https://doi.org/10.25819/ubsi/2944

Combining the Virtual Reality with Biofeedback – State of Research in Nutrition

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Abstract. The digitalization of the health care system promises to improve care through the use of technologies that work with virtual reality (VR). In the field of nutrition research, various settings have taken place. But the research designs known so far were not supported by physiological values. Based on this gap and to structure current and future scientific work in this field I conduct a literature review. A selection of known biofeedback systems will be presented and checked whether they appear at all in the literature in connection with nutrition and VR. Results: The fact that only six papers have shown a sufficient relationship could be used to identify a deficiency. I conclude that VR-related technologies seem to be a promising approach that is worth theoretical and empirical research with increasing physiological parameters to improve nutritional behavior.

Keywords: Virtual Reality, Nutritional Behavior, Literature Review, Biofeedback and Physiological Parameter

1 Introduction

Haven't we all wondered whether we eat healthily? And even if you have a healthy diet, each of us has our cheat days. Be it at a birthday party, a big event, or a TV evening on the couch. We probably all reach too often for fast food, soft drinks, and sweeter than we realize. Especially in times of the corona crisis, when we stay at home as much as possible, I notice for myself that bad routines creep. The frequency of purchase reduced. Food that lasts longer ends up in the shopping trolleys and not necessarily the healthy alternatives. Hamster shopping for canned food, convenience food, and pasta is particularly prevalent in Germany but also all over the world. But even the delivery services are more popular than ever. Who doesn't like to order the pizza or pasta to the door during this time and hopes to support the local gastronomy financially. The incidence of nutrition-associated, non-communicable diseases such as cardiovascular diseases, diabetes mellitus type 2, and cancer is increasing worldwide. The dangers of a weight gain are particularly severe at the moment, as physical activities are limited. Both gyms and sports clubs are closed during the crisis. Psychological factors also play an essential role during this period. How can we arrange a regulated everyday life, which possibilities of employment are possible, how can we prevent possible anxiety states or even depression due to isolation but also maintain simple things like self-discipline and motivation for a healthy lifestyle?

In times of the Corona crisis, digital technologies are in demand as never before. Many different digital technologies are already used for the home office, for social life, and entertainment. Video conferencing is part of everyday working life. Why can't we use these technologies to improve other areas in life? For example, use innovative technologies to lose weight or watch our weight. TV formats such as The Biggest Loser have been using new techniques such as holography or modulable 3D graphics for years. They show candidates what you do to yourself and your body with the heavy overweight and what you could look like with ideal weight. In 2016, 39% of women and 39% of men aged 18 and over were overweight (WHO, 2017). But what about research. Are new technologies also being used here to address the global health problem of obesity?

This article examines a technology that promises both knowledge transfer and physical activity and has shown initial success in treating anxiety and motivational changes. But so far, it is not yet integrated into our daily life. We are talking about Virtual Reality (VR). Which researches are existing Virtual Reality in combination with nutrition and which biophysical parameters are recorded to show the influence on the body? Part of the papers is a literature review in which the VR technology has validated concerning behavioral changes or effects on physiological body properties. So the combination of VR on nutrition and biofeedback signals is scholarly in the literature databases of EBSCO, PubMed, WebofScience, and AIS and Google scholar. Six papers could be integrated into the study. These would be examined for the following factors,

- design
- biofeedback systems
- outcome-oriented
- construct
- effectiveness

The overall research question is included (RQ): Are physiological parameters recorded, using the virtual reality when it comes to diet-related motivation/therapy?

2 Theoretical Background

2.1 Virtual reality Technologie

VR applications place the user in a simulated, 3D environment. Head-mounted displays (HMDs) or VR glasses, such as Oculus Rift or HTC Vive, are used for this purpose, which shows videos and images in 3D format with an integrated screen (like a gym, or a mall). The image sections adapt to the eye and head movements of the user and, in combination with motion sensors, enable the exploration of 3D worlds. The additional use of controllers empowers the user to actively interact with objects in a virtual environment (Anthes et al., 2016). Possible applications for VR range from video games to traveling to places, education, and health applications.

Recent studies show that the concept of cognitive absorption plays a central role in the development of a learning process, such as a change in diet, through information technologies (Ehrsson et al., 2007; Reychav & Wu, 2015). The feeling of having a body in the VR environment (body ownership) is a fundamental aspect of self-confidence (Ehrsson et al., 2007). E.g., escape from your own obese body and adopt an ideal physique. The concepts of agency, i.e., the feeling of being voluntarily in control of one's actions, and body ownership, i.e., perceiving the virtual body as one's own (Slater & Sanchez-Vives, 2016). could be necessary for the nutritional sciences.

2.2 Virtual reality in nutrition

Virtual technologies are already part of current research in the healthcare sector. They are used in the treatment of anxiety disorders, stress, and pain management but also in nutritional behavior (e.g., obesity) (Riva et al., 2016). VR has recently been explored from different perspectives in the field of food consumption studies. For example, the aim of virtual

technologies in eating disorders is to analyze behavior and motivate people to choose the right food and reduce the desire to eat (Gutiérrez-Maldonado et al., 2016). The relationship between external eating habits and food cravings during exposure to VR environments has been investigated, showing that VR cues have been shown to alter emotional, cognitive, and behavioral responses (Ferrer-Garcia et al., 2015). VR technologies offer the advantage that the interaction with one's own body is carried out in the virtual environment and thus has a positive effect on immersion (immersion) (Slater & Sanchez-Vives, 2016). But to what extent is the possibility of immersion used in the field of nutritional science and dietetics. Or in the therapy of obese people and to what extent is this supported by physiological measurement methods.

2.3 Biofeedback

Any learning process that causes a physical reaction can be called biofeedback. For example, if you burn your tongue over a hot drink, you feel a pain that triggers a learning process. Biofeedback devices work similarly, only less painful. Different body functions can be recorded with systems (e.g., heart rate, muscle activity, brain activity) to show the physiological state, changes, and to document the clinical effects of therapy. It shows, for example, what influence the physical condition has on the recovery process (interaction of body and mind). Since there is optical feedback, these systems can also be used to influence bodily functions. Biofeedback systems can be used mainly in the area of stress, and a subsequently supervised meditation, but also in training and conscious tensing of different muscles. In the case of nutrition, the skin conductivity and stress level is decisive, as well as the need for an unhealthy diet, but also the different brain regions. Like emotionally, the different foods are connected to the test persons. (Haus et al., 2016; Lang & Lang, 2007)

Here is a short overview of my experience of different feedback systems which has led me to the topic:

- HRV Monitors: Measures pulse and heart rate variability, measurement on fingers, or earlobes. Often use in lactate test.
- Electrocardiogram (ECG): Measurement of heart rhythm mostly by sensors or chest straps.
- Electroencephalography (EEG): Measurement of brain activity by voltage changes on the head surface (hood). You can use EEG, for example, to burst a balloon by making a nail rotate with your thoughts.
- Electromyography (EMG): Measurement of muscle activity through action currents. The voltage between the two electrodes is measured. I have attached them to the upper and lower leg to measure the muscle contraction in different phases of standing up.
- Skin conductivity (SCR) Measurement of the electrical conductivity of the skin.

The measurement of skin conductivity, in particular, reflects the degree of psychological or physiological arousal triggered by cognition or emotions. The more sweat produced, the higher the current flow. And could play a more prominent role in the following papers.

3 Research Methode

I conducted a literature review of Virtual Reality Technologies (VR) research and practice in nutritional science, including biofeedback. The literature search and screening was done by the author only. A mapping review and a scoping review was used as a methodological foundation (Grant and Booth 2009). The databases on both the information society and medical research have been integrated to ensure that as many relevant articles as possible are reviewed. As the records in these databases (EBSCO, PubMed, AIS, and web of science) were small, an additional search in Google Scholar was performed. Here 1357 results were found, which were identified in a scoping review process to 51 relevant papers.

As the first database, the medical database PubMed was searched. In combination with the term Virtual Reality (VR) and Biofeedback system and conjunction with four essential measurements of the EEG of the EDA, the EMG and HVR 720 titles are found. Since for further research, the measurements in the field of nutrition are of particular interest and not the test for anxiety, sleep disorders, or balance or reactions, and the search was narrowed down in the second step. It would be further searched at PubMed with synonyms for nutrition (nutrition, food diet). Here are nine more articles displayed. These will be included in the further search. The same search query was made in EBSCO (2 hits) and I WebofScience (3 papers). In the AIS database, you can only find articles if you use the search terms in a limited way and make a combination of VR and biofeedback or nutrition. But there are also only two hits. Of the 16 articles found, 2 were duplicates. Due to the small number of hits, a search with biofeedback and virtual reality and nutrition were carried out at google Scholar. 2700 hits were found here. After reviewing the hits of the last ten years (from 2010), 1900 results remained. After excluding patents and quotations, 1410 results remain. By viewing the titles, 46 relevant titles were included, which are related to nutritional situations and biofeedback and VR after seeing the abstracts. Also excluded are items that do not include VR and do not have nutrition as a source or as Nutrition Science. Included are only papers, books, and journal articles in German and English language. Besides, titles that describe an overview of the points of interest after reviewing the abstract are included. Many items could already be excluded after viewing the title and the short description at google, so only 51 hits were taken further. After screening the abstracts, only 12 articles were included in the entire reading process because many reports did not stand the combination. In most cases, nutrition was only given as a source or as a condition or behavior of the research, or reality is a term for a temporal or local reference. After reading the paper, six papers were included in further analysis, which had a study design .

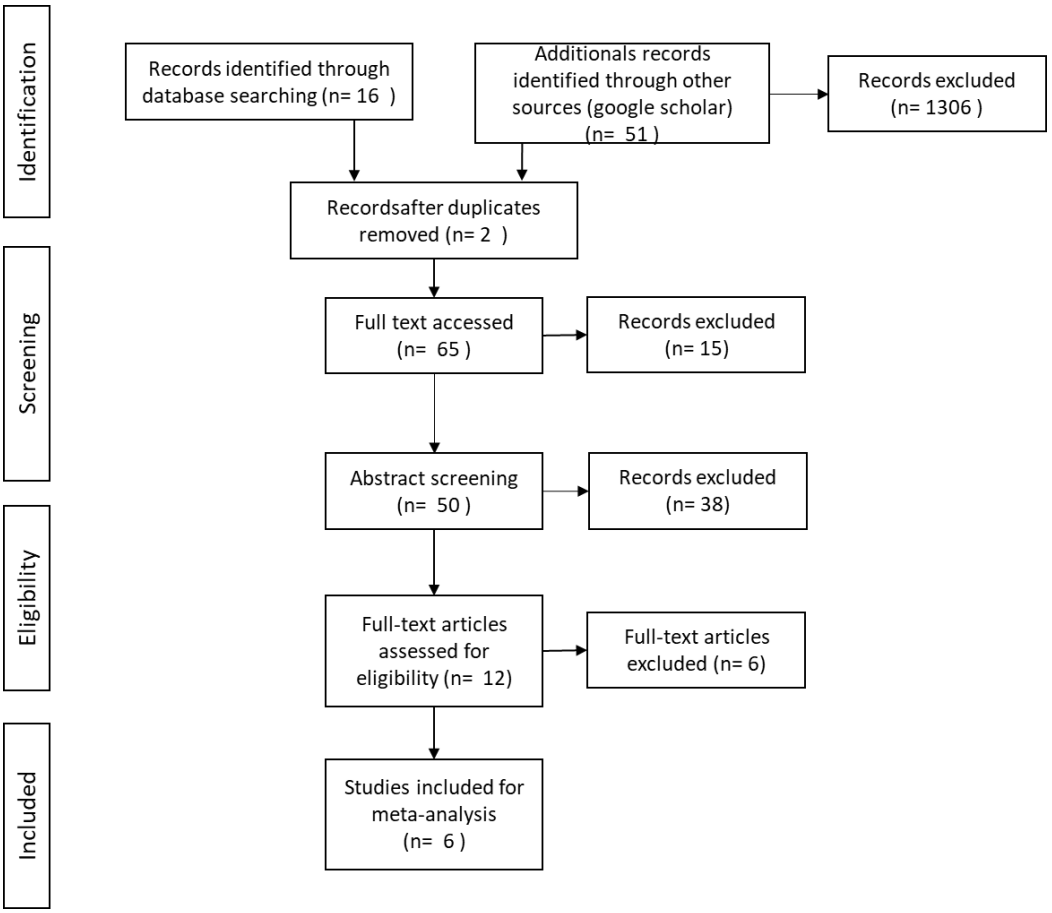

Figure 1. Flow diagram

4 Findings

After reading the Full Paper, six papers have been excluded. On the one hand, three literature reviews examine the topics of the treatment in von obesity and the virtual world (Ferrer-Garcia et al., 2013; Riva, 2011; Riva et al., 2019). These have been counter-read, and the used papers have been viewed again via a reverse-value search. Since they have no outcome themselves, they are excluded. Also, a complete book describing a general overview on the topic of nutrition in VR has been omitted. Individual results cannot be presented (Serino et al., 2016). Looking at Broderick's paper, it turns out that smoking was the issue. The smoking topic is still interesting to mention because the chosen scenario for smoking can also be found on eating behavior, according to Broderick. Here, the measurement of the biofeedback signal via SCR was successful. Since the study had already taken place in 2005, the technology was not yet fully developed, and there were interference frequency limits and movement peaks in the signal.

Nevertheless, he says that the ability to collect valid and reliable physiological data in VRstudies is warranted (Bordnick et al., 2005). The following table shows the included papers. These are further explained in the discussion if relevant

Author, year	**Title**	**Design included (n)**	**Biofeed-back-system**	**outcome-oriented**	**construct**	**effectiveness**
Pennanen et al. (2020)	Effect of virtual eating environment on consumers' evaluations of healthy and unhealthy snacks	Subject-intern experiment n=67	EEG and HVR	Healthy/unhealthy snacks in three conditions, Emotional reaction	/	VR increases eating experience and healthy food choices
Bordnick et al. (2011)	What virtual reality research in addictions can tell us about the future of obesity assessment and treatment	Case study, Future research	HVR, SCR	Abuse, drug, and alcohol	behavior	scientific gains and knowledge using VR approaches in eating addictions, to help explore new dimensions
Ledoux et al. (2013)	Using virtual reality to study food cravings	experimental study n=60	Salivation	Food craving (FC); helthy woman	/	increase FCs making diet compliance more difficult.
Lee and Shin (2013)	Effectiveness of virtual reality using video gaming technology in elderly adults with diabetes mellitus	RCT n=55	Balance, muscle strength, gait, and falls efficacy	Diabetes Mellitus and the risk of falling	/	Useful in the risk of fall for diabetes mellitus
McBride et al. (2013)	Effects of providing personalized feedback of child's obesity risk on mothers' food choices using a	RCT n=221,	Genetic-risk feedback, BMI, Family health history (FHH),	genetic and environmental risk of becoming obese. ordering in at a Virtual restaurant buffet	behavior	The risk of childhood obesity decreases when the inherited risk is communicated to mothers

	virtual reality buffet					
Sgobbi et al. (2017)	The use of sensors in virtual worlds for obesity control	Case study n=4	Motion sensor (movement)	Obesity Virtual gym and additional information	Self-determination, Present, Internet of things	Potential of increase motivation, increase the number of steps

Table 1. Combined studies with VR and Biofeedback in the field of nutrition

5 Discussion

If you take a closer look at the articles found, only very few researchers are working in this field. e.g., Riva looks at nutrition from different positions in connection with food, but not with biofeedback systems. In one of his Reviews, Riva describes how to touse the Allocentric lock theory and negative body image and that it could reduce the rate of unhealthy weight-control behavior (Riva, 2011).

Chiefly the study conducted by Pennanen shows the enormous potential of a combination of the virtual world and biofeedback and nutrition. In an experiment within the subject, virtual reality technology was used under three conditions. The emotional response to the virtual eating environment was tested and correlated with consumer desires, preferences, and hedonic ratings of healthy and unhealthy snacks. In summary, virtual reality technologies could have the potential to support the eating experience and healthy food choices by improving product evaluation. In this context, the results of EEG and heart rate measurements suggest that the consumption of a healthy snack generates more cognitive processing than an unhealthy snack. It could reduce the impact of the virtual eating environment on consumer ratings.

Strictly speaking, the study of McBride et al. (2013) does not have biofeedback in the classical sense. Still, I decided to include this study because it is an excellent example of how the virtual world with biological (here genetic) factors has a positive influence on behavior. They show that when overweight mothers order in a virtual restaurant less if they are aware of the risk of genetic inheritance. (behavioral-risk information plus personal FHH-based risk assessment)

Several included studies have little or no objective, namely the analysis of physical, nutritional behavior in the VR environment. One example is the study of Lee, who is taking care of diabetic Mellitus, which is a nutritional disease, but leaves it out and takes care of balance and gait. She also misses a deposited construct.

In general, I have expected that several studies have already dealt with nutritional behavior to strengthen the investigations. For example, by recording stress levels or heart rates. There is a huge opportunity to develop the work of researchers further and to enhance the evidence with validatable parameters that can be used in clinical practice.

6 Conclusion and Outlook

The results primarily provide an overview of existing research in the field of VR-related technology in nutrition research with validation by biofeedback systems. It shows that there is research in the field of virtual technology in combination with either nutrition or biofeedback systems but rarely a combination. Theoretical constructs from a technology point of view are not found in any of the included papers; however, if psychological theories are used to put them into a broader framework, further research is needed. Thus, a lack of theoretical foundations for a synergetic approach of medically practical technical support is noted but found separate theoretical foundations in research to build on future work.

Overall, VR-related technologies appear to be a promising and dynamic approach to improve the possibilities and effectiveness of nutrition therapy. The review shows a gap for further research. Research gap of combined VR with biofeedback, especially in the area of nutrition.

The limitations of the paper are that a single author wrote this article and that the literature search was conducted from only one perspective.

For my future work, relevant motivational approaches from the health psychological HAPA approach will be integrated for the first time in such a VR and AR environment by training implementation and coping intentions as well as motivational self-regulation strategies to ensure greater success in changing behavior and maintaining success in the long term (e.g., (Ressing et al., 2020)

The recording of physiological values should be standardization in VR research in the health sector so that VR can be recognized in clinical practices and thus, prevention and therapy. Coming back to the research question, it is not yet possible to establish a link between nutritional (motivational) factors, VR, and biofeedback systems.

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