ViTraS - Virtual Reality Therapy by Stimulation of Modulated Body Image - Project Outline

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ABSTRACT

In the recent decades, obesity has become one of the major public health issues and is associated with severe other diseases. Although current multidisciplinary therapy approaches already include behavioral therapy techniques, the oftentimes remaining lack of psychotherapeutic support after surgery leads to relapses and renewed weight gain.

This paper presents an overview of the project **ViTraS** - Virtual Reality Therapy by Stimulation of Modulated Body Image - that addresses these challenges by: (i) Developing an integrative model predicting the influential paths of immersive media for an effective behavioral change; (ii) Developing an augmented reality (AR)-mirror system enabling an effective therapy on body self-perception of patients, and (iii) Developing a multi-user virtual reality (VR)-system supplying social support from therapists and other patients. The three components of the ViTraS projects are briefly introduced, as well as a first VR-based prototype of the mirror system.

CCS CONCEPTS

• **Human-centered computing** → *Virtual reality*; *Mixed / augmented reality*; *User interface design*; • **Applied computing** → *Consumer health*; *Health informatics*; • **Computing methodologies** → *Motion capture*.

KEYWORDS

Virtual Therapy, Obesity Therapy, 4D Body Scanning, Avatar Design

1 INTRODUCTION

In western industrial nations, obesity has developed into a serious disease [18]. In addition to the obvious consequences of extreme overweight, such as damage to the musculoskeletal system, obesity is associated with a large number of severe diseases. As body weight increases (especially above a BMI of 30), so does the risk of fatal disorders such as cardiovascular diseases, diabetes mellitus type 2, strokes, or various types of cancer [1, 13].

Accompanied by physical consequences, patients often show mental disorders [7, 28]. Two main problems are associated with feelings of low self-esteem and being trapped in inactivity: (i) Many patients suffer from a **distorted body image** and consequently a **distorted self-perception** appearing in negative attitudes towards their body and/or a distorted body size estimation (over- or underestimation of the body size). (ii) Since many people consider overweight not as a disease but as self-inflicted, obesity can lead to **social rejection and isolation** and even to bullying in the work context or in everyday life. Due to these problems with self-perception and rejection, many obesity patients tend to isolate themselves and even avoid leaving the house [14].

A number of therapeutic approaches for the treatment of obesity have been pursued in the past. The majority of them target the reduction of weight like in bariatric surgery that reduces the absorption capacity of the stomach. However, the distorted self-perception and self-efficacy as well as social isolation often remain even after weight reduction and can cause rebound effects [25]. To break the circle, for example experiential cognitive therapy (ECT) incorporates virtual reality in cognitive therapy. This method induces behavioral changes by confronting patients with malfunctioning situations in virtual reality, always under the supervision and

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support of the therapist [9, 24]. While Riva and colleagues refrain from including personalized avatars or first-person perspective, research in the field of virtual body ownership shows that the visuomotor coherence with the alter-ego reacts upon self-perception in the real world [12, 16, 17]. Piryankova et al. [21] further demonstrated the importance of personalizing avatars on the accuracy of weight judgments in a group of eating disorder patients.

Even though virtual reality therapy may increase the success of obesity therapy [24], (i) remaining long-term behavioral changes of patients, (ii) the transfer of knowledge on virtual body ownership and avatar design to obesity therapy, and (iii) the facilitation of social contact pose huge challenges to fight with in the therapy of obesity disorders.

This paper presents an overview of the project **ViTraS** - Virtual Reality Therapy by Stimulation of Modulated Body Image - that addresses these challenges. (i) An **integrative model development** includes knowledge from the field of psychology researching on sustainable behavioral changes and effective factors of immersive technology to support behavioral changes. (ii) The development of an **AR-mirror** showing personalized avatars enables an effective therapy on the body perception of patients. (iii) **Networked social VR** environments connect therapists and patients. They enable therapy settings for individuals as well as for groups of geographically distributed participants, hence also fostering inclusion and access to therapy for regions with little supporting infrastructure.

The next section briefly introduces the literature from the field of psychology about models predicting sustainable behavioral changes, and literature about effective factors of immersive technologies on behavioral changes. Then, an overview is given of how the Behavioral Framework of Immersive Technologies (BehaveFIT; Wienrich, Döllinger, and Hein, in prep) includes effective factors from the field of psychology and immersive technology for sustainable behavioral changes (ViTraS Component 1), about the AR and VR therapy demonstrators (ViTraS Components 2 and 3), and about the first prototype of the AR-mirror demonstrator.

2 BACKGROUND

The field of psychology - Models predicting sustainable behavioral changes

Plenty of behavioral models describe key factors impacting on health behavior that facilitate or inhibit behavioral changes (e.g., [3, 6, 23, 26]).

Most of these models distinguish different stages describing mainly the needs and context of a person in the process of a behavioral change (i.e., the pre-decisional stages appearing before the decision to change behavior has been made, the decisional or volitional stages appearing during the planning, and the post-decisional or control stages appearing during or after the execution of behavior). Further, most of the models introduce parameters that can influence the (further) execution of the behavior in the different stages. One main factor across most models and stages is the person's expectation of self-efficacy [6]. In addition, the risk perception (i.e., the perception of being exposed to negative consequences of previous behavior, and the expectation of results), (i.e., the costs and benefits of behavioral change), are important, especially in the early stages of behavioral change [23]. Depending on these factors, the execution and maintenance of a behavioral change can be supported or inhibited.

Applications and limitations of models on obesity patients

Obesity-related behavioral therapy is often carried out after successful bariatric intervention. The patients are therefore already motivated to change their behavior and may already have concrete action plans or have already started to implement this behavior. In some patients, the above-mentioned distortion of body self-perception becomes apparent in an underestimation of the actual overweight [33] leading to an underestimation of their own risk. Hence, with regard to behavioral models, an adjustment of risk perception [26] could help to initiate the behavioral change. On the other hand, many patients have a negative affect towards their body (body image). Thus, already achieved weight reductions and physical changes are either not perceived or graded as marginal [24, 25]. In these cases, personalized feedback of the weight development (reinforcement) during treatment might help to regain a positive body image and more accurate body perception [22].

Another factor among the barriers and resources of the behavioral models is the social feedback or social support of the patients [26]. As already mentioned, social isolation is important for the well-being of obesity patients [14]. Hence, with regard to behavioral models, social support and the increase of social interaction might impact the aimed behavioral change.

However, the application of many factors in the real world is limited. Risk and consequences can be demonstrated on depersonalized examples (e.g., pictures of other patients), a realistic and personalized feedback documentation throughout the therapy process is complex, and relevant others or a therapist for social support are often not available. As a consequence, the volition to change behavior is endogenous, but the gap to a real sustainable change of behavior remains often too large [27]. Accordingly, the ViTraS project incorporates effective properties of immersive technologies to support an effective application of the psychological factors.

Effective factors of immersive technology to support behavioral changes

Past research identified at least five properties of immersive technology that can support patients in the execution of behavioral changes: The dimensions of the sense of embodiment, the self-representation, the representation of the situational context, the possibility of enhanced sensory ability presentation as well as the controlled presentation of other persons/avatars/virtual representations.

The perception and impact of self-representation, of the alter ego, substantially depends on the sense of embodiment (i.e., the acceptance of the virtual representation as part of oneself [11]). The sense of embodiment determines to what extent a person has the feeling to be located in a virtual environment (sense of self location), to own a body (sense of body ownership), and to have the possibility to act and interact in the virtual environment (sense of agency). The visuomotor coherence to the avatar and the personalization of the avatars are essential factors to ensure the sense of embodiment [35].

The design of one's own avatar can also have a great influence on the behavior within the virtual experience and even beyond it [38]. Attractiveness and height [38], age/body size [5] and ethnicity [19] have been shown to have an influence on how a person behaves towards other people in and outside the virtual environment. In the field of body weight, adjusted weight of an avatar can result in a change in the assessment of one's own body weight [15, 31].

In addition, the high level of controllability of virtual environments facilitates the manipulation of the situational context or social situations, i.e. the presence and reaction of others within the environment [4]. Hence, the important social support can be allocated by virtual environments.

Even though empirical results indicate the efficiency of those factors on behavioral changes, the description remains phenomenological. As a consequence, precise predictions on the interrelations between VR-factors and psychological factors in different stages of the behavioral change process are limited. Accordingly, the ViTraS project associates effective properties of immersive technologies with factors identified by the behavioral models.

3 VITRAS COMPONENT 1: BEHAVEFIT

The BehaveFIT model aims to explain the influence of avatar and (virtual) environmental properties on human behavior patterns and habits. It is intended to support the development of AR/VR supported therapy concepts.

In order to explain the psychological mechanisms underlying the immersive therapy system, we developed a first attempt for a holistic behavioral model, which combines components of common behavioral models and integrates influencing factors resulting from the interaction with immersive media. An overview of the model is given in Figure 1.

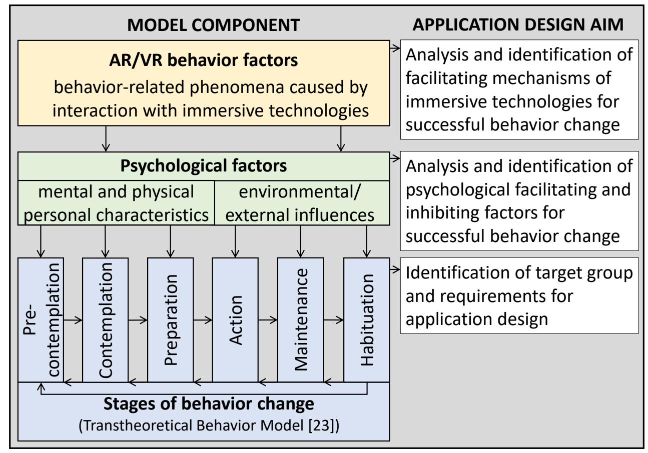

Figure 1: Short overview of the BehaveFIT model: From immersive technologies to behavior stages.

The model is mainly based on work from health psychology (c.f., [8, 23, 26]) and research regarding immersive technologies including knowledge about the sense of embodiment [11, 35], the proteus effect [38] or the effect of virtual social situations [4]. BehaveFIT adapts the idea of stages describing mainly the needs and context of a person in the process of a behavioral change (based on the model of [23], 1, blue area). With the help of the stages, the target group and corresponding requirements for the application design can be identified. Further, the model lists psychological factors that impact on behavioral change. The factors are divided into external influences like social norms or environmental constraints on the one side, and mental (e.g., body image), or physical (e.g., sex) internal characteristics on the other side (green area, based on [8]). The specific definition of these factors is especially important for the success of the respective application/therapy. Finally, the model contains the behavior-related characteristics of immersive technologies including for example embodied self-representation and manipulation, the representation and manipulation of the social context or other persons (or agents), providing additional sensory feedback (yellow area).

The present model allows for concrete influence paths between immersive factors on behavioral changes, mediated by important psychological factors in different stages of the behavioral change process. The definition of the connection between immersive factors and psychological mechanisms requires a precise analysis of the behavior and the respective population. ViTraS addresses the population of obesity patients, analyzes and evaluates concrete influencing paths for the impact of the AR-mirror system (ViTraS Component 2), and the multi-user VR-application on therapy success.

4 VITRAS COMPONENTS 2 AND 3: IMMERSIVE OBESITY THERAPY SYSTEMS

Due to the versatile possibilities of avatar illustration, immersive technologies offer a wide range of opportunities in this area. One important issue that we address in ViTraS is the embodied self-representation in order to correct the body image and self-perception of obesity patients.

ViTraS Component 2: AR-mirror system for body image treatment

The AR-mirror system supports obesity patients in developing a positive body image and a realistic self-perception. The AR-mirror supplies a personalized, photorealistic and modifiable avatar of each patients revealing health consequences or therapy goals. Further, the system involves multimodal interaction with the own avatar facilitating cognitive-emotional effects. The concept is visualized in Figure 2.

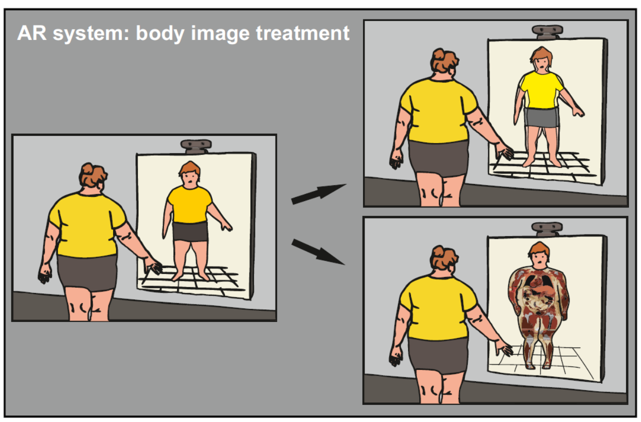

Figure 2: Body-image treatment using systematic real-time reshaping of one's avatar

In analogy to the findings of various studies on body image (e.g., [20]) and body size estimation (e.g., [21, 22, 31] in virtual reality, the self-perception of the patient will be adjusted by modifying the physical dimensions of the avatar (i.e., the degree of overweight). Thus, for example, an initial underestimation of the patient's own weight and a resulting possible underestimation of the risk of developing secondary diseases can be corrected by enlarging the virtual self-representation. In another use case, the progress of an already achieved weight loss could be visualized, and in order to strengthen the patient's motivation and self-efficacy expectation during weight loss. Further applications are planned but not further explained in the present paper.

ViTraS Component 3: Multi-user VR-application for social support

In the additionally planned VR real-time remote system, the possibility of social exchange between patients will be supported. Real-time communication with others provides patients with social support and the opportunity to overcome their social isolation in a safe and controllable environment. It is possible to provide the patient with a self-chosen, anonymized, a photorealistic, or a modified-photorealistic avatar. On the one hand, this is intended to make it possible to decouple one's own appearance from the ability to communicate with other people in order to strengthen self-esteem in social situations. On the other hand, it enables patients to gradually approach communication in the physical world and experience social support. The concept is visualized in Figure 3.

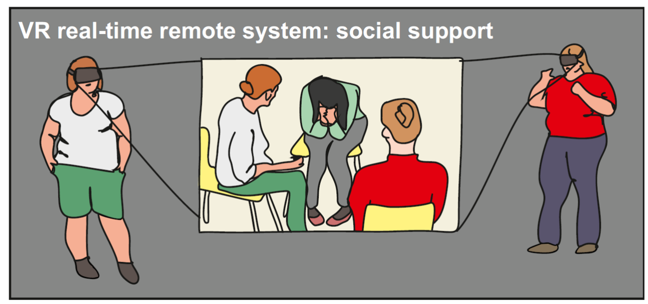

Figure 3: Remote multimodal multi-user social system for real-time communication with other patients

5 OUTLINE OF THE FIRST AR-MIRROR PROTOTYPE

The appearance of the AR system imitates that of a real mirror and accurately integrates the digital avatar into the real space. However, the first prototype of the AR-mirror system was compiled in VR to establish the development process of the embodied self-representation. It is based on the findings of earlier research work of the project partners [2, 12, 16, 35–37].

Avatar Generation

As photorealistic and personalized virtual representations promoting various factors that are for embodiment [35], we use a novel pipeline for fast generation of photorealistic virtual humans [2]. The pipeline is able to create ready-to-animate virtual humans in a duration of less than ten minutes. The user first stands in a huge circular camera rig on which 106 DSLR cameras are mounted. In order to start the scanning process, all cameras are triggered synchronously to capture pictures from different perspectives. A dense textured point cloud is automatically generated from these images and a fully rigged generic human template model is then fitted onto the point cloud. After the personalized model generation is finished, a high-quality texture is built out of model geometry, the corresponding texture layout, and the pictures. Finally, the complete model is exported in a cross-compatible file format.

Motion Tracking

A convincing virtual mirror requires an accurate, robust, and rapid motion tracking of the participants pose represented by an abstract skeleton [37]. For this reason, we rely on the tracking system Captury Live of our project partner The Captury [32] which was developed in an academic context and has since been successively improved [29]. The system allows for a natural, markerless real-time body tracking only by the use of an array of RGB high-speed cameras. The tracked positions and orientations of the skeleton's joints are streamed via VRPN [30] into the virtual environment implementing application to map it on the skeleton of the photorealistic representation of the tracked person's body.

Visualization

In the first VR-based prototype users can see their realistic self-representation in the virtual mirror and interact with it multimodally. We used the modern 3D real-time interactive system development platform Unity 2018.2.10f1 [34] to create a high definition scene which represents a pleasant context-related environment. We placed a virtual mirror into the scene which enables users to observe and interact with their photorealistic virtual self-presentation. The streamed body tracking data is used to animate the users' avatars in real-time. To visualize the whole scene for the user, we use the room-scale virtual reality setup HTC Vive Pro [10]. Figure 4 shows an exemplary use case of the developed prototype in which a participant interacts with an overweight virtual representation of himself.

In sum, the prototype demonstrates the combination of our optimized photogrammetric 3D scanning process, animation, and visualization of individualized avatars.

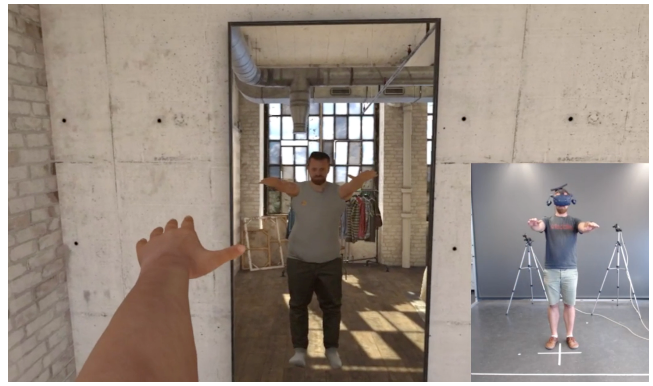

Figure 4: A screenshot of the VR prototype which shows an normal weighted person fully body tracked in comparison to its overweight virtual representation within the virtual environment. The right arm is hidden by the photo excerpt.

6 CONCLUSION

Obesity is associated with severe diseases. Although current multidisciplinary therapy approaches already include behavioural therapy techniques, the oftentimes remaining lack of psychotherapeutic support after surgery leads to relapses and renewed weight gain. This paper presents an outline of an immersive obesity therapy system which can be used as a supplement to classical behavioural therapy. Two important contributing factors to the success of obesity therapy are addressed: (i) The development of a positive body-image via the self-representation in space and (ii) bridging social insecurities via avatar-based remote communication with other patients. A first prototype was developed that confronts the user with a VR-mirror providing either a photorealistic and an overweight reflection. The therapy system is based on an integrative behavioural model (BehaveFIT) that links effective implication of psychological models explaining facilitating and inhibiting factors of behavioral change and the effects occurring during the interaction with immersive technologies on behavioural mechanisms.

The next project steps include the user-centered development and elaboration of the two therapy concepts as well as the expansion of the current prototype for the respective applications. In addition, a validation of the behavioural model and the testing of specific impact processes is planned.

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