 8] could contribute to optimized therapy [18] but are not widely known outside of research.

The second challenge I encountered was the experimental character of the systems and immature technology. My results suggest that present-day VRET systems do not meet therapists' expectations in terms of ease of use and simplicity. One example of the experimental character is the process for set-up of a VRET system (Paper A, C, E). Some currently available VR systems (for example the HTC Vive[1]) need external sensors to allow tracking of the HMD and controllers (called outside-in tracking [104]), which demands their placement during the set-up of these systems and requires sufficient office space (Paper B). However, looking at the progress in technology, visible when comparing the Activity system (see 4.1, designed 2014), where an expert needed to install it, and the PubVR system (see 4.4, designed 2018), which could be installed by a therapist, the technology became more accessible for a broader public. Besides these stationary VR-systems, there are other solutions that use regular smartphones as HMD (e.g., [79]), which, although

[1]https://www.vive.com/us/product/vive-pro2/overview/

less space-demanding, tend to offer a limited set of options necessary (e.g., in terms of interaction) to conduct therapy. With technology advancing, there are systems available that employ inside-out tracking (i.e., no external sensors need to be installed) that may ease the set-up of the system [51]. Along with the technical set-up, the interactions of the VRET systems also appear experimental. The therapist's interaction with the VRET system itself must be investigated and designed thoroughly. The controlling of the systems and the possibly newly introduced interaction paradigms, such as hybrid interaction (Paper C and Paper D), may also add complexity while bringing advantages with it. New opportunities for therapeutic uses must be explored by therapists and should be supported by HCI researchers/professionals to get them to understand the full potential the technology bears.

Related to the experimental character, the third challenge therapists brought up is the accessibility of VRET systems. In general, it may be noted that not all patients benefit from in-virtuo exposures due to various reasons that are also related to VR itself (Paper E). For example, cybersickness [150, 125] is a topic that raised concerns among therapists during interviews and that is present in related literature from the field of VR and is researched in the context of in-virtuo exposures [38]. It may be that patients, who are emotionally activated, experience the effects more severely than healthy users [38, 83]. Also, the accessibility and patient safety of these VRET systems raised concerns among therapists. Among the concerns, it stood out that therapists are concerned about the use of prescription glasses, which do not all fit under an HMD. Furthermore, many current systems (Paper E) are designed so that the patients stand during the exposure, which is both mentally and physically demanding. Standing still and not starting to move around due to limited space in the therapist's offices (Paper B) may be demanding for the patients and challenges the design of the VRET system. Overall, therapists are worried about the increased workload when also having to supervise the patient's physical whereabouts in the room in order to ensure the patient's safety by preventing dangerous situations such as walking into an object (Paper E).

The fourth challenge therapists mentioned in my studies (Paper B and Paper E) is the doubt about reducing therapists' work with the patients and being excluded from conducting exposures by fully automated VRET systems. While this is a common fear when new technology is introduced in an existing work environment [148], and in settings with a vulnerable user group (i.e., patients) there should be an even higher degree of caution. Automated systems are attracting increasing interest in the research community [79, 78, 73] and offer a huge potential for patient care. Despite this, my results suggest that therapists are concerned that automated systems may undermine one of the most important factors in the effectiveness of CBT, the relationship between therapist and patient [36]. The therapist's clinical skills, such as empathy and experience with previous patients, are critical to the successful implementation of VRET in exposure therapy [36] and should therefore not be completely replaced (Paper E). The trend towards automated systems is seen by therapists also to lead to a "one-size-fits-all" therapy (Paper E), which contradicts the importance of individualized therapy [18]. There are approaches to creating systems that allow individualization using methods such as Machine Learning (ML), which aim to interpret sensor data based on physiological data and tailor the therapy based on them [73, 54, 8]. In the growing body of research, however, the outcomes are limited [50]. Such systems that rely on objective measures appear to not have the capacity to account for more complex aspects, such as facial expressions or non-measurable characteristics (e.g. learning progress), which are perceivable for a human observer. Also, when thinking about social scenarios, I consider speech recognition not yet to be sufficiently mature to fully replace a human as a respondent, although, research presents promising results [24]. Moreover, the emotional intelligence of a human is hard to implement in a computer simulation. Despite the advances in AI-supported systems, VR-experienced therapists in my studies doubt the readiness of AI-based systems.

As we have discussed, therapists remain central to the design of VRET systems and to therapy. With the change of my CDR research program towards a holistic therapist-oriented approach, I shifted my focus towards therapists and how therapy is conducted. In that process, I found that therapists appear to be in different roles, which is important to consider when designing VRET systems.

5.2 Roles assumed by Therapists in the course of Exposure Therapy

We will now discuss the roles a therapist plays during exposure therapy. These roles depend on the stage of therapy and activity a therapist is currently conducting (see section 2.1) and, consequently, transition over the course of a therapy process (Paper B and Paper E). In my research, I found that therapists have three roles: *educators*, *motivators* and *orchestrators*.

Examining the transitions of therapists' roles during the stages of therapy revealed that in the early stages, therapists act as *educators* since they, for example, explain the mechanism of fear and how patients would be able to break it eventually [9]. The central role of education is acknowledged in fully automated systems by, for example, a virtual therapist who educates the patients [144, 3]. Besides employing a virtual therapist, VR could already be used in this educational stage, for example, to visualize physiological relationships or as part of relaxation exercises as VR is currently being explored in mindfulness and meditation contexts [87, 119].

During exposures, therapists act as *motivators* who support patients to remain in the phobic situation and not to engage in avoidance behaviors (e.g. turning away or closing the eyes) (Paper B), which would cause the opposite effect to that as desired for the therapy (i.e., the fear will persist). The aim is to get the patients to take another step and endure the stressful and emotional experience. To transition this into a VRET system, therapists must be aware of the current status of the VR and the patient's progress, which implies that a VRET system should allow therapists to supervise the patient's status (e.g. the current view or heart-rate). Current systems mainly allow therapists to have the shared experience on a 2D-screen as either first- or third-person view (as also implemented in the systems presented in Sections 4.1 and 4.4).

In the role as *motivator*, there appears to be a high rate of direct verbal interaction between the therapist and patient during exposures (Paper B). While being easy during in-vivo exposure, the design of VRET systems is challenged by this. VRET systems must be aware that the patients are immersed and that therapists talk to the patients from outside the VR, which may interfere with the scenario's background noise and may cause a break in presence [133].

Therapists also act as *orchestrators* who are observing, assessing and managing the patient's therapy and exposure session. Despite the generally standardized process of exposure therapy by manuals (e.g. [151, 9]), therapists orchestrate therapy and the contents of therapy on different levels (Paper B and Paper E).

It may be noted that there are two types of orchestration: analog and digital orchestration. By analog orchestration, I consider the process and all activities that are not involving technology. For example, therapists orchestrate the order of exercises in their gradual therapy [18]. Furthermore, they orchestrate the *in-sensu* exposures by guiding the patient's imagination [18]. Digital orchestration refers to the orchestration of all digital components of therapy. This could be bio-feedback sensors [7], multimedia content (Paper E), or VERT-systems if available. The role as *orchestrator*, may be considered ambiguous. On the one hand, therapists aim to create an experience that helps the patients to overcome their anxiety, which is considered by Graham et al. to be purposeful orchestration [53]. On the other hand, therapists are challenged to act almost act as a villain [53] when they are orchestrating the patient's exposure. The rationale behind acting as a villain may be increasing the difficulty of the exercises based on the gradual approach [36], which involves acting possibly as a villain in the exposures.

We have seen that therapists step into various roles over the course of therapy. I believe that, even in remote therapy [56, 67, 142, 142], regardless of role, a therapist's engagement with the patient in some form is necessary. The importance of engaging with the patient is also reflected in automated systems, which often introduce a virtual therapist in some form [56, 144, 3]. Furthermore, we have discussed that the orchestration of therapy is already happening and an important topic. VRET systems are one tool in a toolbox therapist are able to choose from. We will now take a closer look in the toolbox and what it means for the conceptualization and design of VRET systems.

5.3 VR as a Tool in Exposure Therapy

In this section, we will discuss the tension of VRET systems being the only tool in exposure therapy versus VRET systems being on tool in a toolbox for psychotherapy in general. The tension may also be seen in my CDR-progress: from a technology-oriented approach, my research program shifted to a holistic view on therapy. This has implications for the design of VRET systems.

Despite the probably misleading term "Virtual Reality Exposure Therapy" suggesting that all exposures are moved to VR, my results suggest that therapists consider it as one tool in a larger toolbox [87, 18] already containing for example bio-feedback sensors. Like other tools, VRET systems may support therapy, but their usage is not a complete therapy itself (Paper E) as it is integrated into the overall procedures and enhances the therapist's choices during therapy. During the evolution of my CDR research program towards the holistic view of therapy, I realized that therapists do not intend to conduct full therapies solely using VR but rather to use it when they feel it is appropriate and beneficial for a patient, for example as an entry point to exposure therapy [20]. Exercises in-vivo will still be needed for patients to transfer the newly learned behavior into real-life situations [100] and for a sustainable symptom reduction [76].

Overall, my results suggest (Paper B and Paper E) a need for a shift in research focus towards the real-world use of VR systems in therapeutic practice. Lindner argues that it is important to research the effectiveness of the interventions and not focus too much on their efficacy [75]. Effectiveness and efficacy can be seen as a continuum, where studies on efficacy evaluate the intervention under ideal conditions and studies on effectiveness evaluate the intervention under "real-world" conditions [153].

Research must find ways and means that provide therapists with tools that allow benefits for all therapeutic practices, not just for individual exposure exercises, as the systems in research currently do (Paper E). Mohr et al. argue that for the success of a shift in present paradigms, as suggested before, there must be close cooperation between various disciplines ranging from psychology to computer science and HCI [98].

In general, therapists are rarely specialized in treating exclusively anxiety disorders, their practices instead broadly offering therapy for various mental disorders and conditions (Paper E). Consequently, a VRET system (or rather a clinical VR-system) should not only support exposures, as suggested by the term VRET, but also be used in other contexts within therapy [81], for example when creating a fear hierarchy in the early stages, or even other mental conditions, for example, addictive behavior [60, 62].

One possible explanation for the present design of VRET systems may be in the paradigm the research is conducted within. VRET systems are mainly used in randomized controlled trials (RCTs), which demand that the interventions are similar for each patient to ensure similar conditions and scientific results [152]. For this type of research, the driving question behind the research is: *"Does it improve the therapy outcome?"* [16]. However, this does not represent the use in therapeutic practice where therapists wish to use the system in a flexible way [36] as it was demanded by therapists during my research (Paper B and Paper E).

VRET systems are seen by the therapists as a tool that could be included in different therapy stages (Paper E). Furthermore, they see potential to further optimize the systems by designing, for example, gamified content [145, 82], which is not possible in a real-world scenario. This flexibility in design in VR is a widely accepted advantage of in-virtuo exposures [118, 89], which allows the creation of an almost infinite number of situations that a therapist can use.

In the example of social anxieties, avatars may be placed in various settings and groups. This allows the therapist to play different roles during an exposure exercise, which is only possible during an in-sensu session where the exposure is conducted in the patient's imagination or in role-plays. The options for the design of VRET scenarios based on traditional in-vivo exercises are limited by it not reaching its full potential [90].

As a result of the embedding of VRET systems in the therapist's toolbox, I believe that VRET systems need to be increasingly designed for flexible use during various stages of therapy to treat a multitude of mental conditions. In my view, this means that the designs of VRET systems should empower therapists to allow them to use the VRET systems as they see fit, and in that way orchestrate therapy.

5.4 Designing orchestrateable VRET systems

As we have seen in the previous sections, therapists as orchestrators see VRET systems as one tool in a toolbox. With the concept of individualized therapy [36, 15, 87], which is also central to my results (Paper B and Paper E), therapists should be empowered to exploit the VRET systems based on their experience and the patient's needs. As my CDR research program has evolved over the course of my research, I have seen the potential of using VR during several phases and activities within the therapy process of exposure therapy and beyond (Paper E). Such a flexible VRET system should allow therapists to continue being creative as practitioners when faced with the complex task of treating disorders [18, 36]. For this purpose, I classified orchestration activities into three stages, which may be labeled as follows: *preparing*, *conducting*, and *reflecting* upon therapy.

During my CDR-process, I came to the conclusion that not only the VRET system tool but also its VR-content need to be orchestrateable. One indication of orchestrateable scenarios is the design of the scenarios. Without orchestrateable scenarios, a designer would need to design either very generic scenarios or numerous specific scenarios covering variations. While generic scenarios may contradict the concept of individualized therapy, a high number of specific scenarios to broaden the choices would mean that a therapist may struggle to be aware of all scenarios with all specifics relevant for therapy, which could call for a supporting structure for therapists. Designing scenarios that are orchestrateable could empower therapists to individualize the scenario and possibly broaden the use of VR in other therapy-related activities that may enable a more efficient course of therapy.

In contrast to the term tailorable, I see orchestrateable as a wider term including not only the set-up of a scenario but also the ability to alter the experience in real-time (I refer to this later as live-orchestration).

By *preparing*, I mean that VR may be employed during activities that set up a patient for exposures (e.g., psychoeducation [144]), but also in activities by therapists in order to provide them the ability to individualize future exposure-based therapy sessions. I classified exposure-based therapy sessions, and their performance under the stage of *conducting*. Here, I wish to emphasize that therapists currently play an active role and wish to keep this active role, which suggests a need for orchestrateable content and sessions. Stemming from results that propose *preparing* and *conducting*, I concluded that there should also be the third stage, *reflecting*, which is also part of the therapy process defined in therapy manuals. As I did not conduct research on this stage explicitly, I have no real hard evidence in my research, but based on the knowledge acquired in the domain I can still have a discussion of it as I see *reflecting* as an important part of looking at the therapy process in a holistic way.

With my holistic account of VRET systems, my results suggest that VRET systems should also be used beyond exposure therapy. Research indicates significant potential in various disorders ranging from addictive behavior [106] to uses in the therapy of ADHD [17]. The daily therapy work implies treating various mental disorders within a single therapist practice (Paper E). The pressure of costs for practices [87], which is one of the doubts related to VRET systems (Paper B), dictates a limited budget available for investments in new technologies (Paper E) where a versatile system may support the decision to invest.

We will now discuss the three stages, *preparing*, *conducting*, and *reflecting*, in individual subsections. In the sections I will provide an overview of the concept, the benefits for both therapist and patients, and I will reflect on current implementations in our systems and also systems from the literature.

5.4.1 Supporting the preparation of orchestrateable sessions

In this section, we will discuss the activities for the preparation of orchestrateable therapy. We will look at the orchestration in terms of the therapy process and the preparation of orchestrateable sessions, i.e., the preparation of the exercise's content. The preparation of orchestrateable exposure sessions may also be considered as *pre-orchestration*.

There are two types of orchestration: analog and digital. The analog part of orchestration refers during preparation to the choice and use of tools that therapists have in their toolbox. Therapists not only choose based on the patient's individual needs, but also on their own preferences, education [81, 87], and knowledge about the options a system offers (Paper E). It is especially important to highlight at that stage that a VRET system is not used in each exposure session [18]. The digital part of orchestration refers to the digital content a therapist can prepare (or pre-orchestrate) and exploit in the VRET system, e.g. choosing a scenario for the patient.

In the context of therapy of anxiety disorders, VR systems could also be used in non-exposure activities. For example, when creating the fear hierarchy (individual ranking of phobic situations) while preparing exposure-based sessions, therapists could use 360°-images or videos captured from a VR scene, or may even immerse the patients in a situation. Furthermore, some parts of the educational practices may be supported by VR, for example to visualize certain physiological reactions, which could support the patient's understanding of certain mechanisms and their interplay.

Furthermore, during the preparation, therapists look for scenarios that resemble the patient's fear hierarchy, which represents a patient's rating of various situations. Ideally, VRET systems provide a rich set of scenarios, which resemble the patient's individual needs [87, 18, 36]. My results, however, suggest that VRET systems, which are used in current practice, provide a limited set of scenarios and a limited range of tailorable content and provoking scenarios (Paper E). It may even be possible, that the VRET system may not include a scenario that addresses a patient's individual needs. These limitations in terms of tailored content may also be caused by the current focus on research where controlled conditions are demanded by the design of randomized controlled trials (RCTs) [15, 14].

One part of *pre-orchestration* is setting the context of the exposures, which reflects the set-up of the general features of the VR scenario. This is specific to the present session, i.e., the patient's condition and progress in therapy. An illustrative example: in arachnophobia (fear of spiders), the movement and appearance characteristics of a spider appear to have an impact on the phobia [80]. The set-up of the scenario would now entail choosing the species of spider to show in the simulation. As a further part of the preparation, therapists may be able to plan the gradual therapy (Paper A and Paper E), which is reflected in the choice and sequence of the exposures a patient is experiencing.

The system PubVR (see section 4.4), which aims at the therapy of public speaking anxiety, for example, allows uploading a custom presentation created by the patient as part of the *preparation*. This allows patients and therapists to exercise the situation with a real-world, individualized example. Furthermore, therapists are able to individualize the audience by placing avatars at desks and to adjust the difficulty, for example, by increasing or decreasing the number of avatars in the audience. These small examples of options for detailed VR-supported preparation of therapy already indicate the power of the activities that contribute to individualized therapy. The upcoming challenge is to design a system that allows therapists to prepare individualized, scalable phobic stimuli.

Empowering therapists to *prepare* scalable phobic stimuli remains a challenge for the design of VRET systems. One opportunity may be to provide therapists with a toolkit that allows them to set up the virtual environment beforehand. These toolkits should allow therapists to easily adapt the phobic stimulus that a patient will be exposed to but also look at other aspects, e.g., the general behavior of an audience, which sets the context. Research indicates that the mood of an audience has an impact on performance [66], which may also trigger different phobic reactions [29]. For each scenario, the orchestrateable features should be analyzed and designs should empower therapists to individualize them. From a practical standpoint, the therapists should also be able to save the tailored scenarios, be it for repeated exposure or the use for a patient with similar needs.

In general, there appear to be individual preferences and approaches therapists have in the context of therapy (Paper E). These personal preferences must be accounted for in the design of the system to provide therapists with the desired degree of freedom. The level of detail to which therapists are able to individualize and orchestrate the VR content was subject to discussion. In general, there was a consensus that therapy should be individualized to a patient's needs [36]. In Paper E therapists stated that it may not be necessary in all cases for scenarios to resemble exact situations in reality, which is also supported by the literature [132]. Other therapists thought that maximum freedom brings them the most benefit for therapy. In the example of our system for the therapy of PubVR, there was a debate as to whether the benefit of therapy is high enough to embody an avatar for all interactions. There may also be parts of therapy where the therapist may pre-orchestrate scenarios (i.e., define certain behavior based on events) and certain behaviors or simply trigger behavior when appropriate. Continuing with the pre-orchestration of scenarios, it may also be possible to prepare full scenarios based on complex sensor input that trigger certain changes in the scenario. Therefore, I consider the research on automated systems (e.g. [82, 8]) as part of pre-orchestrated systems.

The introduction of VRET systems containing a toolkit for pre-orchestration may also have an impact on fully automated therapy systems. Therapists would be empowered to actively shape the content of the individualized exposure and remain in control of the therapeutic progress of a patient. In contrast to the popular advantages of automated therapy, namely time-saving and standardized therapy, this preparation would require therapists to put in effort to pre-orchestrate the scenarios. While the introduction of the concept may contradict some assumptions of automated therapy, it may contribute to a more scalable therapy. I will elaborate on the use of pre-orchestrated scenarios in the context of automated therapy in section 5.4.2, and in use in homework tasks [87] in Section 5.4.3.

5.4.2 Controlling the stimulus: Live-orchestration

In this section, we will discuss the orchestration of the content while *conducting* an exposure exercise, which I define as live-orchestration. We will discuss the types of content a therapist may want to orchestrate and make connections to the previous stage, preparation. Furthermore, we will reflect on automated systems that aim to live-orchestrate therapy and derive possible applications for them.

While *conducting* exposure sessions, therapists orchestrate and individualize the analog and digital content of the exposure exercises (i.e., the phobic stimulus, see Paper A, Paper C, and Paper D). The individualization is based upon a patient's reactions and progress during a session. I refer to it as *live-orchestration*, which can be considered similar to puppeteering where the puppeteer controls, or orchestrates, the play. In the case of therapy, therapists orchestrate the exercises accordingly, as also common in traditional exposure therapy when the therapists, for example, lead the patient's imagination [36]. When using *in-vivo* exposures, therapists, to a certain degree, have the ability to live-orchestrate the analog content and may be able to adapt to the progress made by the patient. For example, when they feel that the patient is ahead of the planned exercises, and it may be too easy, therapists adapt the exercise and if appropriate make it more difficult for the patient [140]. In this discussion, we will focus on the digital part of orchestration, more specifically on the virtual content of an exposure exercise.

In general, *in-virtuo* exposures offer more opportunities to orchestrate the patient's experiences than an *in-vivo* exposure due to the fully orchestrateable content, and allow exact replications by therapists [87, 128]. The complete control of an in-vivo session is hardly possible as there are various influencing factors a therapist cannot control [18], for example, pedestrians passing by or sudden movements by animals. A VRET system that allows live-orchestration provides the opportunity to react to the patient's actions and progresses spontaneously [140], and thus supports the therapist's role as orchestrator.

Most systems presented in the literature focus on the use of simple ways of live-orchestrating, for example, by triggering behaviors as the mood of an audience [140]. In contrast, the live-orchestration that was implemented in our PubVR system (see 4.4), empowered therapists to fully control the interactions between the patient and an avatar. This may in future allow systems to create more complex phobic stimuli, which may resemble real situations. Live-orchestration has several dependencies on other surrounding factors, such as the type of anxiety that is treated, which influences the virtual scenario containing its content and phobic stimulus. Overall, there are two types of virtual content that a therapist may want to live-orchestrate: 1) content that sets the context (e.g., an audience's mood or height of an acrophobia exposure), and 2) directly with the patient interacting content (e.g., avatars or dogs). First, it may be noted that the context is also part of the pre-orchestration that takes place during preparation. Several exercises may be prepared for the gradual therapy a therapist needs to orchestrate, or events a therapist may want to trigger in the role as orchestrator to challenge the patient more. Second, the content that directly interacts with a patient is mainly subject to live- orchestration. The direct interaction may be as part of a social scenario when an avatar verbally interacts with a patient. The directly interacting entities are not limited to social interactions, but may also be animals a patient is afraid of. With increasing complexity and dynamics of a phobic stimulus, computer systems that aim to assess and orchestrate the stimulus may automatically reach their limits [50], which suggests that human therapists are still needed.

Live-orchestration creates scope for creativity with which a therapist may use the system. With the ability to fully control the scenario, therapists can apply the scenario in uses that were not considered by the designer. This contributes to more versatile use of VRET systems in therapeutic practice, which may broaden the use of VRET systems in therapeutic practice. The ability to live-orchestrate an in-virtuo exposure may also provide the opportunity for remote therapy where a therapist is still an active part of the therapy [56, 67, 142]. The advent of powerful and affordable VR hardware may open up opportunities to allow therapy in a patient's home, with a therapist being able to orchestrate the full therapy process remotely. This new form of therapy may lead to more accessible therapy, especially with remote areas where therapists rarely are available in mind. We witnessed a push towards this form of therapy during the COVID-pandemic where, for example, therapy over the phone gained relevance [122]. Furthermore, it may allow therapists to deliver therapy in remote locations where patients would normally struggle to find a place for therapy.

In literature, there are also approaches for automated therapy, which individualize the scenario based, for example, on physiological measures [7, 54] or speech analysis [22] automatically. This may be considered as live-orchestration by the definition we have just discussed. However, considering the design of these systems, I see them rather as pre-orchestrated scenarios because the reactions of the scenario on the physiological measures are pre-defined and simply executed upon an automated trigger. Furthermore, in fully automated systems therapists play no active role in managing the experience besides possibly pre-orchestrating the triggers and events, which they would prepare in pre-orchestration activities. I nevertheless see that there is room for application of these systems, which we will discuss in the next section.

5.4.3 Design opportunities for reflecting on therapy

In this section, we will discuss activities that are performed after an exposure session has been conducted. By progressing my CDR research program, I found that VRET systems may also contribute to activities after the exposure sessions (see also [114, 9]). Although my work has not covered this part of the therapy process, my proposal on to focus on the preparation of orchestrateable sessions and their live-orchestration suggests that there may also be considerations to be made for a post-session stage.

As part of the post-session activities, therapists continue with the patient by *reflecting* on the session, summarizing lessons learned and experiences, and setting up homework for the next session [9, 57]. By taking advantage of opportunities provided by VRET systems the follow-up can use, for example, physiological measures, videos, and other captured parameters from the in-virtuo exposure previously conducted. In the example of physiological data, it could be discussed after an exposure to illustrate certain misperceptions of a patient, such as increased heart rate.

The advance in VR-enabling technology, which led to many smartphones that are able to display VR experiences, could be exploited in homework exercises [87] patients receive at the end of the therapy session. Research indicates that homework and the compliance with it have implications for therapy outcome [57]. Homework has the role to "prove that they [the patients] can do it [outside a therapeutic setting]" [58]. Furthermore, homework may serve as a tool for patient commitment, which leads to patients having a more active role in their therapy [32]. Existing approaches are partly already enhanced by technology, employing for example video recordings [49] or smartphone applications [138].

We can anticipate different options regarding how a VRET system could enrich the existing tools, for example, to capture a video or to provide the patient with a pre-orchestrated version of the same scenario. The videos could be recorded as regular 2D videos from various perspectives, or to benefit from a probably more immersive experience, as 360°-video [86, 85]. It may be useful to record the videos from different angles: the first-person view of the patient, second-person view (i.e., viewing the patient through the eyes of an avatar in the scene), or third-person with the view towards the patient (which would demand a virtual representation of the patient) to possibly further reflect on the behavior. As homework, the patient could then use a smartphone [42] combined, for example, with cardboard to experience the recorded session.

Providing therapists with the tools to prepare therapeutic content for exposures, it may also be possible to let them create automated exposure exercises, which a patient should conduct as part of the homework using his/her smartphone. This would require the tool to be fit for end-user programming [103] as, for example, proposed by Schickler et al. [126], which implies that there must be an effort to design proper tools that are suited to that requirement [127]. The design could include a platform, which allows the design, distribution, and supervision of the scenarios similar to [142]. This platform could also serve as success control, which may increase the patient's adherence and motivation [57]. For the design, it is important to design the application to be engaging and motivating for patients [42].

For adaptive, pre-orchestrated (or automated) scenarios, the design should also consider, for example, including modern wearable devices that may support emotional regulation [64] to understand the patient's current status. Based on the data, the scenario can alter automated and collect valuable data for therapy progress, even for research purposes, while respecting privacy [101]. The data may also help the systems to detect risk situations, which may lead to them being handed back to human care [143]. When connecting the sensors to a platform, it is important to consider privacy when designing usage [101].

We discussed in this section the three stages of orchestration: preparing, conducting and reflecting. We saw that the stages can be used to conceptualize and design a holistic VRET system. We will now move on to discuss implications for the design of VRET systems.

5.5 Design implications for VRET systems

We have seen during the course of the discussion that the design of VRET systems remains a challenge. The concept of orchestration and its underlying phases allow designers to shape designs that therapists can use in their daily work. In this section, we will discuss, first, the present designs of VRET systems and how this may affect their use in therapeutic practice. Second, we will reflect on implications orchestration brings to the design of VRET systems. Lastly, we will have a look at implications for the design of therapeutic VR content.

Ann Blandford argues that HCI plays a central role in designing purposeful health technologies that bring significant benefits to patient care [15]. This can only be achieved by an interdisciplinary approach, where HCI researchers act as mediators between disciplines and stakeholders. Due to the current focus of research with VRET systems, there may be a need for a paradigm shift from the technology and research-centered design towards a therapist-oriented approach [75, 77]. This starts with a thorough understanding of the setting and the circumstances. These range from the physical setting (Paper B), which has impacts, for example, on the room for locomotion, to the structures in the respective healthcare system, which also differentiate between countries, and the therapy process (Paper E).

It is important for therapists that there is a low threshold for the use of VRET systems. The use of the system should be intuitive, self-descriptive, and safe. Therapists may not be accustomed to the technology [36] and may feel unsafe using it with a patient (Paper E). This has implications not only for the software, but also for the hardware of a VRET system. A fast setup must be possible, which also includes the setup of external sensors (e.g., for tracking) and calibrations.

As my CDR research program progressed, I changed my account of VRET systems towards a holistic therapist-oriented approach. This led me to see that VRET systems may also be used in various contexts. To empower therapists to exploit the full potential of VRET systems, they should be designed in a flexible way. Designs should already account for the flexibility by integrating design for orchestration. We will discuss the implications that I uncovered in the following chapter.

5.5.1 Design for Orchestration

During the progress of my CDR research program, I concluded, that it is important to understand that the exposures are one component of exposure therapy [9] and VRET systems have the potential to support therapists beyond the exposures. The proposed framework of orchestrating therapy may provide guidance for design to gain a more holistic picture of the therapy process, which will lead to holistic VRET systems. We will now discuss implications for the design of each stage, i.e., *preparing*, *conducting* and *reflecting*.

Let us remind ourselves that *preparing* contains all activities that a therapist does before a patient is exposed. We discussed that there are two major types, analog and digital orchestration, both of which have implications for the design. Starting with the analog orchestration, I came to the conclusion that VRET systems should be designed to empower therapists to employ VRET systems over the full course of therapy. This means, that the designs should not assume that a VRET system is used at some point during therapy due to various reasons, such as the patient not being able to use VR due to cybersickness [125]. Furthermore, the designs should allow the versatile use of VRET systems outside of exposure sessions. The VR technology provides the opportunity to support more therapy stages during exposure therapy and could also be used in the context of various mental disorders. In the context of digital orchestration, preparation means choosing the proper VR-scenario and setting up the context. It should also be kept in mind that difficulty may be altered during the therapy, which is part of the gradual therapy. For example, in glossophobia (fear of public speaking) it may be necessary to choose from a set of situations such as a larger audience or a small meeting room [79]. The context may then be, for example, the mood of the audience, which could also reflect the difficulty of the exposure session [66, 107].

When creating scenarios, designers should be aware of the elements that set the context of an exercise and design the elements so that they may be altered by therapists. This could mean that designers need to introduce ambiguous elements that could be used in different contexts, or to allow therapists to activate and deactivate certain elements. It may be noted that these elements enable therapists to create complex phobic stimuli individualized to the patient's needs. The ambiguity of scenarios may also support analog orchestration by allowing the use of different anxieties and conditions. For example, a meeting room may be used during presentations (with a big or small audience) but also for job interviews.

While therapists are *conducting* exposures, they also need to be able to live-orchestrate the scenario while still focusing on patient and therapy. I distinguished between two types of orchestrations: orchestration of the context (i.e., no direct interaction with the patient), and orchestration of interactions with the patient. The context is partly set-up during preparation and may, therefore, only be triggered when the therapist sees fit. The direct interaction with the patient has a higher complexity. While live-orchestrating the direct interaction with patients, therapists actively change the behavior of elements that interact with a patient, and even become part of the VR simulation.

For design, this means that the therapist must be made aware of the current interaction space, i.e., whether the context or the direct interactions are orchestrated. The current interaction space of a therapist and the consequences for orchestration can be divided into two parts: during the 2D interaction therapist has the role of an orchestrator from outside the VR and during the 3D interaction therapists are embodying and orchestrating the VR while being part of it. This reflects two distinct modes of interaction, in which the 2D view may allow for overall parameters to be orchestrated (e.g. environment and group behavior) while 3D mode – when embodying an avatar – is limited to parameters of a single virtual instance. When using the system, it must always be clear to therapists what role they are currently in, and the system must also allow for seamless transitions between modes. This may be ensured by using continuous interaction [27], which aims to raise awareness of which mode of interaction, i.e., role, the therapist is currently in.

Note that in the case of (for example) fear of dogs, the therapist may want to control non-human avatars to respond to patient behavior. This may pose new challenges for designers. For instance, looking into how to naturally control a virtual dog's behavior. However, this also offers a strong advantage over in-vivo as there is no way to have full control over real dogs.

The functionality that allows activities surrounding *reflection* should also be considered in the early stages of the design process. For example, the possibility to record any number of data during the sessions for various purposes, e.g., visualization of physiological reactions, depends on the availability and the integration in the system. There, the designer must make choices as to whether an external sensor should be included. Furthermore, the analysis and usage of the data is important to consider. While possibly being useful, it must be kept in mind that each external sensor a patient needs to wear increases the complexity of the set-up and has implications for the workflow of therapists (e.g., disinfecting the sensors after use). Hence, the decision to integrate sensors must be taken in close cooperation with therapists.

Before we discussed the role of fully pre-orchestrated (automated) systems that may be used in the context of homework. To empower therapists to pre-orchestrate (automated) exposure sessions, VRET systems should provide a way to prepare the scenario's elements beforehand. It may be useful to create a toolkit that allows therapists to *program* the behavior based on actions or reactions of the patient. In consequence, the patient's reactions must be recorded in some way, which creates a need for various sensors (e.g., galvanic skin resistance or speech recognition) that are integrated in a VRET system patients could use at home.

We have discussed implications that arise with the concept of orchestration. We have not yet touched on the therapeutic content itself, i.e., the VR. There are several considerations that are relevant, which we will discuss in the next section.

5.5.2 Designing Therapeutic VR Content

During my research, I learned that presence is a relevant measure when it comes to therapy. While this was not the focus of my research, I still wish to discuss thoughts I had and lessons I learned while my CDR research program was evolving. We will now discuss the importance of presence, take a look at social presence, and discuss locomotion as an influencing factor of presence.

In general, it may be noted that besides the discussed need for orchestrateable VRET systems, the content, i.e. the VR, has specific design requirements. First, it is important to understand that VR scenarios must evoke a high sense of presence [83, 38] for the patients. Presence is an important measure of the quality of the VR content [136, 154, 82] and reflects the subjective sense of being in a virtual environment while being physically somewhere else [136, 154]. Research indicates that presence influences the patient's anxiety [83] and, in turn, emotionally activated persons tend to have a higher sense of presence [83, 38]. This underlines the importance of presence in the context of in-virtuo exposures and the design of the VR-content. Presence has various dimensions which are relevant for use in VRET. There are factors that influence presence and its dimensions [123], which may be modified by the design of the VR scenario. For example, the use of a body representation of the immersed user, as described in Paper A, may support the patient in estimating distances and heights in a VR scenario as indicated by Mohler et al. [96]. However, it may be noted that presence is an individual measure and greatly depends on the immersed person, who perceives the virtual environment differently. During my research, I even received feedback that some patients did not feel present in a scenario and, consequently, did not get emotionally activated.

When including avatars (as in Paper C and Paper D), which a patient should interact with during the exposure, other dimensions of presence, such as social presence [111], become relevant and pose implications for the design of the VR-content. The gold standard which social presence is compared to is the regular face-to-face interaction [18], that is employed during in-vivo exposures. Considering in-virtuo exposures containing interactions with an artificial human representation, there is a visible gap to overcome. As Oh et al. [105] note, there are elements in the design that influence the perception of social presence, such as interactivity, depth cues, and audio quality. Interestingly, characteristics such as visual representation, display, and general modality appear to have less of an impact. Oh et al. found evidence that uncomfortable persons feel generally less social presence compared to people that engage more in social interactions [105]. This is particularly relevant for the therapy of social anxiety disorders, where the social interaction triggers the anxiety.

Locomotion, which represents the methods to move within a VR scenario [123], is an influencing factor of presence I wish to address. There are a variety of methods that may be applied, ranging from natural walking, where a user can walk freely in a tracked room, to controller-based locomotion. The most natural, and therefore positive for the experience and presence, is free walking [146]. This is restricted by the space available for tracking. As noticed in Paper B, the available space in therapists' offices is limited and may be not suited for natural walking. The design of a VRET system should take this into account by creating scenarios that do not demand too much locomotion or with the use of techniques such as walking in place [135]. In contrast, in my results, some therapists argued in favor of conducting the exposures while the patients are seated because there are some patients who are physically incapable of standing for the full duration of an exposure session. However, the seated position limits the options for locomotion in the VR to, for example, teleportation and controller-based interactions, which are suspected to have a negative impact on the immersed user's presence and could cause motion sickness [46].

5.6 Methodological reflections

In this section, I will reflect on my research mainly from two standpoints. First, I will reflect on the CDR process and how my research program evolved. Second, I will discuss and reflect on my research in the context of VRET and mental health.

This is to highlight that my approach to the research of VRET developed from a technology-centric research program towards a therapist-oriented research program, which led me to investigate the therapy process in more detail and depth. This research aimed to go beyond clinical trials towards the design of VRET systems that aim for therapeutic practice. During the course of my research, I was able to get in touch with therapists, patients, developers, and other important stakeholders in the healthcare system. These contacts influenced my progress and informed decisions and the changes in my research program.

Overall, my research was framed by CDR, which reflects the construction of knowledge containing content beyond the outcome of studies reported in papers. For me, as an HCI researcher, in particular there was much to learn from many sources outside of studies that are consequently not published. The rich variety of sources nevertheless allowed me to progress with my research program in the way I did by looking at the work from different perspectives. It helped me to create ideas and build concepts, which always were a product of close cooperation with researchers within clinical research.

Unlike the studies generally conducted in the context of VRET, which are mainly driven by clinical trials, I worked with prototypes to experiment with early concepts that should convey and evaluate the idea behind it. The clinical work focuses on the efficiency of the therapy, i.e., the therapy outcome [16]. While this is obviously an essential step in the development of new forms of therapy, it must also be noted that the systems used in RCTs hardly represent the envisioned use in day-to-day care and the studies demand a lot of effort. Furthermore, I realized early in my research that therapists are key users of the system and that they must already be involved in the early stages of therapy. Present research, also on the side of engineering, focused mainly on VR to create the best immersive experience for the patient.

My role as an HCI researcher also implies that I had limited access to therapeutic settings, especially when patients were involved [33, 16]. Despite the issue, I was able to participate in exposure sessions, which helped my understanding of the context of use, the therapist's tasks, and the therapy itself. Besides the observation of exposure sessions, I was in continuous exchange and contact with therapists, which brought in their experience and thoughts on my ideas, concepts, and prototypes.

All prototypes that were part of my research are pre-clinical and were not tested with patients suffering from the anxiety disorder concerned, but with healthy participants. The use of healthy participants in studies is reflected in the two-phased development process for technologies in a mental health setting proposed by Coyle et al. [33]. The authors suggest two distinguished phases, in which development takes place. The first phase is pre-clinical with an HCI researcher as the leader of the development and study, while the second is a clinical study led by clinical researchers. In contrast to their approach, I initially explored the design space and conducted an analysis where I learned about the field and the requirements. I consider these steps essential for my deep understanding of the domain and to have shaped my progress.

Furthermore, with the progress of my research program, I was looking beyond the exposures, which is the therapeutic intervention, to the full process of therapy. I see this as the main concern when we wish to develop VRET systems to be used in therapeutic practice.

Despite my research focusing on therapists, I did not involve therapists in all of my studies, but conducted the studies with non-clinical participants. The prototypes that we implemented and evaluated were all in the early stages of development where the research should indicate basic characteristics (e.g. perception of the avatar animation as in Paper C or the concept of continuous interaction in Paper D), where specific knowledge of therapy is not necessary. As proposed in the two-phased design process [39, 33], the next step is to expose the concepts and prototypes to therapists, which I started in Paper E.

Chapter 6

Conclusions

With this chapter, we will conclude my thesis and return to my research questions. I will start with final remarks and move on to my research questions. This will be followed by a few thoughts on possible future work.

The aim of my research was to help to transition VRET systems from research settings into therapeutic practice. During that endeavor, my CDR research program has evolved. I started with a technology-oriented approach to VRET, which evolved to a holistic, therapist-oriented approach to VRET. In summary, my results suggest that psychotherapy, in general, can benefit from an advance of VRET systems. We have discussed that therapists still see challenges for VRET systems. These may be labeled as *readiness*, *experimental character*, *accessibility*, and *reduction of therapist's work*. The challenges emphasize the importance of a therapist-oriented approach to VRET systems as they appear to be fundamental barriers to the transition of VRET systems into therapeutic practice. With the holistic account for exposure therapy, three roles that a therapist assumes in the course of exposure therapy emerged: *educators*, *motivators*, and *orchestrators*. The variety of roles indicates that therapists play a central role in the use of VRET-systems.

The roles therapists assume during therapy are essential to understand and investigate during the design process, because they influence the design and conceptualization of VRET systems. These should empower therapists to exploit the full potential a VRET system can contribute to effective and efficient therapy. We have discussed the fact that VRET systems are one tool in an already rich toolbox available to therapists in the context of therapy. I wish to highlight that I understand VRET systems not only as a tool for exposure sessions but as a tool for the complete process of exposure therapy, even beyond exposure therapy in more general therapeutic uses. Hence, therapists should be empowered to use the system in more creative, flexible ways, which challenges the design of the VRET-systems. One of the therapist's roles during therapy is the role as an *orchestrator* who manages therapy and the exposure exercises of a patient. To support the role, VRET-systems should be designed as orchestrateable systems. We have seen three stages of therapy where orchestration may be used: while *preparing*, *conducting* and *reflecting* exposure therapy. For the *preparation* of an exposure session, therapists are orchestrating the analog (e.g., different exercises of the therapy) and digital (e.g., the VR-scene) content of the therapy. The preparation, or pre-orchestration, of exposure sessions in particular has implications regarding how the VRET systems may be used. The pre-orchestration of the VR scene may reduce the workload while conducting and opening up opportunities while reflecting upon an exposure session. While *conducting* the exposure session, therapists wish to stay in control of the phobic stimulus and, therefore, should be able to live-orchestrate the VR-scene. This contains the phobic stimulus and all context that the patient is exposed to. Here, we see the dual role a therapist plays during therapy: while being a motivator, therapists must act as orchestrator, which could mean acting almost as a villain who challenges the patient exposed. We can already that this challenges the design because the therapists cannot focus on one role at a time. In addition, during post-session activities, when *reflecting* on therapy, VRET systems may bring benefits to therapy. Part of the reflection after therapy sessions are exercises a patient should perform at home. With the advent of VR-enabled smartphones, there may be opportunities for therapy because many patients are able to use their own devices to experience VR content. Therapists may be empowered to *pre-orchestrate* these homework exercises using a toolkit integrated in the VRET system.

We saw during the discussion that automated systems may be considered as *pre-orchestrated* systems. In these systems, the scenarios are pre-orchestrated with all the therapeutic content and possibly adaptations based on measures or triggers that are utilized while the patient is exposed. There appears to be a tension between fully automated systems that therapists rejected during my research, and the opportunity that arises with them in a semi-automated therapy approach. As we have seen, there may be ways to use pre-orchestrated systems during homework where patients perform exercises alone.

All the points that we have discussed influence the design of a VRET system. The systems should be designed for orchestration. The orchestration should be introduced as an integral part into the system, i.e. it should be designed so that therapists are empowered to use it in creative ways, including beyond exposure therapy. Consequently, all content and interactions should be designed specifically for orchestration, containing orchestrateable elements.

Finally, let me return to my research questions:

Research Question I:

What challenges underlie using VRET as a tool in therapeutic practice?

I have found two major challenges to transition VRET-systems into therapeutic practice: a shift towards more therapist oriented VRET-systems, and the lack of therapist empowerment. I have found two major challenges to transitioning VRET systems into therapeutic practice: a shift towards more therapist oriented VRET systems, and the lack of therapist empowerment. The first major challenge I found is thus the lack of VRET systems that are designed for therapeutic practice by designing them in a more therapist-oriented manner. Therapists, in general, have a positive attitude towards using VRET systems, but such systems should reflect their daily work. The present systems are mainly designed for the use in standardized environments, which does not reflect the out-patient settings where VRET-systems will be used when they are deployed widely. Therapists have different roles during therapy: they act as educators, motivators, and orchestrators. Especially while therapists are conducting therapy, they have two roles at the same time: they are motivators and orchestrators. Understanding these roles is important for therapy because they are central to delivering an efficient therapy and, therefore, should be integrated in the designs. As the second challenge, I found that research and the VRET-systems need to empower therapists on different levels. By integrating therapists with various backgrounds in the design of new VRET-systems, they will be given the opportunity to provide insights and support, thus creating VRET-systems that reflect their needs. There may be various ways to integrate them, for example participatory design activities or as testers of early designs, as in my research.

Besides empowering therapists during the design process, the design of VRET-systems should empower therapists to be able to orchestrate all phases of therapy: *preparing*, *conducting* and *reflecting*. This empowers therapists to use VRET-systems in a more versatile way. This implies that designers should look beyond the exposures and address all phases of therapy. By designing VRET-systems for orchestration, we empower therapists to use the systems during therapy as they think best for patients and the therapy process.

Research Questions II:

In what ways can VRET-systems be made more versatile for therapeutic practice?

In order to create more versatile VRET-systems, they should be designed holistically with therapist empowerment in mind. This can be achieved by designing orchestrateable VRET-systems that a therapist can exploit to individualize therapy to a patient and use beyond the exposure sessions.

Orchestrateable VRET-systems enable the therapists' creativity to exploit the VRET-system's capabilities in various contexts, for individual patients and over a range of mental disorders. By designing orchestrateable VR-scenarios, they can be used as a flexible tool in the therapy of various mental disorders. Besides the orchestration of one scenario for multiple patients, it may be possible to create a set of scenarios for use in different contexts. For example, a scenario for social anxiety disorder can also be used in the role plays that are part of many therapies. This opens up more uses and may also show the investment in such a VRET-system to be reasonable when it is possible to use the tool in various ways. Allowing therapists while *conducting* therapy to be able to live-orchestrate the scene may also make the systems more versatile. The concept of live-orchestration enables therapists to adjust therapy in real time by orchestrating the phobic situation through adjustment of possibly ambiguous elements of the VR-scene. This allows therapists to respond and treat patients individually based on their present progress and how they feel on the day concerned.

Adding the ability to reflect on therapy using a VRET-system embeds the system even further in the therapy process. If the VRET-systems provide therapists with a toolkit that enables them to pre-orchestrate homework, the system may be used even further, possibly outside of exposure therapy.

6.1 Future Work

My work lays the foundation for future research that advances VRET-systems for therapeutic practice. I wish to emphasize that besides advanced patient experiences and the therapy outcome itself, there is the need for more therapist-oriented activities. Considering uses outside of exposure therapy, or even combining systems for different use cases, may be a way to push VR in general closer to uses in therapeutic practices.

To exploit the full potential of VR, designers should also think beyond resembling reality and bring exposures into virtuality. There are already promising concepts in research that could contribute to better adherence to therapy. For example, gamification [55], which could possibly exploit further motivational mechanisms for patients [82]. This may have the potential to ensure more commitment by patients and stronger adherence to the therapy. Furthermore, research indicates that the use of in-virtuo exposures may facilitate the start of therapy as patients are more willing to start therapy [48], which may even be supported further by introducing gamification.

In general, post-session activities (i.e., *reflecting* on therapy) and the use of VR may be the subject of future work. I have only begun to address those in Paper V but believe there are plenty of applications that can be used during and outside of therapy sessions to reflect on therapy and continue the learned behaviors. VR could be used to reflect on the therapy session, which is already a regular part of therapy, not addressed so far in many VRET-systems. Furthermore, there appears to be an area of application in the context of homework where a patient needs to exercise without the help of a therapist. With pre-orchestrated systems, a therapist may prepare the homework and tailor it to the specific needs of a patient and what comes next in the therapy process.

Furthermore, there appears to be the opportunity to conduct remote semi-automated therapy with the therapists pre- or live-orchestrating the exposure from the office while the patient is at home. With the advent of cheaper VR hardware, it may even be possible for the patients to use their own device. This may lead to better patient access to therapy, especially in remote regions where access to therapists is restricted by the distance patients need to travel. Furthermore, it may become possible to treat anxieties, which could not be treated in remote locations, such as entering a subway. While remote therapy may offer great opportunities, more research is still needed.

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