A Taxonomy of Virtual Reality Applications for the Treatment of Anxiety Disorders

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A TAXONOMY OF VIRTUAL REALITY APPLICATIONS FOR THE TREATMENT OF ANXIETY DISORDERS

Research Paper

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Abstract

Anxiety disorders are one of the most common psychiatric disorders. Exposure therapy has proven to be a suitable way of treatment for anxiety symptoms. Currently, there are ambitions to digitalise exposure therapy based on Virtual Reality (VR). While a variety of studies verify the effectiveness of Virtual Reality Exposure Therapy (VRET), less research focus on the application of VRET in practice. The objective of this paper is to identify and compare VRET application scenarios from a theoretical and empirical perspective to develop a taxonomy of VRET applications. The findings suggest that companies should focus on holistic VR environments, concentrate their applications on specific age groups and integrate features for the treatment of mild symptoms. Research opportunities occur with regards to the examination of the effectiveness of VRET for mild symptoms and VRET as a new type of stand-alone therapy.

Keywords: Virtual Reality, Anxiety Disorders, Exposure Therapy, eHealth.

1 Introduction

With 61.5 million people affected each year, anxiety disorders are the most common psychiatric disorder in the European Union (Wittchen et al., 2011). In the United States, even about every third adult (31.1%) is suffering from anxiety disorders at some time in her/his life (Alegria et al., 2007). For the treatment of anxiety disorders, both pharmacological and psychological therapy approaches exist. Regarding the latter, Cognitive-behavioural therapy is considered the most effective (Mangolini et al., 2019), as is exposure therapy (ET) as approach for treatment (Foa, 2011; Hofmann and Smits, 2008; Norton and Price, 2007; Rothbaum and Schwartz, 2002). In ET, patients are confronted with a situation or object of fear either in vivo (in real life) or in sensu (in their thoughts) to reduce their negative reaction to these stimuli in future scenarios. However, most people affected by anxiety disorders do not receive treatment. A worldwide study suggests that 26.7% of people suffering from anxiety disorders receive any treatment while only 9.8% receive a treatment that is considered as adequate. For the untreated patients, the chronic symptoms endure, which leads to severe impairments (Alonso et al., 2018).

Due to this gap in treatment, Virtual Reality based exposure therapy (VRET) is being discussed as an avenue to make the treatment of anxiety disorders more accessible and cost-effective. VRET adapts the approach of in vivo ET by creating a computer-generated virtual environment to systematically expose the patient to specific feared scenarios while the environment is updated in a natural way based on the user’s head and body motion (Parsons and Rizzo, 2008). Several studies examined the effectiveness of VRET with the result that VRET allows a reduction of phobia compared to control conditions and patients on waiting lists, and is neither more nor less effective in reducing phobia than in vivo exposures (Carl et al., 2019). However, apart from clinical trials and experiments, less research focus on the actual transfer and usage of VRET as application and product on the market.
Hence, the objective of this study is to identify and compare application scenarios of VRET. For this purpose, a literature review is conducted which should reveal application scenarios that are currently discussed in research and form the basis for the development of a taxonomy of VRET applications. The aim of the taxonomy is to examine the existing market of VRET products regarding their application scenarios and to classify them systematically. The comparison of the literature review and empirical sample allows to identify and discuss possible discrepancies between theory and empiricism. The taxonomy gives patients and therapists an overview in terms of suitable VRET applications for the treatment of anxiety disorders and allows the identification of new business opportunities. At the same time, researchers in the field of IS and psychology may use the taxonomy as basis for their experimental approaches and use it as a blueprint for Virtual Reality (VR) based therapy scenarios. The findings suggest that companies should focus on holistic VRET environments, concentrate their applications on specific age groups and integrate features for the treatment of mild impairments as the majority of people with anxiety disorders suffer from mild (43.5%) or moderate (33.7%) symptoms (Alegria et al., 2007). Research opportunities occur regarding the examination of the effectiveness of VRET, especially for mild symptoms, and VRET as a new type of stand-alone therapy.

To accomplish the objectives of this study, the paper is structured as follows: In section 2, the methodology of the paper is described, divided in the systematic literature review and the taxonomy development process. In the literature review section (section 3), relevant topics in the research field are identified and analysed, serving as the basis for the taxonomy development in section 4. The results of the taxonomy are discussed in section 5, leading to implications for both research and practice. Finally, the findings are summarized, and the limitations of the study are described in section 6.

2 Methodology

The methodology of this study is guided by the recommendations for conducting systematic literature reviews under consideration of the PRISMA guidelines and for taxonomy development based on Nickerson et al. (2013). The process of the literature and company selection is illustrated in figure 1.

2.1 Systematic Literature Review

The literature search and selection process is based on the PRISMA guidelines for systematic literature reviews and meta-analyses (Moher et al., 2009). Following the guidelines, eligible keywords and information sources were identified and described, the search and study selection process illustrated, and the collected data synthesised by deriving categories of relevant research topic. The objective of the literature search is to identify literature reviews on VRET for anxiety disorders in English and German language. To ensure that the technologies discussed are relevant to today's market, the release date of literature was limited to the last 5 years. These filters were pre-set in the search query for the PubMed database which were identified as eligible for the search process. The search string contained key terms that were preliminary selected based on a pre-screening of relevant literature (search string: VRET OR ("virtual reality" OR VR) AND (phob* OR anxi* OR psychology OR treat* OR therapy OR "mental health")). The initial search resulted in 372 articles. In a first step, the title and abstracts of these articles were read. In this process, only articles were included that were published in peer-reviewed journals or books. In addition, primary studies and articles dealing exclusively with mental disorders other than anxiety disorders were excluded, as well as studies in which VRET is not addressed and articles that were not accessible (criterion LR1). This process led to the exclusion of 351 articles (figure 1). In a second step, the full text of the remaining 21 articles were read and assessed in terms of their suitability for the study. Eight articles were excluded due to insufficient information regarding VRET, VRET intervention and anxiety disorder as well as one article that only contained a list of literature (criterion LR2). Lastly, a back and forward search was conducted which revealed one additional publication that was included in the sample. The remaining 13 studies build the basis for the literature review and the derivation of the first conceptional dimensions and characteristics in section 3.
2.2 Taxonomy

The taxonomy development is conducted in two phases. First, a database with empirical objects is created. The database should contain all market products which offer a treatment of anxiety disorders based on VRET. Second, the taxonomy is developed based on the guidelines of Nickerson et al. (2013).

![Figure 1. Literature and company selection process.](image)

**Database**: In a first step, all VRET products and companies offering VRET products that could be found in scientific publications or newspaper articles were extracted in a preliminary web search. In a second step, the identified companies were searched for in the database Crunchbase, the world’s largest start-up database. All companies, except one (ZeroPhobia), were found in Crunchbase. In a third step, the categories that were assigned to these companies in Crunchbase were listed and all companies in the database extracted which belonged to one of these categories (search string: (“virtual reality” OR “augmented reality”) AND (psychology OR mHealth OR healthcare OR medical)), resulting in 341 entries (figure 1). After the removal of duplicates, 234 companies remained. In a fourth step, the descriptions of the companies were read, and all companies have been excluded that clearly state to not offer VRET as a product (criterion DB1, 170). In a fifth step, the websites of the remaining 64 companies were analysed. 42 of the companies did not offer VRET applications but other VR based products, e.g., virtual simulations for surgery (criterion DB2). Furthermore, thirteen companies (criterion DB3) were removed since they had no website (8), were an affiliated company to one already listed (1), had no content available in English or Germany language (1), too little information about the product (2), or had the VRET product in planning (1). Hence, the final sample includes nine companies. Since three of these companies offer two different products, the database ultimately contains twelve products (table 2).

### Objective Ending Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>All objects / representative sample of objects have been examined</td>
<td>No dimensions or characteristics were merged / split in the last iteration</td>
</tr>
<tr>
<td>No object was split / merged with other objects in the last iteration</td>
<td>Every dimension is unique and not repeated</td>
</tr>
<tr>
<td>At least one object is classified under every characteristic of every dimension</td>
<td>Every characteristic is unique within its dimension</td>
</tr>
<tr>
<td>No new dimensions or characteristics were added in the last iteration</td>
<td>Each cell (combination of characteristics) is unique and not repeated</td>
</tr>
</tbody>
</table>

### Subjective Ending Conditions

<table>
<thead>
<tr>
<th>Condition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concise:</td>
<td>the number of dimensions must be informative without being overwhelming</td>
</tr>
<tr>
<td>Robust:</td>
<td>the dimensions and characteristics must allow a distinction between the empirical objects of interest</td>
</tr>
<tr>
<td>Comprehensive:</td>
<td>all objects within the domain of interest should be classified and all dimensions of the objects in the domain of interest should be identified</td>
</tr>
<tr>
<td>Extendible:</td>
<td>new dimensions and new characteristics of existing dimensions should be easily added to the taxonomy</td>
</tr>
<tr>
<td>Explanatory:</td>
<td>the dimensions and characteristics should be explanatory with respect to the objects</td>
</tr>
</tbody>
</table>

**Table 1.** Ending conditions based on Nickerson et al. (2013).
**Taxonomy:** In a second step, the taxonomy is developed based on the guidelines of Nickerson et al. (2013). The method is iteratively structured and defines the procedure, the necessary steps of the taxonomy development, and the ending conditions in detail. It is particularly suitable for the objective of this study, as it enables both empirical and theoretical findings to be combined. The taxonomy process is divided in three phases: the determination of the meta characteristic, the determination of ending conditions and the development of the taxonomy. The meta-characteristic indicates the point of view under which the data is analysed. All characteristics, which are determined during the taxonomy development should be a logical consequence of the meta-characteristic. The meta-characteristic in this study is “VRET applications for anxiety disorders”. The ending conditions determine when the taxonomy development process is completed. Nickerson et al. (2013) distinguish between objective and subjective ending conditions (table 1). While the objective ending conditions are determined, the subjective ending conditions can be defined individually. However, both objective and subjective ending conditions recommended by Nickerson et al. (2013) are used in the taxonomy development process in section 4. Before the taxonomy is developed, literature on VRET applications is reviewed to derive preliminary dimensions and characteristics for the taxonomy development.

### 3 Literature Review

The 13 studies resulting from the literature selection process in section 2.1 are listed and categorised in relation to their respective topics in figure 2. The topic *definition* refers to the definition of basic terms and concepts regarding VRET while the *adverse effects* can have a negative effect on the usage of the technology and thus can be considered as a *risk* for VRET applications. The *target group* is relevant for the technology in use, the *presence and immersion*, the *chances and risks* and effectiveness of VRET applications. The topics *presence and immersion* are two different constructs but are often used synonymously. Hence, the findings from the studies are summarised in the four categories *technology, presence and immersion, chances and risks, and effectiveness*. The conceptual dimensions and characteristics that originate from the literature review process are illustrated in figure 3.

#### 3.1 Technology

Virtual Reality (VR) can broadly be defined as a way to visualise, manipulate and interact with complex data through computers (Rizzo et al., 2018) in which a more natural form of interaction is possible compared to conventional peripheral devices. VR is not defined or limited by the use of any particular technology but rather a combination of different hardware and software components (Rizzo et al., 2018). In terms of hardware components, specific output devices are required for the visualization of the virtual

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**Authors** | **Topics**
---|---
Botella et al. (2017) | Definition, Effectiveness, Chances, Risks, Technology, Presence, Immersion, Adverse Eff., Target Group
Diemer & Zwanzger (2019) |
Frayman et al. (2017) |
Gillebert (2016) |
Grenier et al. (2015) |
Lindner et al. (2017) |
Maples-Keller et al. (2017) |
Mishkind et al. (2017) |
Oing & Prescott (2018) |
Parsons et al. (2017) |
Rizzo et al. (2018) |
Shiban (2018) |
Wilson & Soranzo (2015) |
environments. A distinction can be made between three presentation media: a flat screen, the Cave Automatic Virtual Environment (CAVE) and Head-Mounted Displays (HMDs). Whether the presentation of three-dimensional content via flat screens can be considered as VR is a matter of controversy in research due to the low immersion. Hence, flat-screen applications are referred to as non-immersive VR (Freeman et al., 2018; Rizzo et al., 2018). An alternative to VR experiences via flat screens is the CAVE. The CAVE is an entire space used for the projection of a virtual environment (Shiban, 2018). In turn, the CAVE is generally more expensive than flat screens and HMDs (Rizzo et al., 2018; Wilson and Soranzo, 2015). A special feature of the CAVE is that it offers enough space for several people to experience the same virtual environment simultaneously (Rizzo et al., 2018). However, the greatest interest in the use of VR in psychotherapy is directed towards HMDs (Freeman et al., 2018). An HMD consists of two screens in a pair of glasses and can generate VR experiences by displaying images on these screens. Thereby, sensors track the user’s movements and update the images in real time according to the changed body position (Shiban, 2018). The different types of HMDs can be distinguished based on their input devices, i.e., PCs, smartphones or game consoles (Parsons et al., 2017), along with stand-alone HMDs. The choice of the input device has decisive consequences for the application design and the target group (Lindner et al., 2017): smartphone-based HMD systems represent the most cost-effective option, but also offer a smaller field of view and fewer possibilities for user interaction than the more expensive PC, stand-alone or game console based systems. Furthermore, it is almost impossible to share the view with smartphone-based HMDs which makes it more difficult to integrate a therapist into the exposure, PC-based hardware does not have these limitations but is more expensive and often difficult to operate by the patients themselves. For the user interaction, it is unclear as to whether a higher level of user input generally leads to a higher effectiveness (Lindner et al., 2017), i.e., a reduction of phobias. It is assumed that the specific disorder is relevant for consideration regarding the user input. Patients who fear heights (acrophobia) should probably be able to get closer to the abyss on their own, whereas patients who fears spiders (arachnophobia) could even be more anxious by the fact that they are not able to move while the spiders are coming towards them; however, it might be helpful to be able to stretch out and touch the spider (Lindner et al., 2017).

### 3.2 Presence and Immersion

The technology in use and the degree of user interaction in the environment have an impact on the presence and immersion that the user witnesses during the VR experience. The terms presence and immersion are often used synonymously but in fact describe completely different concepts. Presence describes the extent to which users can immerse themselves in the computer-generated worlds and transfer their self-perception to the virtual environment (Diemer and Zwanzger, 2019). Immersion, however, is a measure of the hardware components’ value. Accordingly, immersion is a determinant of presence (Diemer and Zwanzger, 2019). Hence, although the immersion contributes to the extent to which users feel integrated in the virtual environment, it is not the only indicator for a high presence. Other factors influencing the degree of presence are the user characteristics, the emotional state of the user and the authenticity of the environment (Gilbert, 2016; Wilson and Soranzo, 2015). While characteristics and emotional state are inherent to the users, the perceived authenticity can be influenced by the designer of the virtual environment. Authenticity is created by expectations and motivation (Gilbert, 2016). Considering expectations, the perceived realism of the environment it not the decisive factor. On the contrary, a well-designed virtual environment can even deliberately exclude certain irrelevant aspects from the real world to avoid disturbances and to highlight objects that are relevant to the expectations. Considering motivation, it is crucial whether the virtual world serves the user’s purpose. The realism of the exposure can even be modulated in favour of therapy (Lindner et al., 2017), to foster the motivation of the target group more strongly. For example, in contrast to exposure in vivo, graduated exposure could start with the exposure to a blue, smiling spider, which does not exist in reality but offers a suitable therapy entry point.
### 3.3 Chances and Risks

Apart from the manipulation of the reality, an exposure in virtuo (in virtuality) offers further chances that cannot be achieved by classical exposure therapy. In comparison to classical exposure therapy, VRET allows to simulate feared situations that are associated with considerable organisational and financial effort in vivo, i.e. flights, and even confront users with conditions that are impossible in reality, i.e. the treatment of the fear of ghosts (Botella et al., 2017). In addition, the privacy of the patients can be better protected in a VRET because it is not performed in public spaces (Grenier et al., 2015). Another advantage is the planning and controlling of the exposure: Due to the computer-generated environment, the frequency and length of the exposure units and the intensity of the phobic stimulus can be determined with a high degree of precision (Wilson and Soranzo, 2015). This is particularly advantageous for patients who reject exposure because they perceive the exposure as too aversive. Patients are safe at any point during the exposure and the stimulus is under complete control by the patients themselves or their therapist (Mishkind et al., 2017). Apart from these advantages, VRET allows to integrate elements of gamification (Lindner et al., 2017). Integrating these elements could lead to an increased willingness to seek the feared situation more often and to continue the treatment. However, it is important that the gamification elements, which can be implemented in the form of levels, points, rewards, and goals, do not distract from the therapeutic goal. Furthermore, the culture, gender and socio-economic status of the target group must be considered in the design to create an effective application. But VRET is not only an alternative to in vivo exposure, but may also be suitable to replace in sensu exposure (Grenier et al., 2015) since it is often difficult, especially for the elderly, to create a thought of an image that is realistic enough to elicit an aversive response. At the same time, the elderly particularly suffer from intangible worries and fears, i.e. fear of disease or losing independence, that cannot be easily addressed in vivo but could be treated with an exposure in virtuo. However, despite these advantages, VRET is liable to risks that VR applications are generally known for. The usage of virtual exposure can lead to cybersickness (Mishkind et al., 2017). The symptoms of cybersickness are like those of seasickness, i.e., nausea, dizziness, malaise, and headaches. The occurrence of the symptoms depends on various factors. Currently, there is no consensus in research on whether a higher immersion leads to more severe symptoms (Wilson and Soranzo, 2015). In addition, the weight of older HMD models can cause neck pain (Oing and Prescott, 2018). Therefore, the potential adverse effects of VRET need to be monitored by the therapist although most of the symptoms ease on its own after the treatment (Grenier et al., 2015).

### 3.4 Effectiveness

Both the chances and risks of VRET have an impact on the effectiveness of the applications. Today, the effectiveness of VRET applications has been confirmed in various randomised controlled trials (Shiban, 2018). The studies show a high effectiveness of VRET in reducing anxiety symptoms in contrast to patients on waiting lists with no treatment and a similar effectiveness in comparison to patients treated with classic exposure therapy (Oing and Prescott, 2018). Most of the studies examine specific phobias, especially aviophobia, acrophobia and arachnophobia. Although less research has been conducted on social phobia and panic disorder, there is evidence that these can likewise be treated effectively in virtuo (Maples-Keller et al., 2017). Solely, studies on VRET for the treatment of generalised anxiety disorder are sparse as it is difficult to implement a standardised scenario that includes the different stimuli of the disease (Maples-Keller et al., 2017). While most studies focus on the effectiveness of VRET in combination with a classical therapy, VRET can be used as stand-alone therapy (Lindner et al., 2017), i.e. between in vivo exposures or as self-management application. Considering the latter, the human therapist is replaced by a virtual therapist in a virtual office who also conducts the psychoeducation prior to the exposures. In addition, this virtual therapy allows to include other actors, e.g., a spider expert who can provide useful information to a patient suffering from arachnophobia. However, this approach is considered as a new form of therapy. While the former approaches use VR as a tool in a rather "classical" exposure therapy setting, i.e. extend the therapy by technology, a therapy with a virtual therapist constitutes an entirely different setting (Botella et al., 2017; Diemer and Zwanzger, 2019). Hence, the effectiveness of this automated form of VRET must be examined separately.
4 Taxonomy Development

As the basis for the taxonomy development, the results from the literature review are synthesised to conceptional dimensions and characteristics (figure 3). The taxonomy is developed in 6 iterations (figure 4), leading to the final taxonomy in figure 5. In every iteration, either the conceptual-to-empirical or the empirical-to-conceptual approach is applied (Nickerson et al., 2013). The conceptual-to-empirical approach consists in the conceptualization of dimensions based on the researcher’s notion about the similarity / dissimilarity of objects without examining the actual objects. In the empirical-to-conceptual approach, an object or a subset of objects is classified by the researcher to identify common characteristics.

4.1 Iterations

For the 1st iteration, the conceptual-to-empirical approach is chosen because an understanding of relevant theoretical aspects already exists due to the previously conducted literature review. Each of the products under consideration uses an HMD as hardware. Input devices for all products are either stand-alone technologies or smartphones. Furthermore, one product could be identified that supports both technologies. Regarding the target customer, the products are either sold to patients or therapeutic institutions. Two products are distributed to both parties. In addition, the dataset contains both empirical objects with concomitant therapy and virtual therapists while one product offers consultation with licensed therapists via telephone or video calls. Furthermore, one product could be identified that is specifically for adolescents. All other products do not indicate that they are targeting a specific age group. Two products are used to treat phobic disorders and generalised anxiety disorders. The other products aim exclusively on patients with phobic disorders. No object could be identified that explicitly states to use gamification. The dimension "exposure scenario" requires a too high level of detail at this point, as there are products that have a multitude of different scenarios in their portfolio. These two dimensions are therefore discarded in the first iteration. A mapping of the exposure scenarios is attempted again at a later stage if necessary. Since new dimensions and characteristics were added, the ending conditions are not met, and a further iteration is required.

For the 2nd iteration, the empirical-to-conceptual approach is chosen. One product is selected from the database which is sold to patients (Invirto) and one product which is sold to therapeutic institutions (OxfordVR). In this way, further possible differences between the two products should be identified. One of the products is used at home while the other is used in a clinic. In addition, one of the products can be used for self-management therapy and the other as an extendable element during a classical therapy. Differences between the two objects also exist regarding access restrictions: one product allows the patients unlimited access while the other one does not provide access anymore after the treatment is completed. The duration of the VRET also varies. One product provides 12 hours, the other 2 hours of therapy on average. Since new dimensions and characteristics were added to the taxonomy, the ending conditions are not met, and a further iteration is required.
### Meta-Characteristic: VRET applications for anxiety disorders

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>age</td>
<td>adolescents</td>
</tr>
<tr>
<td>anxiety disorder</td>
<td>phobia</td>
</tr>
<tr>
<td>input device</td>
<td>SM</td>
</tr>
<tr>
<td>therapist</td>
<td>human present</td>
</tr>
<tr>
<td>target customer</td>
<td>patients</td>
</tr>
<tr>
<td>duration of treatment</td>
<td>2 h</td>
</tr>
<tr>
<td>therapy embedding</td>
<td>independent</td>
</tr>
<tr>
<td>treatment location</td>
<td>home</td>
</tr>
<tr>
<td>access limitations</td>
<td>none</td>
</tr>
</tbody>
</table>

#### Dimension Characteristics

**1st Iteration**
- age: adolescents
- anxiety disorder: phobia
- input device: SM
- therapist: human present
- target customer: patients
- duration of treatment: 2 h
- therapy embedding: independent
- treatment location: home
- access limitations: none

**2nd Iteration**
- age: adolescents
- anxiety disorder: phobia
- input device: SM
- therapist: human present
- target customer: patients
- duration of treatment: 2 h
- therapy embedding: independent
- treatment location: home
- access limitations: none

**3rd Iteration**
- age: adolescents
- anxiety disorder: phobia
- input device: SM
- therapist: human present
- target customer: patients
- duration of treatment: 2 h
- therapy embedding: independent
- treatment location: home
- access limitations: none

**4th Iteration**
- age: adolescents
- anxiety disorder: phobia
- input device: SM
- therapist: human present
- target customer: patients
- duration of treatment: 2 h
- therapy embedding: independent
- treatment location: home
- access limitations: none

**5th Iteration**
- age: adolescents
- anxiety disorder: phobia
- input device: SM
- therapist: human present
- target customer: patients
- duration of treatment: 2 h
- therapy embedding: independent
- treatment location: home
- access limitations: none

---

**Legend:**
- Dimension excluded in the following iteration
- Change dimension / characteristic description in iteration
- New dimension / characteristic in iteration

**Abbreviations:**
- GAD: Generalised Anxiety Disorder
- NLP: Natural Environment Phobia
- AP: Animal Phobia
- SM: Smartphone
- PC: Personal Computer
For the 3\textsuperscript{rd} iteration, the empirical-to-conceptual approach is chosen again with two different applications from the sample. As in the second iteration, one product is selected from the database which is sold to patients (ZeroPhobia) and one product which is sold to therapeutic institutions (Limbix). Apart from access and duration of treatment, products vary in the number of anxiety disorders that can be treated with the application. One product is only tailored to the treatment of a single anxiety disorder (fear of heights) while the other can treat up to eight different anxiety disorders. In addition, one product is prescribed by doctors. Hence, the anxiety disorder must be diagnosed in a clinical sense. The other product is also intended for the treatment of mild symptoms and does not require a prescription. Both products offer a graduated approach for the exposure. In the case of Limbix, the therapist determines the steps of the exposure, whereas ZeroPhobia delegates this decision to the patient. The products also differ in the degree of therapy integration. ZeroPhobia is a complete therapy programme while Limbix is only a tool that can be used in a face-to-face therapy setting. Since new dimensions and characteristics were added to the taxonomy, the ending conditions are not met, and a further iteration is required.

For the 4\textsuperscript{th} iteration, the conceptual-to-empirical approach is chosen to improve the dimensions and characteristics created so far, as it is assumed that there might be dimensions that can be merged. The dimensions "therapy embedding" and "completeness of therapy programme" are to be regarded as identical in terms of content and can be merged to the binary dimension "therapy form" with the characteristics "independent" and "concomitant". Furthermore, some dimensions and characteristics are revised to achieve conceptual clarity. These revisions are validated based on the dataset while all empirical objects are considered. This process revealed that only two of the products contained information about the duration of treatment and the type of graduation. It is therefore not possible to establish meaningful characteristics. In turn, the dimension is removed from the taxonomy. To differentiate between products that are location-independent and those which can only be used in certain facilities, the dimension "treatment location" is extended through the characteristics "therapy centre" and “therapist” which replace the characteristic “therapeutic institution”. The dimension "number of treatable anxiety disorders" has been extended by further empirical data. Since dimensions were combined and renamed, and characteristics added, the ending conditions are not met, and a further iteration is required.

The focus of the 5\textsuperscript{th} iteration is to gain a better understanding of which anxiety disorders can be treated with which products. Since the different existing classes of anxiety disorders are already known, the conceptual-to-empirical approach is chosen. First, the categories of anxiety disorders are separated into the dimensions “specific phobia” and “non-specific disorder” and validated against the entire dataset. The "specific phobia" dimension is too broad, as both number and form of treatable specific phobias can vary greatly between products. The characteristics of the non-specific disorders were extracted from the products in the dataset. Accordingly, the dimensions are adjusted. The examination of the products additionally revealed that some products have a disorder-based focus and others are scenario-based, i.e., some products offer a catalogue of exposure scenarios, each of which suitable for several disorders, while in turn the other products provide exposure to treat a specific disorder. Thus, the focus is added to the taxonomy as dimension. Since new dimensions and characteristics were added to the taxonomy, the ending conditions are not met, and a further iteration is required.

In the 6\textsuperscript{th} iteration, the empirical-to-conceptual approach is chosen to validate whether dimensions have been overlooked in the analysis. For this purpose, all products in the database were reviewed in relation to the dimensions and characteristics in the taxonomy. In this process, no new dimensions and characteristics were added, changed, or removed. The taxonomy appears concise, robust, comprehensive, extendible, and explanatory. Consequently, both the objective and subjective ending conditions (table 1) are met.

### 4.2 Taxonomy

The final taxonomy based on the selected VRET companies (table 2) and the literature review consists of 14 dimensions with two to four characteristics (figure 5). Each object in the database can be assigned
VRET for Anxiety Disorder

<table>
<thead>
<tr>
<th>Company</th>
<th>HQ</th>
<th>Product</th>
<th>Product ID Taxonomy</th>
<th>Accessible / Taxonomy</th>
<th>Exclusion Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curis AI Inc.</td>
<td>US</td>
<td>MyCuris</td>
<td>-</td>
<td>No / No</td>
<td>Insufficient information</td>
</tr>
<tr>
<td>Limbix</td>
<td>US</td>
<td>Limbix VR Kit</td>
<td>P1</td>
<td>Yes / Yes</td>
<td></td>
</tr>
<tr>
<td>Mimerse</td>
<td>SE</td>
<td>Speaking Places</td>
<td>P2</td>
<td>No / Yes</td>
<td>Company active but application currently not available</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(for patients)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Speaking Places</td>
<td>P3</td>
<td>No / Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>(for therapists)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moodru</td>
<td>US</td>
<td>Moodru</td>
<td>-</td>
<td>No / No</td>
<td>No accessible website</td>
</tr>
<tr>
<td>Oxford VR</td>
<td>UK</td>
<td>Fear of Heights</td>
<td>P4</td>
<td>Yes / Yes</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Social Engagement</td>
<td>P5</td>
<td>Yes / Yes</td>
<td></td>
</tr>
<tr>
<td>Psious</td>
<td>ES</td>
<td>Psious</td>
<td>P6</td>
<td>Yes / Yes</td>
<td></td>
</tr>
<tr>
<td>Sympatient</td>
<td>GE</td>
<td>Invirto</td>
<td>P7</td>
<td>Yes / Yes</td>
<td></td>
</tr>
<tr>
<td>Thrive Therapeutic Software</td>
<td>UK</td>
<td>Agoraphobia Free</td>
<td>-</td>
<td>No / No</td>
<td>Company active but do not longer offer VRET products</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arachnophobia Free</td>
<td>-</td>
<td>No / No</td>
<td></td>
</tr>
<tr>
<td>ZeroPhobia</td>
<td>NL</td>
<td>ZeroPhobia</td>
<td>P8</td>
<td>Yes / Yes</td>
<td></td>
</tr>
</tbody>
</table>

The Product ID Taxonomy serves as identifier for Figure 5

Table 2. Selected VRET companies.

to exactly one characteristic for each dimension. The objective of the taxonomy was to identify the differences of VRET products regarding their application scenarios. Accordingly, the taxonomy is not a complete description of individual VRET products. Since the meta-characteristic covers a wide range of topics, subordinate meta-characteristics are introduced. Reviewing the dimensions reveals that the dimensions consider the patients, the specific disorder, information about the therapy design, and the distribution of the products. Accordingly, the subordinate meta-characteristics are patient, disorder, therapy and distribution, and all dimensions were assigned to one of these meta-characteristics.

**Patient:** Only one of the products (Limbix VR Kit) aims at a specific age group (adolescents). All other products do not focus on a specific age group. In addition, there are both products for patients with a clinically diagnosed anxiety disorder only (n=5), and for all patients (n=3).

**Disorder:** The products differ in the number and type of anxiety disorders that can be treated. Most of the products focus on the treatment of social phobia (n=6) while generalised anxiety disorder can only be treated with two products (Psious, Limbix VR Kit). These two products are also the products the most anxiety disorders can be treated with. Furthermore, two products (Oxford VR - Fear of Heights, ZeroPhobia) are only for the treatment of one specific phobia (acrophobia). The Limbix VR Kit includes both situational phobias and injury phobias. Psious also offers treatments for animal and nature phobias. Treatments for panic disorders are supported by four products. Agoraphobia can be treated with three of the products.

**Therapy:** The type of therapy can be distinguished according to whether the product is used as an independent therapy (n = 3) or in combination with a classical therapy (n = 5). Consequently, all companies that offer a treatment of mild symptoms also provide an option for an independent therapy. All products that are used independently require only a smartphone as input device. The products that are used to concomitant a therapy, are based on a stand-alone device or PC. This pattern is also prominent in relation to the therapy location; products that offer independent therapy are used at home or in the private premises while products that concomitant a therapy are used in the medical office of the therapist (n = 3) or in a designated therapy centre (n = 2). Huge Differences occur in the dimension “therapist”. For three products, a human therapist is present in person (n = 2) or via telecommunication (n = 1) and concomitants the virtual exposure while three products rely on an avatar as therapist. Interestingly, the use of an avatar is not limited to independent, but therapy-concomitant products.

**Distribution:** Two of the products are sold directly to patients. In addition, one product is sold simultaneously to patients and therapeutic institutions. All those products can be used independently. In
two of the cases, the access for patients is unlimited. The remaining products (n = 5) cannot be purchased directly by patients but are sold exclusively to therapeutic institutions or registered therapists. The access of the patient is limited in four of those products which are used only in therapeutic facilities. The focus of the products can be scenario-based (n = 2) or disorder-based (n = 6). Scenario-based means that the product comprises a portfolio of different exposure scenarios with which several anxiety disorders can often be treated. For example, the fear of speaking to groups can occur in the context of various anxiety disorders and the corresponding exposure scenario can therefore be used for the treatment of this fear in all patient groups. However, most products offer a programme for treating a particular disorder, which includes different scenarios tailored to the disease. All products for independent usage are disorder-based.

![Product ID Taxonomy Table]

**Figure 5.** Final taxonomy with associated company products.
5 Discussion and Implications

In the discussion, the findings from the literature review and the taxonomy are summarised and compared to emphasise the consensus between theory and empiricism.

First, the use of the specific VR technologies is intensively discussed in the literature (Wilson and Soranzo, 2015). Freeman et al. (2018) emphasise that HMDs are the most prominent and important hardware devices for VRET applications. This is confirmed by empirical evidence. All products in the sample are based on HMD technology. However, there are differences with regard to the input devices. Lindner et al. (2017) stress that the choice of the input device has a significant impact on the application design and the target group. The findings from the taxonomy show that especially products which are intended for independent usage and sold directly to patients, rely on smartphones as input devices. In contrast, products which focus on a concomitant therapy approach in therapy centres or therapist offices mostly use stand-alone HMDs or PCs as input devices. Consequently, VRET applications for independent usage show a lower immersion than concomitant VRET products. Although the relationships between immersion, presence and effectiveness is a matter of controversy in the context of VRET research, immersion is a determinant for presence which in turn influences the user’s perception of anxiety (Diemer and Zwanzger, 2019). Therefore, the VRET products for independent usage face a trade-off between accessibility and quality. However, the current technological developments in relation to HMDs provide chances for VRET companies to overcome this trade-off. Newly published stand-alone HMDs, such as the Oculus Quest, allow for a high immersion at an affordable price and thus may be an interesting alternative for self-management applications.

Second, a major advantage of VRET often discussed in literature is the degree of configurability and the possibility to integrate elements of gamification to increase the motivation for the exposure therapy (Botella et al., 2017; Lindner et al., 2017; Wilson and Soranzo, 2015). The extent to which the applications are individually configurable or whether gamification elements are present in the applications could not be conclusively clarified by the taxonomy. However, all products offer a selection of defined exposure scenarios for the treatment of specific disorders. Accordingly, the applications contain standardised scenarios and do not include exceptional aversive stimuli. Thus, individualised scenarios still require an exposure in vivo. In addition, although the majority of studies consider specific phobias (Maples-Keller et al., 2017), most VRET products do not focus on specific phobia, despite their a high prevalence. One reason may be that the development of an exposure scenario is resource intensive and since a variety of specific phobias exist, a large number of specific scenarios would have to be developed. From an economic point of view, there are consequently less incentives to develop those scenarios, as the customer segment is rather small. Creating holistic virtual environments that can be extended by specific phobias, i.e., an environment for agoraphobia with the possibilities to integrate a variety of animals, may resolve the problem of cost-intensive developments for single case scenarios and allow for an enhanced configurability. Interestingly, although few studies examine the usage of VRET to treat generalised anxiety disorders (Maples-Keller et al., 2017), two products offer generalised anxiety disorders treatment. Literature emphasises that the main issue is the design of standardised scenarios for non-tangible and multiple concerns which are typical for generalised anxiety disorders. The VRET application “Psious” solves this issue by implementing a scenario in which the patients find themselves in "their own" living room, watching a programme on television, i.e., about various diseases such as cancer, high blood pressure and heart attacks. Hence, VRET products encounter currently discussed issues in literature with approaches, that have not been considered in literature, especially in relation to generalised anxiety disorders. Examining these products may lead to further findings regarding the effectiveness of VRET. Apart from these applications and scenarios focusing on in vivo exposures, Grenier et al. (2015) emphasise that VRET can also be an effective alternative to exposure in sensu. This is especially true for the elderly who may have difficulties in creating realistic images of thoughts and often suffer from intangible concerns. However, no product could be identified that is specifically designed for older people. In turn, this may be a promising opportunity for VRET companies.
Third, literature and practice show discrepancies in terms of the addressed severity of the diseases and the patients’ independence in using the application. In the literature, studies on the treatment of anxiety disorders that are not clinical diagnosed is sparse although statistics provide evidence that most people suffering from mild (43.5%) and moderate (33.7%) symptoms (Alegría et al., 2007). In contrast, three products have been identified which allow the treatment of mild symptoms. Offering these products appears to be expedient both from an economic perspective and the personal interests of those affected. Hence, VRET for mild symptoms do not only offer opportunities for VRET companies but an avenue for further research. In the same vein, companies consider the treatment with independent self-management applications, while research on these self-management tools is sparse and the effectiveness of VRET as a stand-alone self-management tool without therapeutic concomitant remains unclear (Botella et al., 2017; Diemer and Zwanzger, 2019; Lindner et al., 2017). However, empiricism provides evidence that most of the currently offered products are not meant for independent usage. The products that are for independent usage, embed automated avatars or telepresence in the therapeutic treatment. For example, ZeroPhobia uses an avatar as therapist to concomitant the therapy and Invirto involves a human therapist in a pre-, intermediate, and post-therapy conversation via telecommunication. All self-management applications are also disorder-focused. Since the user must have a comprehensive understanding on when to select which scenario, this seems reasonable. Hence, while these stand-alone VRET products are considered as a new form of therapy in its own right, research on the effectiveness of this new form of therapy is still in its infancy.

6 Conclusion and Limitations

The objective of this study was to systematise VRET application scenarios based on a systematic literature review and the development of a taxonomy. The results from literature imply that the configurability of VRET applications is one of its major advantages and specific phobias have a high prevalence. However, the configurability of the VRET products could not be conclusively clarified and VRET applications for specific phobia are sparse. Creating holistic virtual environments that can be extended by specific phobias may reduce both costs and resources to allow for such configurable implementations. In addition, theory stresses the possibility of integrating gamification elements to foster the motivation of patients to seek the exposure but none of the current products include these elements which provide market opportunities for VRET companies. Considering the target customer, theory emphasises that there are advantages of VRET scenarios for specific age groups, however only one age-specific application could be identified during the analysis of market products. In addition, the current developments regarding HMD hardware and statistics about the prevalence of anxiety disorders provide opportunities for both research and practice. While current products for independent usage rely on smartphones as input devices, advanced HMDs are now available which allow for a high quality at an affordable price. At the same time, statistics provide evidence that most people suffer from mild and moderate symptoms of anxiety disorders but only few companies consider the treatment of these mild symptoms in their applications while research on the effectiveness of independent VRET applications and VRET for mild symptoms is sparse.

The limitations of the study emerge from the methodological approach due to a high trade-off between the degree of detail and clarity. For example, a detailed description of the products’ scenarios would have been of interest, but every product contained several scenarios, which must either be abstracted or summarised as individual dimensions, leading to strong overlaps of other important aspects. Furthermore, the basis for the product information were the company websites. Thus, only application scenarios could be considered which were explicitly advertised by the provider. Since the market for VRET products is currently rather small and still in its infancy, the taxonomy can only be a cornerstone for the analysis and consideration of VRET products. However, the taxonomy provides a basis for future classification and evaluation of new VRET products, the identification of innovations, and can serve as a blueprint for other VR based therapy settings. The taxonomy can easily be supplemented with additional dimensions and characteristics as the research design expands. Future research may focus on testing and evaluating the products in the taxonomy with patients and therapists.
The efficacy of cognitive

References


