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FARE—Food Augmented Reality Exposure.

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Introduction

Anxiety and fear responses play a central role in the development and maintenance of eating disorders (EDs). Up to two-thirds of individuals with EDs report a lifetime anxiety disorder [1], demonstrating significant comorbidity between these conditions. Research indicates that anxiety around eating and food avoidance are prototypical features of EDs, with intense fears related to weight gain, loss of control, and body image driving restrictive and compensatory behaviors [2]. This anxiety-driven model suggests that ED behaviors often occur at times of high anxiety and serve to reduce this distress through avoidance or escape responses.

Given the crucial role of anxiety in EDs, a promising intervention is exposure therapy, which involves confronting feared stimuli in the absence of feared consequences, and is well-established as an effective treatment for anxiety disorders. When applied to EDs, exposure therapy aims to reduce food-related anxiety and avoidance through repeated encounters with feared foods and eating contexts.

The theoretical understanding of how exposure therapy works has evolved significantly over time. Initially, exposure interventions were believed to operate through habituation, where repeated exposure to a feared stimulus (conditioned stimulus, e.g., a food) without the feared outcome (unconditioned stimulus, e.g., anxiety) would weaken their association. Under this model, early exposure-based treatments for EDs focused primarily on preventing fear responses through exposure and response prevention, such as having patients consume feared foods (e.g., high-calorie foods) while preventing compensatory behaviors.

However, contemporary models of exposure therapy have shifted toward an inhibitory learning framework [3]. Rather than weakening the original fear association, this model suggests that exposure therapy works by creating a new, competing learning experience where the feared stimulus is associated with safety. This framework emphasizes the importance of expectancy violation and developing tolerance for uncomfortable emotions, rather than simply reducing fear responses. While this updated theoretical approach has enhanced exposure therapy for anxiety disorders, its application to EDs remains largely unexplored, suggesting an important opportunity to optimize exposure-based interventions for this population [3].

The Value of AR in Food Exposure

Even if food exposure can be a promising treatment approach for EDs, implementing in-vivo food exposure can be challenging in clinical settings due to practical limitations.

Virtual reality (VR) technology has emerged as an innovative solution to deliver food exposure therapy in a controlled and accessible manner [4]. VR environments allow patients to engage with feared food stimuli while maintaining standardized exposure conditions across individuals. Additionally, VR enables the manipulation of specific variables during exposure and real-time measurement of behavioral responses like food-related gaze patterns and approach behaviors. Furthermore, VR can be used to implement positive mood strategies for enhancing inhibitory learning of food-related anxiety. In particular, it can be used to introduce positive presences (e.g., a pet) that can be helpful in overcoming food anxiety [5].

While VR, thanks to the possibility of creating synthetic reproductions of any environment, can be extremely flexible in giving the illusion of seeing the virtual food in a possible context without the need of being physically there, augmented reality (AR) presents complementary advantages [6].

First, AR does not require neither to create a set of synthetic environments nor to strive for making them as realistic as possible, because the application directly leverages the real-world as its environment. The cost of the 3D modeling effort in building the system is thus significantly reduced because it can concentrate only on the realism of the food, which is the only element of the experience that remains virtual.

Second, the fact that the patient can experience the AR food in the physical world increases ecological validity, because it makes it possible to carry out exposure protocols in the actual contexts where the patient experiences symptoms triggered by food exposure. In VR, it would be economically unsustainable to create ad-hoc environments for each patient, especially if they have to be high-fidelity photorealistic reproductions of the specific patient’s real contexts. Unlike AR, VR can thus provide only a contextual representation that is abstract and noticeably different from the patient’s real, familiar and problematic context.

Third, carrying out food exposure through AR can make training and learning more effective than the abstract VR environments, because the training is situated in the patient’s physical context. According to situated learning theory, learning is most effective when it occurs in the same context in which it will be applied [7]. Moreover, while abilities learned in a VR training are not guaranteed to transfer to the real world, abilities gained through AR in the real environment can be more reliable.

Fourth, the full experience of seeing food superimposed onto real contexts can be provided also through mobile devices (a smartphone or tablet) that the patient already owns. This makes food exposure protocols conveniently accessible to almost anyone, while using devices as headsets in most cases would require to lend the headset to the patient or to have the patient purchase the device. Moreover, using the patient's own devices increases ease of use because the patient is already familiar with them.

Compared to a mobile device, using an AR headset adds the advantage of keeping both patient's hands free and also removing the display and its frame from patient's view and awareness, maximizing the illusion of seeing the virtual food as actually present in the real world. The main reason why research did not consider this possibility so far was due to the high cost of AR headsets which were typically manufactured by companies working in niche markets. The recent release of low-cost headsets with quality AR capabilities for the consumer market (e.g., the Meta Quest 3) is a game-changer that enables building AR food exposure applications at costs that do not surpass those of VR applications and can be even lower for the previously described reasons.

Food exposure in AR is also of interest in non-clinical areas. A relevant example is provided by marketing, in which AR food is of interest both to academia for research purposes and to industry for enhancing the customer experience and influence consumers [8].

The Project FARE

The FARE (Food Augmented Reality Exposure) Project represents a strategic collaboration between two leading research centers: the Human-Computer Interaction (HCI) Laboratory at the University of Udine, Italy, and the Humane Technology Laboratory at Università Cattolica del Sacro Cuore in Milan, Italy. The HCI Laboratory at Udine has successfully spun off AVIETRA (www.avietra.com), a company specializing in virtual reality solutions for health and safety applications.

The FARE system implements food exposure therapy through AR, directly addressing the theoretical and practical advantages outlined before. The system comprises two key phases:

1. Assessment Phase: Patients interact with virtual food items through an AR headset. Patients can grab the virtual food with their hands and manipulate it to observe it from different viewpoints. They can also bring it closer to their mouth as if they were eating it. When ready, patients rate both anxiety and craving levels on a 1-5 scale. This quantitative approach enables systematic measurement of behavioral responses, similar to what Pallavicini et al. [6] considered in their exploratory AR study with obese patients.
2. Personalized Exposure Phase: Drawing from patient-specific anxiety and craving ratings, the system creates customized exposure sessions focused on trigger foods. This aligns with contemporary inhibitory learning frameworks described in the introduction, where exposure therapy aims to create new, competing learning experiences rather than simple habituation.

A video demonstration of the system can be watched at https://youtu.be/PumK-9O5Ens. Future developments of FARE will include the options of displaying virtual pets and/or virtual humans in the second phase. These two virtual elements are meant to respectively induce a positive mood and provide social support, as proposed in the VR system by Natali et al. [5]. However, thanks to AR, patients using the FARE system will benefit from virtual pets and virtual humans in their real kitchens and homes. Moreover, while the virtual human in Natali et al. spoke by simply following a preset script, the project FARE plans to design a conversational virtual human powered by a Large Language Model.

Conclusions

The FARE system provides a model for translating exposure therapy research into a clinic-ready AR intervention that leverages both the technological benefits of virtual content and the ecological validity of real environments.

As explained by Dr. Chiara Rossi, clinician and psychotherapist, “Given that integrating simulative technologies with evidence-based treatments for eating disorders leads to significantly improved outcomes, implementing AR food exposure protocols like FARE may help make evidence-based care more accessible and cost-effective. The use of AR, compared to VR, allows exposure therapy to occur directly in patients' real environments where symptoms typically manifest, potentially increasing ecological validity and skills transfer. We believe that implementing AR exposure in clinical settings may increase patients’ engagement by making them able to experience the exposures in their actual living spaces. A patient's experience of success within AR - seeing and interacting with virtual food in their real kitchen or dining room - may enhance self-efficacy more directly than VR, as the skills are practiced in the exact contexts where they'll be applied.”

In this view, a comprehensive study of AR food exposure in real-world clinical settings represents a promising direction for advancing ED interventions. Continued research should focus on developing standardized AR protocols that can accelerate the implementation of technology-enhanced treatments from research into real-world clinical practice.

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