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Effects of Exposing Patients With Anorexia Nervosa to a Virtual Reality Kitchen Environment

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Abstract

Anorexia nervosa (AN) is characterised by severe caloric restriction, fear of weight gain, and a distorted body image. Typically, patients associate food and eating with feared negative consequences. Exposure therapy (ET) is aimed at reducing the fear response towards a phobic stimulus, and might hold potential in reducing food-related anxiety and avoidance in AN. The current pilot study aimed to explore the feasibility and impact on food-related anxiety of a virtual reality (VR) food exposure intervention (VRET) in AN.

Thirty-six female patients with AN receiving intensive treatment for their eating disorder, i.e., day care, took part in the study. Participants were randomised to an experimental group (virtual kitchen condition) or a control group (virtual nature condition). Participants were exposed to one condition or the other for five consecutive days (each session lasted approximately 5 minutes).

The first aim was to assess the feasibility of the VR intervention by measuring the dropout rate of participants from the VR intervention and the feeling of discomfort and presence experienced by participants immediately after VR exposure. In addition, spontaneous comments of participants after the VR exposure were collected. The second aim was to test the impact of the VR intervention over time (before vs after the VR intervention) on anxiety towards eating (anxiety when thinking about the next meal, NMA, and anxiety as measured immediately before consuming a standardised meal at the day hospital, PMA) and towards food pictures (anxiety towards foods, FA, and wanting of foods as a measure of avoidance, FW). The third aim was to test whether these measures of eating and food anxiety (NMA, PMA, FA, FW) changed over time (before vs after the VR intervention) when compared between conditions (kitchen vs nature).

The data collected showed a good feasibility of the study, as the dropout rate was low, the sense of presence medium-high, and the feeling of discomfort medium-low. Both sense of presence and feeling of discomfort were higher in the kitchen condition. Anxiety towards eating and towards specific foods did not differ over time nor between the two VR conditions. Given the importance to device effective treatments for AN, future research could further explore feasibility and impact of the current intervention by increasing the number of participants and by delivering the intervention after the weight restoration phase of AN treatment is completed, when patients have more control over eating and could therefore be less prone to develop and reinforce food aversion.

Introduction

Study Background and Rationale

Anorexia Nervosa (AN) is a debilitating disease characterised by extreme calorie reduction, fear of gaining weight, and a distorted body image (American Psychiatric Association, 2013). Mortality among patients with AN is five times higher than in the general population and only one third of patients with AN recover after nine years, highlighting the necessity to devise effective treatments for AN (Eddy et al., 2017; van Eeden et al., 2021). Although current treatments for AN, including CBT-AN and MANTRA, show some effectiveness, a large proportion of patients that start a treatment do not complete it or do not recover from AN (Fairburn et al., 2003; Mountford et al., 2021). It is therefore essential to explore new treatments for AN.

Recent research has investigated the similarities between EDs and anxiety disorders (Strober, 2004). Anxiety disorders, and in particular specific phobias, are characterised by the association of a fear response to a neutral stimulus. To reduce the anxiety deriving from this association, patients often avoid the stimulus (avoidance) and engage in behaviours aimed at neutralising or reducing their anxiety (safety behaviours). In anxiety disorders, exposure therapy (ET) is one of the most effective techniques to reduce the association between phobic stimulus and feared outcome (Schaumberg et al., 2021). According to the principles of the inhibitory learning model, and in particular of expectancy violation, ET should be structured to create a gap between the feared and actual outcome of the patient (Craske et al., 2014). In AN, food is hypothesised to become a phobic stimulus (Strober, 2004) associated with feared outcomes such as weight gain and loss of control. Therefore, ET is being investigated as a technique to reduce the anxiety associated to food, and therefore the avoidance and ritualistic behaviours that AN patients engage with food; that eventually lead to the severe undernourishment that is characteristic of the disorder (Schaumberg et al., 2021).

Study Outline

In this pilot study, we aimed to investigate the feasibility of a one-week virtual reality (VR) ET (VRET) intervention by measuring the dropout rate from the intervention; the sense of presence and the feeling of discomfort reported by participants immediately after the VR exposure; and by recording spontaneous comments of participants after exposure. In addition, we aimed to measure the impact of the VRET intervention on four measures of eating and food-related anxiety. Anxiety towards eating was measured by asking patients to report their anxiety levels when thinking about the next meal (Next Meal Anxiety, NMA) and immediately before eating a standardised meal at the day care centre where they received

intensive treatment (Pre-Meal Anxiety, PMA). Food-related anxiety was measured by asking participants to rate their levels of anxiety (Food Anxiety, FA) and their levels of avoidance (measured as Food Wanting, FW) towards food pictures. We aimed to test differences on these outcome measures across time (before vs after the one-week VR intervention) and across VR condition (experimental vs control VR exposure conditions). Participants were females with AN recruited in day hospital structures in Italy. Our choice of participants aimed at selecting a group as homogeneous as possible (all in semi residential intensive treatment, AN diagnosis only) to reduce the number of variables at play. In addition, it could be useful to device an additional form of treatment in the phase of weight restoration, that is particularly challenging and critical in the recovery of AN patients (Olmsted et al., 2010).

We used a virtual reality (VR) setting where participants were immersed in a virtual kitchen and asked to handle virtual foods (experimental group) or in a virtual nature environment (control group). VR was used for two main reasons. First, to maximise the gap between the feared stimulus (food) and feared outcome (weight), according to the principles of expectancy violation (Craske et al., 2014). In addition, it would be important to explore the feasibility of VRET interventions to eventually encourage their application. Although VR is currently expensive and therefore limited to specific clinical or research context, future technical developments could extend its use to wider therapeutic settings or to self-delivered interventions: this could increase the frequency and variability of exposure sessions, and therefore their effectiveness (Craske et al., 2014; Freeman et al., 2018; Grochowska et al., 2019).

Thesis Outline

This thesis started by introducing the topics focus of the study. Chapter 1 explores eating disorders and their treatment, highlighting how new forms of treatments should be devised to improve patients' recovery rates. Among eating disorders, Chapter 1 focusses on anorexia nervosa, that is the disorder object of this study. Chapter 2 draws the relationship between eating disorders and anxiety disorders, illustrating how both presents impairment in the mechanisms of implicit learning and fear conditioning. Chapter 2 continues by discussing exposure therapy as an appropriate treatment for both anxiety and eating disorders. Chapter 3 introduces virtual reality as an instrument to improve exposure therapy, in terms of facility of delivery and of effectiveness. In addition, Chapter 3 presents the current studies investigating the use of virtual reality exposure therapy in eating disorders and anorexia nervosa.

Chapter 4 draws on the previous chapters to present the current gap in the literature and to justify the current study. Chapter 4 ends with a presentation of the research question

and of the aims of the study. Chapter 5 describes in detail the methodologies and materials used in the study, together with an outline of the procedure of the intervention investigated and of the statistical analysis used. Chapter 6 presents the results of the research, in terms of the descriptive data aimed at characterising our sample and of the inferential data aimed at addressing our research aims. Finally, Chapter 7 is dedicated to the discussion of the data collected. The chapter opens with a summary of the aims and of the results of the study and continues with a detailed analysis of how our data are placed in the wider literature, how our results can be explained, and how the study can be improved. Future directions for the research in the field are also offered. Chapter 7 ends with a short set of conclusions that summarise the current study and describe its role in the current panorama of research on the use of virtual reality exposure therapy with patients with anorexia nervosa.

Contribution of the Author in the Study

During my internship in the day hospital of the Centro Regionale per i Disturbi del Comportamento Alimentare, Azienda Ospedaliera di Padova (September 2023 – February 2024), I run the one-week VR intervention within the first two weeks of new patients entering the structure and collected the data. For my data analysis and for this thesis, I was authorised to also use data collected in other structures and by other people before me.

Chapter 1 – Eating Disorders and Anorexia Nervosa

Characterisation of Eating Disorders

Eating disorders (ED) are psychiatric disorders characterised by an "over-evaluation of eating, shape and weight and their control" (Fairburn et al., 2003, p. 522). Assessment of people with suspected ED should consider a range of factors, including rapid loss of weight; change in eating behaviours; fixation with weight and/or body shape; avoidance of social circumstances (mostly those involving food); physical signs of undernourishment; medical symptoms such as endocrine or menstrual alterations, abdominal pain, or hypoglycaemia; associated mental health disorders including depression, obsessive compulsive disorders (OCDs), and anxiety; and whether they are part of environments highly associated to EDs, such as professional sport and fashion (NICE, 2020). Body weight is usually assessed using the Body Mass Index (BMI), which is calculated by dividing the weight in kilograms by the square of height in meters (American Psychiatric Association, 2013). Since EDs can pose serious risks to physical health, electrolyte balance and ECG should be checked in some circumstances, including the rapid loss of weight (NICE, 2020).

Data on EDs is extremely variable depending on several aspects including the sample examined, the measurement tools used, and the nation investigated (van Eeden et al., 2021). The lifetime prevalence of all EDs is estimated to be 8.4% in the female population and 2.2% in the male population (Galmiche et al., 2019; van Eeden et al., 2021). The quality of life is significantly reduced in patients with ED, with more than three million healthy life years lost worldwide every year and a mortality rate that is five times higher compared to the general population (van Eeden et al., 2021; van Hoeken & Hoek, 2020). Patients with EDs often avoid seeking help, partially because of a denial of the condition or because of the stigma around it; with important consequences on the possibility to quantify and treat EDs (van Eeden et al., 2021).

EDs include Anorexia Nervosa (AN), Bulimia Nervosa (BN), Binge Eating Disorder (BED), avoidant-restrictive food intake disorder (ARFID), and Other Specified Feeding and Eating Disorders (OSFED). ARFID involves the avoidance of food that often leads to malnourishment, but without body image disturbances nor fear of weight gain; OSFED, on the other hand, are EDs that do reach clinical severity without meeting the specific criteria for AN, BN, or BED (American Psychiatric Association, 2013). It is common for patients to experience more than one in their lifetime, which highlights the commonalities among the different EDs (Fairburn et al., 2003).

Anorexia Nervosa

Anorexia nervosa (AN) is characterised by an extreme fear of gaining weight and a distorted body image that result in a severe restriction of caloric intake even at a very low weight. BMI is used as a specifier to assess severity of AN, going from mild (BMI ≥ 17), to moderate (BMI between 16 and 16.9), severe (BMI between 15 and 15.9), and extreme (BMI < 15) (American Psychiatric Association, 2013). Underweight itself leads to biological changes ("starvation syndrome") that exacerbate some of the psychological symptoms of AN, impair neurocognition, and reduce the effectiveness of treatment (Fairburn et al., 2003; Schaumberg et al., 2021; Steinglass & Walsh, 2006). The DSM-5 has identified two subtypes of AN: *binge-eating/purging* and *restricting-type*, depending on whether patients engage or not, respectively, in binge-eating/purging behaviours. According to recent transdiagnostic models of EDs, the two subtypes have common underlying mechanisms, also shared with BN, as schematically illustrated in Figure 1 (Fairburn et al., 2003).

Patients with AN often engage in a series of ritualised behaviours that they apply to food and eating and that contribute to prevent a sufficient caloric intake, such as dividing foods into "safe" and "unsafe," eating at a specific pace, always having some food left in the plate, consuming foods in a specific order (Steinglass & Walsh, 2006). Some patients with AN have personality traits such as perfectionism, obsessive personality, harm avoidance, reduced novelty seeking, and cognitive rigidity; suffer core low-esteem and interpersonal difficulties; and have difficulties in the processing and expression of emotions (Fairburn et al., 2003; Oldershaw et al., 2019; Steinglass & Walsh, 2006; Strober, 2004). These traits are present before the onset of the disorder, make it more likely to occur, and are worsened by starvation; creating a vicious circle for the development and maintenance of AN, and making recovery more difficult (Steinglass & Walsh, 2006).

AN is the psychiatric disorder with the highest mortality rate (Chesney et al., 2014). The lifetime prevalence of AN has been estimated to be between 0.1-3.6% in females and between 0-0.3% in males (Galmiche et al., 2019). The incidence of AN was found to be stable in the last 10 years, although some studies suggest an upward trend (Martínez-González et al., 2020; van Eeden et al., 2021). The average age of onset of AN is 15 years old for females, although the onset age might be decreasing (van Eeden et al., 2021). The onset age in males is similar, although data are less certain in this regard (van Eeden et al., 2021). This is an age when the brain goes through a dramatic development, and therefore a lack of nutrients can have important effects in the short and long term (Currin & Schmidt, 2005). For

this reason, and the other potential adverse effects on physical health, early intervention is particularly essential in the treatment of AN.

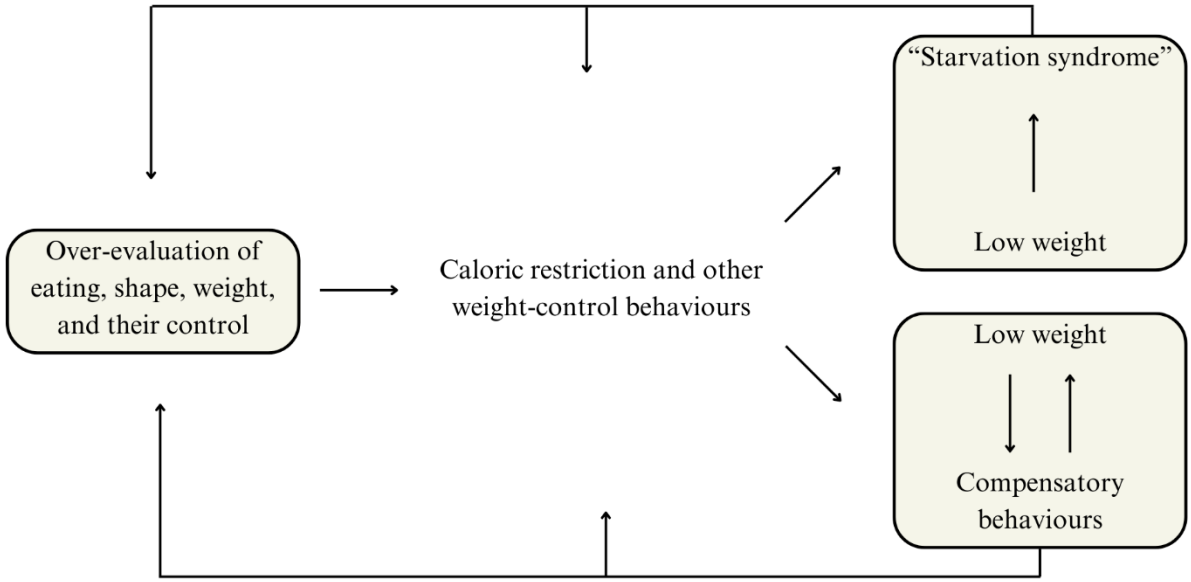


Figure 1

Schematic Maintaining Mechanisms of Anorexia Nervosa.

The top part of the figure depicts the restricting subtype of anorexia nervosa, the bottom part depicts the binge eating/purging subtype. Adapted from Fairburn et al. (2003).

Bulimia Nervosa

According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5), bulimia nervosa (BN) is a disorder characterised by binge eating and compensatory behaviours that occur at least once a week for three months (American Psychiatric Association, 2013). Binge eating episodes are defined by the large amount of food eaten in a discrete amount of time and by a sensation of control loss while eating. Compensatory behaviours, on the other hand, are conducts aimed at weight loss such as vomiting, using laxatives and diuretics, fasting, and excessive exercise (American Psychiatric Association, 2013). The lifetime prevalence of BN has been estimated to be between 0.3-4.6% in females and between 0.1-1.3% in males (Galmiche et al., 2019). The peak incidence of BN is between 15 and 29 years, with an increasing trend in the general population (van Eeden et al., 2021).

According to one conceptualisation of BN, the disorder is maintained by a distorted evaluation of self-worth, that is extremely self-critical and mostly focussed on body weight, body shape, and eating habits; this focus leads to a restriction in food intake and to the

compensatory behaviours (Fairburn et al., 2003). The episodes of binging, on the other hand, can be explained by the severe dietary restriction that BN patients undertake. When BN patients happen to break one of the extreme rules they have devised about eating, they interpret this as a loss of self-control, which acts as a trigger to temporarily abandon their restrictive eating habits. Since the binge itself is then interpreted as a major loss of self-control, it is followed by further extreme restrictions, which will lead to a vicious circle of more episodes of binging and more severe restriction (Fairburn et al., 2003). Furthermore, binges occur more frequently in correspondence with changes in mood, and in particular with adverse mood states. Since binges are also used to modulate extreme moods, they are further reinforced. BN patients often believe that compensatory behaviours will minimise the effect of binging, and therefore are less motivated to stop the episodes of uncontrolled eating. In addition to this main mechanism, four further, broader maintaining factors are theorised to be present in some patients with BN: extreme perfectionism, low self-esteem, difficulty to deal with intense mood states, and interpersonal difficulties (Fairburn et al., 2003).

Binge Eating Disorder

Binge eating disorder (BED) is characterised by episodes of binge eating that occur at least once a week for at least three months and that cause high levels of distress. The episodes of binging, unlike in BN, are not associated with compensatory behaviours; therefore, BED is highly associated with obesity (American Psychiatric Association, 2013; Hutson et al., 2018). Unlike BN and AN, dysregulated eating in BED is hypothesised to be less linked to the need of controlling body weight and body shape and more associated to impulsivity; attention bias towards food; and impairment in self-control, mood regulation, and reward processing (Hutson et al., 2018). The lifetime prevalence of BED has been estimated to be between 0.6-5.8% in females and between 0.3-2.0% in males, making BED the most prevalent ED (Galmiche et al., 2019; Hutson et al., 2018).

Treatment of Eating Disorders

Treatment of AN

Given the risks that it poses to physical health, the first step for the treatment of AN is medical stabilisation and weight restoration (NICE, 2020). Acute medical care should be put in place if patients present severe signs of malnourishment, electrolyte imbalance, and/or dehydration. Acute treatment can occur in semi-residential or residential structures, where the choice is determined by the state of health of the patient, the need to monitor their medical parameters, and the level of support that the family can provide (NICE, 2020). The goals of inpatient treatments are mainly the stabilisation of medical conditions, weight restoration,

stopping weight-control behaviours, and a multimodal therapeutic exploration of issues underlying the disease (Olmsted et al., 2010). The specific modalities of treatment can vary in the different structures, and usually involve specific requirements about attendance and length of stay of patients, a weekly schedule of activities, and follow the principle of graded task assignment (the gradual transition from easier tasks with a low level of difficult to a higher level of difficulty with less support).

Inpatient treatments are usually the first step of a recovery path that will then focus on maintaining the behavioural changes obtained and continuing to work on the overvaluation of food, eating, weight, and body shape (Olmsted et al., 2010). Eating-disorder-focused cognitive behavioural therapy (CBT-ED) and Maudsley Anorexia Nervosa Treatment for Adults (MANTRA) are two of the psychotherapeutic interventions recommended for AN (NICE, 2020). CBT-ED is the most used manualised psychotherapy for adults with AN (Frostad & Bentz, 2022). It usually consists of 40 weekly sessions (biweekly in the first few weeks) (NICE, 2020). Through psychoeducation about the disorder and nutrition, cognitive restructuration, improvement of social skills, and emotion regulation, CBT-ED aims to promote healthy eating, the achievement of a weight appropriate for the age and height range, and the prevention of relapse. Between therapy sessions, CBT-ED encourages self-monitoring of food behaviours and associated thoughts and emotions, together with homework to put in practice what was learned during sessions (NICE, 2020).

MANTRA is a cognitive-interpersonal model and consists of 20-40 weekly sessions. It is based on the four factors that, according to Schmidt, Wade, and Treasure (2014), maintain the disorder: a rigid and perfectionistic information-processing style, distorted socioemotional processing, the belief that the AN pathology has a role in patients' life (pro-AN beliefs), and the high expressed emotivity and/or accommodation of the disorder put in place by others. Undernourishment is both a consequence and a maintenance factor of these four premises. Therefore, in addition to tackling the concerns about weight and body shape and delivering psychoeducation about healthy eating and the risk of malnourishment, MANTRA addresses underlying issues such as a negative self-perception, interpersonal difficulties, and the development of a "non-anorexic" identity. To achieve that, MANTRA uses the support of a workbook divided in different modules that are linked by an encouragement to self-compassion.

For younger patients, the anorexia-nervosa-focused family therapy for children and young people (FT-AN) is recommended by NICE guidelines (2020). FT-AN consists of 20 sessions spread out over a longer period of time (up to one year) and highlights the role of the

family in helping the patient to recover. The family/carers of the patient can be present in the sessions. The second phase of the treatment aims to support the patient to reach some level of independence in the handling of AN before ending the treatment. If FT-AN is not appropriate or effective, NICE (2020) recommends CBT-ED, with the participation of family/carers to some of the sessions.

Treatment of Bulimia Nervosa and Binge Eating Disorder

For the treatment of BN in adults, NICE guidelines (2020) recommend bulimia nervosa-focused guided self-help programme. Patients are given self-help materials and receive 4-9 short 20-minute sessions aimed at supporting patients to follow the program. If the self-help programme is not appropriate or effective, BN patients can be offered cognitive-behavioural therapy (CBT) for adults with bulimia nervosa (CBT-BN), which focuses on psychoeducation about healthy and regular eating, recognising triggers for the binges, self-monitoring eating behaviours, and addressing concurrent issues with body image (Fairburn et al., 2003; NICE, 2020). BED patients are offered a similar treatment, with a binge-eating-disorder-focused guided self-help programme first and CBT-ED for adults with BED if the first has proven not appropriate or effective. In addition, BED patients can also be offered group CBT-ED sessions, which follow a program similar to individual CBT-ED. While children and young adults with BED are offered the same treatment as adults, children and young adults with BN are recommended bulimia-nervosa-focused family therapy (FT-BN), centred on the role of the family to support the patient with recovery. All psychological treatments for BN and BED are not directly aimed at losing weight (NICE, 2020).

Efficacy of the Treatments for Eating Disorders

All the interventions discussed above have showed evidence of efficacy in the treatment of EDs. Treatment in semi-residential or residential settings proved effective to increase BMI of patients, reduce their ED psychopathology and bulimic symptoms (Olmsted et al., 2010). CBT-BN was shown to be more effective than pharmacotherapy and a number of other treatments (Fairburn et al., 2003; Monteleone et al., 2022; Wilson et al., 2002). MANTRA and CBT-ED have been proved effective in promoting an increase in BMI, reducing ED psychopathology (Mountford et al., 2021). For younger people with AN and BN, family-based treatments have given the most favourable results, with 30-50% of the patients reaching their target weight goal at the end of the treatment and mostly maintaining it after four years (Le Grange et al., 2014; Lock, 2015; Monteleone et al., 2022). Effectiveness of interventions involving families was also shown in young adults with AN (Monteleone et al., 2022).

Despite their wide use and effectiveness in the treatment of EDs, these interventions show important limitations. Semi-residential and residential treatment have a dropout rate ranging from 13 to 51%, lower for semi-residential and higher for residential intervention (Olmsted et al., 2010). In addition, although very effective in the short-term, an average of 30% of AN inpatients relapse, with a higher risk in the first year after treatment (Olmsted et al., 2010). The high relapse rates suggest that the treatment in semi-residential or residential settings does not always generalise to the outer environment once the patient leaves the structure (Steinglass et al., 2011; Wilson et al., 2007).

The rate of remission for both MANTRA and CBT-ED are between 20 and 60%; more than half of the treated BN and BED patients still engage with binging behaviours at the end of the treatment; and just more than half of ED patients that start a treatment also complete it (Fairburn et al., 2003; Mountford et al., 2021). In particular, studies on the efficacy of CBT have shown mixed results, suggesting that its focus on the cognitive aspects of the disorder—namely, addressing the exaggerated concern of patients with weight and body shape—might not be sufficient to treat AN (McIntosh et al., 2005; Pike et al., 2003; Steinglass et al., 2011). A recent meta-analysis by Monteleone et al. (2022) showed how most individual psychotherapies (e.g. CBT-ED, MANTRA) where no more effective than treatment as usual in adult patients with AN. To confirm the limited effectiveness of current treatments for EDs, only two thirds of patients with BN had recovered at a 9-year follow up, while less than one third of patients with AN had recovered after the same amount of time (Eddy et al., 2017).

It is therefore essential to investigate new treatments to address more effectively the needs of individual patients, and possibly to target other aspects of the EDs that have been overlooked by current treatments. Recent research has highlighted overlaps between the psychopathology of EDs and anxiety disorders, rooted in abnormalities in the process of "fear learning" in both disorders (Strober, 2004). In addition to adding elements to the characterisation of EDs, the growing body of research linking anxiety disorders, EDs, and AN points to the possibility to target anxiety in the treatment of EDs and AN. Exposure therapy is one of the most effective treatments for anxiety disorders, based on the principles of fear learning and conditioning. Investigation of the adaptation of exposure therapy to EDs could therefore add an important contribution to their treatment.

Chapter 2 – Exposure Therapy for the Treatment of Eating Disorders

Fear Learning and Conditioning

Exposure therapy is rooted in the principles of implicit learning—a learning process that occurs outside awareness—and in particular of "classical conditioning." According to classical conditioning, an aversive stimulus (unconditioned stimulus, US) elicits an aversive response (unconditioned response, UR). Repeated pairing of a neutral stimulus (conditional stimulus, CS) to an aversive US causes the neutral CS to elicit an anticipatory fear response (conditional response, CR) (Figure 2) (Schaumberg et al., 2021). As a consequence, presentation of the CS alone will activate anxiety and fear responses. Importantly, classical conditioning and implicit learning lead to the development of patterns that occur outside awareness, and that will often continue regardless of the outcome (Steinglass & Walsh, 2006). Two of the possible outcomes of the CS-US association are avoidance of the CS and the use of safety behaviours/signals, actions or stimuli that are perceived to reduce or eliminate the likelihood that the US will occur (Murray et al., 2016). Avoidance and safety behaviours lead to a relief from anxiety and fear in the short term, without addressing directly the aversive association. Instead, a vicious circle of anxiety and avoidance is established that is at the root of some anxiety disorders including specific phobias (Schaumberg et al., 2021).

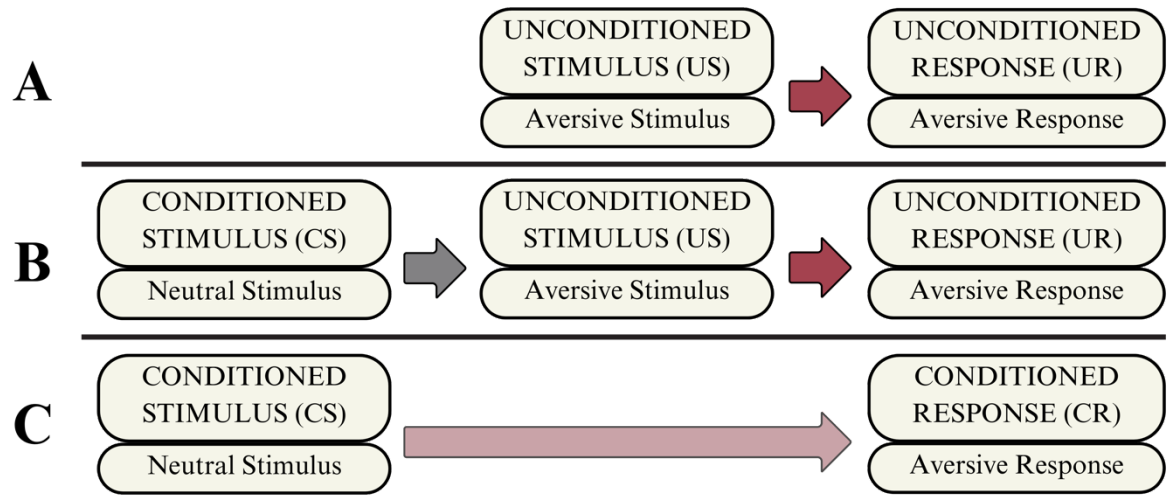


Figure 2

Schematic Representation of Classical Conditioning in Fear Learning.

Exposure Therapy to Contrast Fear Associations

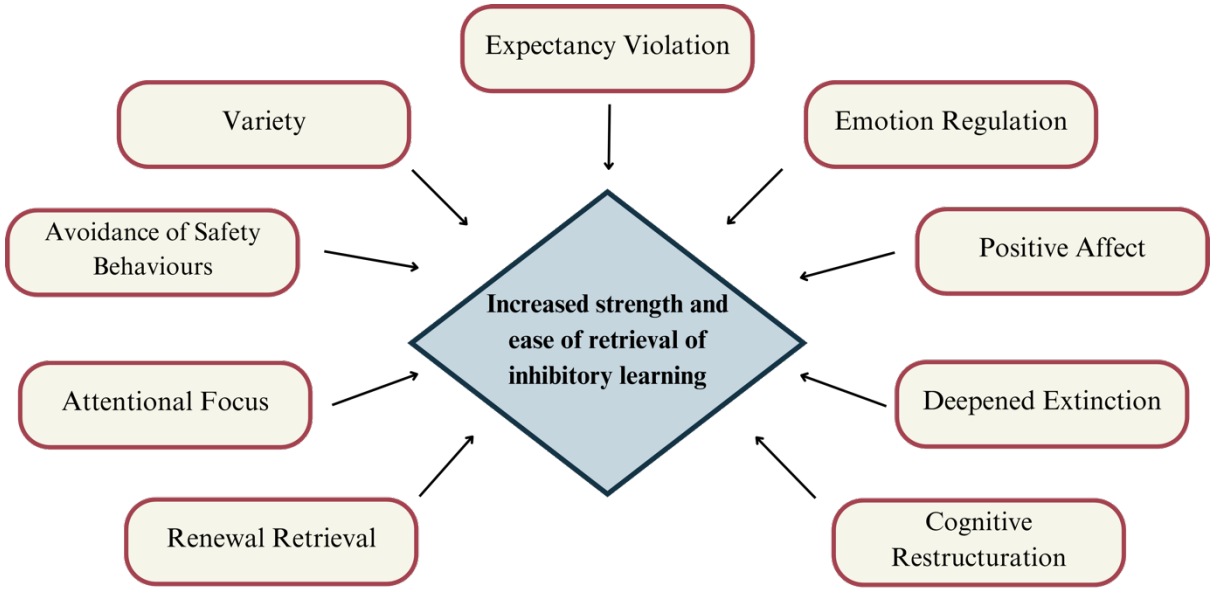
In evolution, conditioning and fear learning were essential to survive life-threatening events in the surrounding environment (Mineka & Öhman, 2002). It is hypothesised that, in anxiety disorders, fear learning is pathologically increased, which results in a quick and easy pairing of neutral stimuli to fear and anxiety responses that are resistant to extinction; possibly because of an impaired inhibition of the amygdala (Quirk & Gehlert, 2003).

Exposure therapy (ET) aims to contrast the association between the neutral CS and US through a "repeated approach towards fear provoking stimuli" (i.e., the CS) in the absence of the aversive US (Craske et al., 2014, p. 10), and while refraining from performing anxiety-neutralising behaviours such as avoidance and safety behaviours. Exposure can be performed using real objects or situations (in-vivo exposure); imagination (imaginal exposure); body sensations (interoceptive exposure); or virtual reality (virtual reality exposure) (Craske, 2015; Riva, 2022). During ET, patients learn that the CS stimuli is not (or only rarely) followed by the aversive US. This weakens the association between CS and US, and consequently reduces the anxiety connected to the CS (Hoffman & Smits, 2008; Murray et al., 2016). ET is largely used in CBT for anxiety disorders, including agoraphobia, social anxiety disorder, obsessive compulsive disorder, and specific phobia; these are disorders characterised by extreme and persistent anxiety that is out of proportion compared to real danger, or in the absence of danger (Schaumberg et al., 2021).

Habituation and Inhibitory Learning Model in Exposure Therapy

Two models have been developed to explain the mechanism behind ET. According to the "habituation model of extinction," given certain conditions, recurrent exposure to a phobic stimulus leads to "habituation," which is a progressive reduction of response consequent to repeated stimulation; and therefore, to a decrease of the fear, anxiety, and avoidance associated with the stimulus (Rankin et al., 2008). According to this model, decrease of anxiety within individual sessions in predictive of a decrease in anxiety between sessions (i.e., from one session to the next), and of the overall success of the intervention (Craske, 2015). However, exposure-based cognitive behaviour therapy as it was delivered so far was shown to have high dropout rates, approximately 50% effectiveness, and a return of the fear in a portion of patients (Craske, 2015). In addition, habituation has been found to have limited applications, for example during exposure to stimuli not associated to further predictions (e.g., a fear of mice that is not associated to the fear of contracting a disease from them) (Murray et al., 2016; Rankin et al., 2009).

In recent years, the habituation model has been largely replaced by the "inhibitory learning model." According to this model, the phobic association is not erased by exposure therapy, but rather inhibited while a new, more positive, and eventually stronger association with the CS is formed (CS-no US) (Buchholz et al., 2022; Craske et al., 2014). According to this model, and in contrast with the habituation model, reduction of anxiety over the exposure session is not predictive of the effectiveness of ET: the strength of the new association is verified instead after the whole intervention is over (Craske et al., 2014). Based on these premises, it is fundamental that the new association is strong enough to be able to consistently overrun the old, fearful one. Some of the strategies to strengthen the new association are the use of a variety of stimuli and contexts, encouragement of attentional focus on the phobic stimulus and emotion regulation, induction of positive affect, renewal retrieval after ET has been completed, and expectancy violation (Figure 3).



Note. Adapted from Craske et al. (2014) and Craske (2015).

Figure 3

Strategies to Enhance Inhibitory Learning During Exposure Therapy.

The effectiveness of using a wide range of stimuli and contexts of exposure is supported by evidence in the cognitive science field, which suggests that variability increases the assimilation of new information. It is therefore important to use a range of CS and contexts (e.g., a plastic spider, a picture of a spider, a real spider; in an indoor environment, a

park, etc.) to consolidate extinction learning (Bjork & Bjork, 2013; Bouton, 1993; Hildebrandt et al., 2012; Murray et al., 2016; Mystkowski et al., 2002). The CS, in addition, should be the main focus of attention during exposure, as changes in associative strength will be directed towards the more prominent stimulus (Craske et al., 2014). The induction of positive mood during ET is rooted in the concept of *evaluative conditioning*. Evaluative conditioning refers to the valence that is conditioned to the CS, independently from the associated US. Therefore, also after the extinction of the CS-US association, the "feeling" associated to the CS may persist; with a negative evaluative conditioning being more resistant than a positive one (Murray et al., 2016; Vansteenwegen et al., 2006). Change of the valence associated to the CS (counterconditioning) could therefore strengthen the new, alternative association. Closely linked to the induction of positive mood, emotion regulation during exposure aims to test the patients' expectations about their ability to tolerate negative emotions, and to create strategies to regulate them more functionally (Reilly et al., 2017). Craske et al. (2014) suggests that simple affect labelling—describing one's emotional states—can enhance emotion regulation. Renewal retrieval, which is the frequent exposure to the CS after ET completion, also aims at strengthening the new CS-no US association so that it becomes more prominent than the old, phobic one (Craske, 2015).

Finally, expectancy violation consists in a breach of the expectations linked to the CS: to be effective, exposure should be designed to ensure a maximum violation of the feared outcome (US) (Craske et al., 2014). Therefore, exposure should continue not until the fear response has declined, but until the expectancy has been maximally violated. At the beginning of the exposure intervention, the therapist should elicit the feared outcome from the patient ("anticipated negative outcome"), and then discuss the non-occurrence of the outcome at the end of exposure. This and other cognitive restructuring strategies such as decatastrophisation—working with the patient to reduce the level of treacherousness that the stimulus poses for them—could consolidate inhibitory learning (Craske, 2015). To ensure maximal expectancy violation, two additional strategies can be applied: deepened extinction and removal of safety behaviours/signs (Craske et al., 2014; Murray et al., 2016). Deepened extinction consists in the combined exposure to two CS stimuli associated with the same US that have already been extinguished separately. Since the predicted fear response to the combined CS is larger than the fear response associated to the individual CS, the discrepancy between predicted and actual US will be amplified and therefore lead to a more effective extinction learning. At the same time, preventing safety behaviours demonstrates that the reduced association between CS and US is not due to their enactment.

Eating Disorders as Anxiety Disorders

Recent research has highlighted overlaps between EDs psychopathology and anxiety disorders. A comprehensive review by Schaumberg et al. (2021) illustrates how EDs and anxiety disorders are closely linked genetically, with an estimated heritability between 40 and 60%. In addition, patients with EDs and anxiety disorders share neurocognitive processes such as heightened attention to threat and cognitive inflexibility; and personality traits such as harm avoidance, perfectionism, and intolerance of uncertainty (Schaumberg et al., 2021). People with ED show strong anxiety about eating, often because food is associated to weight gain and its perceived consequences—the judgment of other people and disliking how the body feels (Levinson & Williams, 2020; Schaumberg et al., 2021; Strober, 2004). The fear of food can result in its avoidance, especially in AN, and the use of safety behaviours, both characteristic of anxiety disorders (Butler & Heimberg, 2020). In binge eating, anxiety is activated by the presence of cues that suggest the occurrence of episodes of binge eating (Rosenbaum & White, 2013). At the same time, pathological eating behaviours such as binges also serve to temporarily reduce anxiety (Lavender et al., 2013).

Anorexia Nervosa as Anxiety Disorder: Aetiology

In AN, an over-generalised and pathological process of fear conditioning often occurs because of traumatic experiences connected to food, observation of repulsion and avoidance towards food of others (vicarious learning), or learned negative consequences of food and eating, such as critiques or shaming (operant conditioning); with a contribution of cultural influences, genetics, developmental factors, and psychological traits (Cardi et al., 2019; Strober, 2004; Treasure et al., 2012). Consistently, AN patients often report having observed anxiety around eating in their primary carers, received rigid rules about eating, and had traumatic experiences linked to food and eating (Cardi et al., 2019; Simonazzi et al., 2023).

Simonazzi et al. (2023) examined the relationship between anxiety and AN. The study investigated ED psychopathology of the patients; subjective anxiety; food-related anxiety, which encompassed general anxiety related to food, cognitions about the consequences of eating, and the use of behaviours to contain food-related anxiety (safety behaviours); and food-related aversive experiences, which encompassed unpleasant experiences linked to food, negative attitudes about eating perceived in the environment, and negative psychological consequences perceived after eating that the patients had experienced during childhood or adolescence. The study showed that subjective anxiety was a significant predictor of both food-related anxiety and ED psychopathology, while food-related aversive experiences were a significant predictor of ED psychopathology.

Anorexia Nervosa as Anxiety Disorder: Characterisation

AN patients report anxiety about food, meals, and their consequences on body weight and shape, a response observed in anxiety disorders towards the feared stimuli (Steinglass et al., 2011). Anxiety, in turn, has a direct effect on AN symptomatology, with higher levels of pre-meal anxiety being associated to a reduced caloric intake during the meal (Lloyd et al., 2021). A model by Strober (2004) suggests that anxiety-related characteristics of AN are rooted in abnormalities in the process of implicit learning and fear learning in both disorders, which would result in a more prompt association of a CS with an aversive response that is also more resistant to extinction compared to healthy controls (Cardi et al., 2012; Klump et al., 2004; Lambert et al., 2021; Steinglass & Walsh, 2006). This premorbid disturbance, together with traits such as obsessive personality, perfectionism, and cognitive rigidity, make patients with AN more prone to create and follow rigid dieting behaviours and routines that are resistant to change in response to changing circumstances; and that are worsened by starvation itself (Steinglass & Walsh, 2006).

The link between AN and anxiety disorders encompasses many aspects of the disorder. Patients with AN seem to have higher anxiety levels in comparison to healthy controls, even after weight normalisation (Steinglass et al., 2011; Yackobovitch-Gavan et al., 2009). Furthermore, anxiety has been found to be an important vulnerability factor for AN with a role in predicting the severity of symptoms and the outcomes of treatment (Murray et al., 2016). In fact, approximately 50% of AN cases have an anxiety disorder in comorbidity, which often precedes the ED (Steinglass et al., 2011; Waller & Mountford, 2015; Yackobovitch-Gavan et al., 2009). At the neurological level, AN patients were found to have abnormal activation in response to food stimuli of brain areas associated to anxiety disorders, including the pregenual anterior cingulate cortex; an area involved in the automatic regulation of negative emotions (Young et al., 2020). Genetic studies also confirms that anxiety disorders are more common among relatives of AN patients (Strober et al., 2007).

Research by Steinglass & Walsh (2006) examined parallelism between OCD and AN, both characterised by intrusive thoughts (related to weight gain and food in AN) and compulsive behaviours aimed at keeping the intrusive thoughts and the anxiety that comes from them under control. Indeed, the rituals about eating that are used to reduce anxiety can be associated to safety behaviours observed in phobic disorders and OCDs (Cardi et al., 2019; Steinglass et al., 2011; Tappe et al., 1998). These behaviours peak when patients are underweight, but also persist after weight restoration (Steinglass & Walsh, 2006).

Understanding the core fear underling the conditioning is essential to target the correct CS and US during ET, thus ensuring the effectiveness of the treatment (Murray et al., 2016). It is still debated whether in AN the CS is represented by food, with the US being weight gain, or by weight gain itself, with the US being a violation of a self-concept and judgement of others (Murray et al., 2016; Schaumberg et al., 2021). Although these mechanisms are likely to contribute to the development of the disorder and to be in a dynamic relationship, research suggests how patients with AN show an increased avoidance towards food, while also engaging in several ritualised behaviours around foods (Schroeder et al., 2024; Steinglass & Walsh, 2006). As discussed, avoidance and safety behaviours are common responses used to avoid or reduce the anxiety connected to the phobic stimulus; therefore characterising food as one of the phobic stimuli, or CS, of AN patients (Murray et al., 2016). In addition, recent research by Levinson and Williams (2020) has identified fear towards food as a major mediator of restriction, one of the main symptoms of AN and EDs. In this framework, exposure therapy could be used as a mean to reduce the association between food and its feared outcomes, which could help in turn to alleviate anxiety symptoms towards eating and restrictive behaviours (Levinson & Williams, 2020).

Exposure Therapy in Eating Disorders

In their article, Steinglass et al. (2011) describes the adaptation of ERP to AN. In ERP for AN, the patient is asked to create a hierarchy of the most feared foods and situations, reporting their level of distress for the different situations. The patient is then exposed to the feared stimulus (food) while paying full attention to sensations and physical feelings and is asked to bear anxiety rather than avoiding it, according to the principles of habituation. In this setting, response prevention consists in avoiding any safety behaviour usually employed during eating, and any compensatory behaviour between exposure sessions. A psychoeducational intervention supports ERP by addressing the principles behind emotional regulation, anxiety, and the link between fear and EDs. By recognising their sensations as manifestations of anxiety rather than reality, the patients can break the association between the feared stimulus and danger/anxiety, and therefore break the association between safety behaviours and relief of anxiety. When tested on a group of inpatients with AN that had already undergone weight restoration, ERP was found to be more effective than a control treatment to increase caloric intake of patients (Steinglass et al., 2014).

Leaving from these premises, Cardi et al. (2019) aimed to test the acceptability and efficacy of ET in a sample of 18 patients with AN that were not receiving any concurrent treatment. During the course of eight 60-minute sessions, patients were exposed to different

foods in each session, and were asked to focus on emotion labelling and on the mismatch between the feared outcome and the actual outcome, as suggested by the inhibitory learning model (Craske et al., 2014). In addition, patients were encouraged to continue the exposure sessions autonomously to generalise the results outside the clinical setting. The intervention was found to be highly acceptable, since none of patients dropped out and all but one declared they would have continued with the treatment if given the chance. Although patients did not habituate to eating over the eight sessions (i.e., their anxiety when exposed to food did not decrease from one session to the next), an increase in BMI as well as in the confidence in the ability to change were observed at the end of the treatment; together with a reduction in restriction and concerns about eating (Cardi et al., 2019). Successive research suggested that ET contributed to changes in the dorsolateral prefrontal cortex, an area involved in deliberate attention and emotion regulation (Young et al., 2020). The same study showed how interpatient differences in specific brain areas (insula) were predictive of their therapeutic outcome, suggesting that these criteria could be used to assess the suitability of individual patients for specific treatments (Young et al., 2020).

Exposure therapy in ED has mostly been used for BN and BED, primarily to address the binge eating and the purging behaviours. The underlying theory about use of ET is that the sight of food, in particular foods that are usually "forbidden," is associated with anxiety, that in turn leads to binging behaviours (Martinez-Mallén et al., 2007). Reduction of food-related anxiety with ET could therefore lead to a decrease of binge episodes in BN patients. To achieve that, several studies have used exposure and response prevention (ERP), where patients are exposed to large quantities of food and are prevented from eating it (ERP-binging) or purging after having consumed it (ERP-purging) (Butler & Heimberg, 2020).

In a study by Martinez-Mallén et al. (2007), exposure to food (handling, smelling, acting as if about to eat it but without eating the food) was shown to reduce the number of binge episodes and a range of psychopathological symptoms (anxiety, depressive symptoms, bulimic and anorexic symptoms) both immediately after the treatment and after a six-month retest. In this study, purging behaviour (vomiting) was not reduced after the end of treatment, but it was after six months. This difference led the authors to hypothesise that binge eating and vomiting could have partially independent causes, where the first is driven by food-related anxiety and the latter by other cognitive and emotional aspects such as the drive for thinness (Martinez-Mallén et al., 2007). Other studies that used ERP-binging and ERP-purging had promising outcomes, although they have mostly been run on small samples of patients (Butler & Heimberg, 2020).

Food-based exposure therapy has also been tested as part of the treatment of ED inpatients (Farrell et al., 2019). In their study, Farrell et al. (2019) tested exposure to a range of food-related activities such as consuming normal portions of food, or consuming specific foods. At the end of the treatment, patients showed a reduction of eating anxiety, food avoidance, and compensatory behaviours (self-inducing vomiting and compulsive exercising). In addition, patients evaluated the treatment favourably in terms of its helpfulness and appropriateness to their emotional needs (Farrell et al., 2019).

Limitations in the Use of Exposure Therapy in Anorexia Nervosa

In their review investigating the use of ET in EDs, Butler & Heimberg (2020) discuss how ERP treatments have shown some efficacy on AN patients in terms of reduced anxiety towards food and increased calories intake, although these results are limited by the small samples and by the presence of other concurrent treatments (Cardi et al., 2019; Steinglass et al., 2011, 2014). In addition, the weight gain consequent to ET is often marginal, while it became more significant when ET was associated to D-Cycloserine, an N-methyl-D-aspartate (NMDA) receptor agonist known to facilitate fear conditioning extinction in anxiety disorders (Levinson et al., 2015; Murray et al., 2016; Steinglass et al., 2007). Most of the ERP studies conducted so far, in addition, have been carried out when a large portion of the weight had been restored, at the end of the inpatient treatment, and have a used a protocol based on the habituation model rather than on the inhibitory learning model (Levinson et al., 2015; Steinglass et al., 2007, 2014).

According to the habituation model discussed above, repeated exposure to a phobic stimulus should reduce the fear and anxiety associated to it (Rankin et al., 2008). Instead, in AN, repeated food exposure in the form of forced feeding, commonly used during AN acute therapy, seems to have aversive consequences, reinforcing rather than reducing the repulsion towards food (Batsell et al., 2002; Treasure et al., 2012). According to the inhibitory learning model, ET should not aim to reduce the fear response through repeated exposure to the CS, but should work to create alternative, more positive associations with the CS (Craske et al., 2014). This would in turn reduce the anxiety associated to the CS, reduce typical anxiety responses (such as avoidance and the use of safety behaviours) and change the emotional valence associated to the CS, that is negative in most cases (Reilly et al., 2017).

One of the strategies suggested within the inhibitory learning model is expectancy violation, which works by creating a mismatch between the CS and its feared outcome (Craske et al., 2014). Applying this model to ED, expectancy violation could involve presentation of food in a form that does not lead to the associated aversive consequences,

including loss of control, intake of calories, and weight gain. In this sense, therefore, use of virtual reality might represent an effective way to separate food and its aversive consequences in exposure therapy for AN.

Chapter 3 - Virtual Reality Exposure Therapy in the Treatment of Eating Disorders

Characteristics of Virtual Reality

Virtual reality (VR) can be defined as "an advanced form of human–computer interface that allows the user to interact with and become immersed in a computer-generated environment in a naturalistic fashion" (Schultheis & Rizzo, 2001, p. 82). There are three core dimensions to VR: the immersion, usually provided by a display mounted on the head, the interaction, achieved through hand-held remotes, and the subjective sense of presence (Grochowska et al., 2019). This latter can be described as a sensation of actually being in the virtual environment, achieved to a different degree according to the level of immersion provided by the VR instrument, and can affect the effectiveness of a VR experience (Souza et al., 2021; Riva, 2022).

Applications of Virtual Reality to Clinical Settings

In clinical settings, VR has mostly been applied to exposure therapy, in particular for the treatment of anxiety disorders, eating disorders, schizophrenia, substance dependence, and obesity (Grochowska et al., 2019). Virtual Reality Exposure Therapy (VRET) has been largely applied to the treatment of specific phobias, where users are exposed to the digital presence of the feared stimulus within the virtual environment. A number of studies have shown that VRET is more effective than CBT with imaginary exposure and as effective as CBT with in vivo exposure, and that its gains are generalised to real-life (Grochowska et al., 2019; Morina et al., 2015).

Besides being effective, VRET offers the possibility of an extremely realistic exposure with a minor use of resources compared to in vivo exposure (Freeman et al., 2018). At the same time, use of VRET overcomes the difficulties encountered with imaginary exposure by people that struggle to control their thoughts or with imaginative difficulties (Vincelli, 1999). In addition, VRET offers the opportunity to create an experience that is tailored to the needs of the patient and highly controllable by the therapist, which could improve the effectiveness of treatment (Freeman et al., 2005; Grochowska et al., 2019). VRET has also been shown to be well received by its users and less associated to the stigma of clinical treatment, with a feeling drowsiness being the sole side effect experienced by some users (Carvalho et al., 2010; Garcia-Palacios et al., 2001; Langlet et al., 2021). Finally, notwithstanding the high costs of software design and hardware at present, some VRET interventions do not require the presence of a therapist, which could make VRET suitable for home use by patients and cheaper in the long term (Freeman et al., 2018; Grochowska et al.,

2019). These elements suggest that VRET has the potential to become more largely integrated in clinical practice.

Virtual Reality in the Assessment and Treatment of Eating Disorders

In EDs, VR has been used with different applications. A review by Riva et al. (2021) describes the main interventions used for the treatment of EDs: VR reference frame shifting, bodily illusions, modifications of attentional biases, and VR cue exposure. VR reference frame shifting is a VR adaptation of imagery techniques. Through immersion in a realistic but safe and controllable virtual environment, VR reference frame shifting has to potential to reduce negative emotions associated to past distressful memories and to improve management of present or future critical situations. When applied to BN and BED in combination to CBT, VR reference frame shifting has resulted in a decrease of both negative cognitions on the self and behaviours such as binge eating and vomiting, in the short- and long-term (Riva et al., 2021).

The VR techniques of bodily illusions and modifications of attentional biases are still at their very early applications. Bodily illusions have been used to address body image distortions that are common in EDs (Riva & Melis, 1997). This VR technique involves the use of avatars to assess body representation disturbances, for example through the manipulation of 3D figures in an immersive environment to picture the ideal body, the perceived body, the healthy body (Riva et al., 2021; Wiederhold et al., 2016). According to Riva and Melis (1997), body image distortions are cognitive biases, and therefore partially unconscious. The discrepancy between the user's proprioception and the signals received by the VR environment can increase the awareness of perceptual processes. This, in turn, can facilitate a change in the body image as patients attempt to achieve consistency among body representations (Riva et al., 2021; Riva & Melis, 1997). Adding a VR bodily illusions component to CBT has showed improvements in body image of patients with BN and AN (Perpiñá et al., 1999), and embodiment of an avatar by patients with AN has resulted in a reduction of bodily distortions, body-related anxiety, and fear of gaining weight (Riva et al., 2021). The third technique described by Riva et al. (2021)—modification of attentional biases—consists in the integration of VR with eye-tracking systems to enable objective measurement of the attention (e.g., time of fixation, proportion of time spent) on specific body parts, with the potential to assess body representation disturbances. Although promising, these VR techniques are still preliminary and require further research.

The fourth VR technique addressed by Riva et al. (2021), VR cue exposure, is one of the most diffused clinical applications of VR in EDs. Among the advantages, VR cue

exposure allows an exposure to both proximal (e.g., food) and distal (e.g., environment where the food is usually consumed) stimuli that is ecological but safe, and that can be tailored to the needs of each patient (Riva et al., 2021; Wiederhold et al., 2016). To support the validity of VR cue exposure, VR foods were shown to elicit similar emotional responses to real foods, and stronger than those elicited by pictures of food (Gorini et al., 2010; Gutiérrez-Maldonado et al., 2006; Wiederhold et al., 2016). In addition, high-calorie foods were shown to cause more anxiety than low-calorie foods, and food-related VR environments (dining room, kitchen) provoked more anxiety and food craving than food-unrelated environments in patients with EDs (Ciążyńska & Maciaszek, 2022; Gutiérrez-Maldonado et al., 2006). Although research in this field is still limited, efficacy and acceptability of VR cue exposure for the treatment of EDs are promising (Cardi et al., 2012; Perpiñá & Roncero, 2016; Riva et al., 2021). From now on, VRET will be referred specifically to VR cue exposure treatment.

Virtual Reality Cue Exposure for Anorexia Nervosa

Research using VRET with AN patients is extremely limited. Cardi et al. (2012) exposed to VRET an individual patient with AN that had not recovered from her condition despite seven months of CBT, recovery groups, and a pharmacological treatment. Over a week (seven sessions, 60 minutes long), the patient T. was exposed to a series of low- and high-calorie foods, that she was asked to handle and then consume. Both within each session and at the end of the week of exposure, a decrease in fear, anxiety, and guilt associated to eating was observed. At the end of the exposure, T.'s mood, social life, and family life improved; her depression, anxiety, and eating symptoms decreased; and she started to include a wider variety of foods in her diet. T.'s BMI also increased. Finally, T. rated the exposure to be enjoyable and helpful, and "a gentle way of easing me back into being around high calorie and high content foods" (p. 244). The study showed VRET to be acceptable and effective, and therefore encourages further research on the application of VRET to the treatment of AN.

A successive study from Cardi's group investigated VRET exposure in a larger group (145) of patients with AN (Natali et al., 2024). To test what additional factors could maximise its effects, they added two conditions to the baseline kitchen environment exposure: positive mood induction (using a virtual pink elephant) and social support (using avatars that spoke supportive messages). Importantly, both additional conditions were structured and evaluated in collaboration with patients with an ED. The presence of the pink elephant was more effective than the other two conditions to reduce food-related anxiety. This is consistent with the inhibitory learning model (Craske et al., 2014) that suggests that

positive mood induction is one of the strategies that can reinforce the formation of a new, more positive association with the former phobic stimulus.

Virtual Reality Cue Exposure for Bulimia Nervosa and Binge Eating Disorder

VRET for the treatment of BN and BED aims to reduce the association of the CS (food) with responses of anxiety or craving that, in binge eating, are considered to be the triggers of binge behaviours; that in turn are also causally related to purging behaviours (Riva et al., 2021). Although current research is limited and has yielded contrasting results, VRET was shown to be effective to reduce anxiety and cravings in patients with BN and BED, and to help them to develop coping strategies towards food triggers (Brown et al., 2020; Burton & Abbott, 2017; Butler & Heimberg, 2020; Low et al., 2021). VRET has also been used in combination with other interventions. Experiential Cognitive Therapy (ECT), a therapy that uses a combination of 3D avatars, CBT, and psychoeducation, was showed effective to reduce binging behaviour in patients with BED (Riva et al., 2003).

A randomised-controlled trial carried out by Ferrer-García et al. (2017) supported the efficacy of VRET. Patients with BN and BED that had already undergone an unsuccessful CBT treatment received either six additional biweekly sessions of CBT or the same number of VR cue exposures. As in the classical exposure technique, patients undergoing VR cue exposure were initially asked to decide which foods (pizza, cake, hot dog, etc.) and environment (kitchen, dining room, café, etc.) elicited the highest level of craving. Patients were then exposed to a 3D, interactive combination of the stimuli they had rated as most threatening, and their anxiety levels were periodically measured. Exposure ended after their anxiety level had dropped to 40% of their initial anxiety or after 60 minutes. Results showed that both treatments were effective, but VRET showed better results in the reduction of food-related anxiety, of the tendency to engage in binge episodes, and of binge eating and purging episodes, both short- and long-term. At a six-months follow up, a decrease in binge and purging behaviours was present in both samples but it was still larger in the VRET group (Ferrer-Garcia et al., 2019).

Suitability of Virtual Reality for the Treatment of Eating Disorders

To explain the effectiveness of VR for the treatment of EDs, Riva et al. (2004) refers to the five stages of change by Prochaska and DiClemente (Raihan & Cogburn, 2013). According to these authors, the process of change goes through five steps, where one of the most critical stages for patients of EDs is “contemplation”: patients see the motivation for change as well as the motivations against it, and cannot choose between the two options. Two therapeutical techniques to overcome this phase and move to the next (“determination”) are

the asking the “miracle question” and “searching for exceptions.” In the first technique, the client is asked what would happen if they magically got rid of their ED. In the second technique, the patient is asked about times when they had managed their ED better. According to Riva et al. (2004), VR has the potential to put these two techniques into practice by immersing the patient in a realistic situation where they are forced to face the discrepancy between present reality and an alternative one: it allows patients to “experience” the change in circumstances that they still consider to be safe. In other words, VR is used as an instrument to challenge the assumptions of its users, substituting them with more realistic perceptions and thus opening the way to change (Ferrer-Garcia et al., 2013; Riva et al., 2004).

Roncero and Perpiñá (2015, 2016) also highlight how VR, with its characteristics of immersivity, presence, and greater ecological validity than the therapist office, can act as a “rehearsal” to real life, where the patient can explore their emotions and cognitions in a safe albeit realistic setting; and possibly work to develop effective coping strategies. An additional advantage is that all parameters can be controlled strictly, thus allowing to adapt to the needs of the client that can practice management of eating behaviours and also of the emotional and relational skills that are connected (Ferrer-Garcia et al., 2013). VRET is also particularly suited to be adapted to a protocol following the inhibitory learning model, as it offers the potential to use a variety of stimuli and contexts while maximising the expectancy violation between the presentation the CS and its feared outcomes, including anxiety, weight gain, and loss of control (Cardi et al., 2019). Finally, validation and diffusion of VRET could enable its use as a self-delivered form of treatment outside the clinical setting, potentially increasing the frequency of exposure sessions, reducing their cost, and favouring renewal retrieval—the reinstatement of the CS-no US association after ET’s conclusion—that can strengthen the inhibitory learning response and enhance its retrieval (Craske, 2015).

Chapter 4 – Current Study: Description and Hypotheses

VRET exposure therapy is a promising treatment for AN. It is rooted in the common ground between AN and anxiety disorders, suggesting that an association between a neutral stimulus (CS, food) and a fear response (US, weight gain) leads in AN patients to avoidance of food and to engagement in ritualistic behaviours to minimise anxiety (Schroeder et al., 2024; Strober et al., 2004).

Use of VR to deliver ET has two advantages. First, according to the inhibitory learning model, aim of ET is to substitute the phobic CS-US association with a new, more positive CS-no US association (Craske et al., 2014). According to the inhibitory learning model and in opposition to the classical habituation model, reduction of anxiety towards the CS is not expected during or immediately after exposure, but only at follow up after the end of the intervention. In order for the new association to be stronger, ET should aim to maximise the gap between the feared and actual outcome of exposure to the phobic stimulus (expectancy violation). By breaking the connection between food (CS) and weight gain (US), VR allows maximal expectancy violation, therefore maximising the effect of ET (Craske et al., 2014; Riva et al., 2021). The second advantage of using VRET for the treatment of AN is that it could represent a support to AN existing treatments both during the critical weight restoration phase, where effective interventions could reduce the immediate risks on physical health, and in later stages of the recovery. Since the effectiveness of ET increases with the number of sessions and the variety of exposure stimuli, it would be useful to implement the VRET intervention so that it could be eventually used flexibly and autonomously by AN patients (Craske et al., 2014; Rankin et al., 2009; Riva et al., 2021).

VRET for the Treatment of Anorexia Nervosa: The Gap in the Literature

Uses of VRET in AN has been extremely limited. A case study by Cardi et al. (2012) showed how VRET was acceptable and effective in reducing anxiety linked to food and psychopathological symptoms. A successive study by Natali et al. (2024) added to a VR kitchen environment a social support condition (presence of an avatar speaking words from a supportive script) or an induction of positive mood condition (a small pink elephant) to increase the effect of one single session of VRET. However, these studies lacked a negative control group to use as a comparison to the VR kitchen intervention.

This pilot study aimed to explore the feasibility of a VRET intervention and to investigate its impact on eating- and food-related anxiety in patients with AN during the phase of weight restoration. We recruited patients from four the day hospital structures for EDs in Italy and exposed them to a one-week of VR intervention modelled after the one used

by Natali et al. (2024). Following from their study, we exposed participants to VR for five minutes per day for five days. During exposure, patients were asked to interact with virtual foods that were selected based on research by Cardi et al. (2019). The wide range of foods used ensured exposure to a variety of stimuli, as recommended for ET (Craske et al., 2014; Rankin et al., 2009). Foods were all present at the same time in the kitchen, and not introduced one by one following a hierarchy as in classical ET (Rankin et al., 2009). In fact, random and simultaneous presentation of foods that elicit different levels of anxiety should maximise expectancy violation (Craske et al., 2014; Natali et al., 2024).

The first difference introduced by this study to the research from Natali et al. (2024) was the use of a VR nature scenario as a control to the VR kitchen scenario. The second difference was to expose participants to five VR sessions, compared to the single session of VR exposure employed by Natali et al. (2024); in order to strengthen the inhibitory learning response by increasing the amount of exposure to the feared stimulus (Craske et al., 2014). Finally, we allowed participants to choose one of three kitchen scenarios and one of three nature scenarios, instead than assigning participants to one scenario for the whole duration of the VR intervention. This choice was made to reduce the number of variables at stake, also given the limited number of patients and the exploratory nature of this study.

Research Questions and Aims

Our research question aimed to explore the feasibility of the VR intervention used in this study. In addition, it aimed to explore the impact of a one-week VR intervention on eating- and food-related anxiety across time (before vs after VR intervention) and across VR conditions (kitchen vs nature condition).

Aim 1. To explore the feasibility of the VR nature scenario.

To achieve this aim, we measured the dropout rates from the VR intervention and we collected the spontaneous comments of participants on the VR scenarios. In addition, we measured participants' sense of presence and their feeling of physical discomfort.

Aim 2. To explore the impact of the VR intervention on eating- and food- related anxiety over time.

To investigate this aim, four measures of anxiety were used. 1) The level of anxiety when thinking about the next meal (Next Meal Anxiety, NMA); 2) the level of anxiety immediately before immediately before consuming a standardised meal at the day hospital (Pre-Meal Anxiety, PMA); 3) the level of anxiety when watching food pictures (Food Anxiety, FA); 4) the level of avoidance when watching food pictures (measured as Food Wanting, FW).

Changes over time in these four outcomes were tested by measuring them before and after the one-week VR intervention.

Aim 3. To explore differences between kitchen and nature exposure conditions in their impact on eating- and food-related anxiety over time.

To explore this aim, NMA, PMA, FA, and FW were measured before and after the one-week VR intervention and compared between the two VR conditions (kitchen vs nature condition).

Chapter 5 - Methods

Design

The study had a quantitative mixed design and consisted of one week of VR exposure (five-minute sessions for five days). The condition of VR exposure represented the independent variable (IV) with two levels: exposure to a VR kitchen environment (Kitchen, experimental group) and exposure to a VR nature environment (Nature, control group). Each condition had three sub-levels, that corresponded to three different scenarios that could be selected by participants before every VR exposure: Kitchen Only, Pet, and Avatar for the Kitchen condition and White Winter, Red Fall, and Blue Ocean for the Nature condition. To explore the feasibility of the VR intervention (Aim 1), three dependent variables (DVs) were measured: the sense of presence and the feeling of discomfort reported by participants immediately after VR exposure, and the dropout rate of the participants from the study. In addition, spontaneous comments of participants regarding the VR exposure were collected. For Aim 2 and 3, change in four DVs (Next Meal Anxiety, Pre-Meal Anxiety, Food Anxiety, and Food Wanting) was assessed over time (before vs after the VR intervention, Aim 2) and compared across conditions (Kitchen vs Nature conditions, Aim 3). All variables are described below.

Participants and Setting of the Study

Participants were recruited from January 2023 to February 2024. Inclusion criteria were: 1) knowledge of the Italian language and 2) being in intensive treatment for an eating disorder. Exclusion criteria were: 1) age under 14 years; 2) diagnosis of neurological disorders; 3) diagnosis of psychosis or substance abuse disorders; 4) visual/auditory deficits not corrected by glasses/ear plugs; 5) non-tolerance to virtual reality exposure (e.g. cybersickness, dizziness). All participants provided written informed consent. In the case of underage participants, consent was provided by the parents or legal guardian. The study was approved by the ethics committees of Vicenza Hospital (reference number 1831) and was conducted in accordance with the latest version of the Declaration of Helsinki.

Participants were recruited from day hospital centres at the Eating Disorder Unit of the University Hospital of Padova, the Eating Disorder Unit of the San Bortolo Hospital of Vicenza, the Eating Disorder Unit of Treviso and the Eating Disorder Unit of Salerno. These are semi residential units where patients receive intensive treatment, that accommodate ED patients from Monday to Friday, from the early morning to the afternoon. Patients in day care centres are characterised by high ED severity and by a motivation to carry out the treatment, often after that an outpatient treatment had not proven effective. During semi residential

treatment, patients are required to consume three daily meals (two snack and a main meal, the lunch) that they are asked to complete at every meal within a set amount of time. Patients agree their meals with a clinical team, and meals become progressively more challenging over time in terms of caloric content and presence of phobic foods. In addition, patients attend daily educative and therapeutic activities and individual therapeutic sessions (mostly CBT-ED). For this study, participants were recruited within the first few weeks of their arrival at the day hospital centre.

Materials

Demographics

The following information were asked to participants: age (years), gender, education level (years), occupation, period (present/absent), use of contraceptives (yes/no), and current medications use. Additional information such as current diagnosis, weight, and height was obtained from medical records to calculate body mass index (BMI = weight (kg)/[height (m)]^2) to avoid asking sensitive information to participants.

Baseline Tests

The Eating Disorder Examination-Questionnaire (EDE-Q) and the Depression Anxiety Stress Scales (DASS-21) were used as baseline measures before the VR intervention.

EDE-Q. The EDE-Q is the self-report version of the EDE and is used to evaluate the psychopathology of ED (Fairburn & Beglin, 1994). It has 28 items and provides two types of information: the frequency of key behaviours associated with ED and the severity of aspects of the psychopathology of eating disorders. This latter feature is described by four subscales:

- Restraint: items 1, 2, 3, 4, 5. E.g., item 1: “Have you been deliberately trying to limit the amount of food you eat to influence your shape or weight (whether or not you have succeeded)?”
- Eating Concern: items 7, 9, 19, 20, 21. E.g., item 9: “Have you had a definite fear of losing control over eating?”
- Shape Concern: 6, 8, 10, 11, 23, 26, 27, 28. E.g., item 26: “How dissatisfied have you been with your shape?”
- Weight Concern: items 8, 12, 22, 24, 25. E.g., item 22: “Has your weight influenced how you think about (judge) yourself as a person?”

Scores range from 0 to 6, with higher scores corresponding to worse pathology. Scoring of each subscale is obtained by summing the ratings of the individual items and dividing this

number by the number of the items in each subscale. The global score is obtained by summing the scoring of the four scales and dividing it by four.

The Italian version of the EDE-Q has high internal consistency and test-retest reliability for global and subscale scores, and validation of the scale confirmed that patients with ED had higher scores than controls (Calugi et al., 2017). In this study, we used the Italian version of the EDE-Q. In particular, the global score of the EDE-Q and the scores of the "Restraint" scale were used to characterise the sample (Calugi et al., 2017). Cronbach's α for these scales was measured, with values > 0.7 indicating that the scale had good internal consistency (Tavakol & Dennick, 2011). Cronbach's α of the "Restraint" scale of the EDE-Q (α = 0.814) and of the EDE-Q global score (α = 0.748) showed that the scales used had good internal consistency (Tavakol & Dennick, 2011).

DASS-21. The original DASS-21 (Lovibond & Lovibond, 1995) comprises 21 self-report items, assessing three main areas over the previous week:

- Depression. Evaluates dysphoria, hopelessness, depreciation of life, self-blaming, inertia, and anhedonia. E.g., item 13: "I felt down-hearted and blue."
- Anxiety. Evaluates autonomic and skeletal muscle arousal, situational anxiety, and subjective anxiety. E.g., item 2: "I was aware of dryness of my mouth."
- Stress. Evaluates difficulty to relax, exaggerated arousal, impatience, and being easily distressed and restless. E.g., item 6: "I tended to over-react to situations."

Respondents rate the frequency of experiencing symptoms over the previous week using a 4-point Likert scale (0 = "never happened," 1 = "happened sometimes," 2 = "happened quite often," 3 = "happened almost always"). Higher scores indicate more severe symptoms.
The Italian version of the DASS-21 (Bottesi et al., 2015) was used in our study. Authors recommend using a total score to measure overall distress, that was used in this study. Cronbach's α for these scales was measured, with values > 0.7 indicating that the scale had good internal consistency (Tavakol & Dennick, 2011). Cronbach's α of the DAAS-21 global score (α = 0.943) showed that the scale had good internal consistency (Tavakol & Dennick, 2011).

Pre-Post Exposure Measures

Next Meal Anxiety (NMA) was recorded every day immediately before and immediately after the VR exposure. This was a measure of the anxiety that participants felt

when thinking of their next meal ("How anxious do you feel when you think of your next meal?"). It was measured on a 1-100 scale.

Post Exposure Measures

Sense of presence and feeling of discomfort were measured every day immediately after VR exposure, while dropout rates were calculated at the end of data collection.

Presence. The sense of presence was used as a descriptive measure of to evaluate how present the participants felt in the virtual environment, a sensation that changes according to the level of immersion provided by the VR instrument and that can affect the effectiveness of VR interventions (Souza et al. 2021; Riva, 2022). It was measured every day immediately after VR exposure on a 1-100 scale.

Discomfort. The physical feeling of discomfort was used to measure the feasibility of VR exposure (Carvalho et al., 2010). It was measured every day immediately after VR exposure on a 1-100 scale.

Dropout rate. This was measured as the percentage of patients that dropped out, interrupted one or more VR sessions, or did less than five exposures of VR.

Pre-Post Intervention Measures

Two measures were recorded before starting the VR intervention and after the last day of the intervention: Pre-Meal Anxiety (PMA) and Food Evaluation Scale (FES).

Pre-Meal Anxiety (PMA). Immediately before consuming a standardised lunch at the day hospital, participants were asked to evaluate their anxiety on a 1-10 scale.

Food Evaluation Scale (FES). Participants were presented with 21 pictures of foods with different caloric content on a computer and were asked to give a rating from 1 to 100 using a Visual Analogue Scale (VAS) of a) how much they wanted to eat that food (Food Wanting, FW) and b) how anxious they felt if imagining to eat that food (Food Anxiety, FA). FW was used as a measure of food avoidance (Natali et al., 2024) (Figure 4). Images of foods were extracted from a database by Blechert et al. (2014).

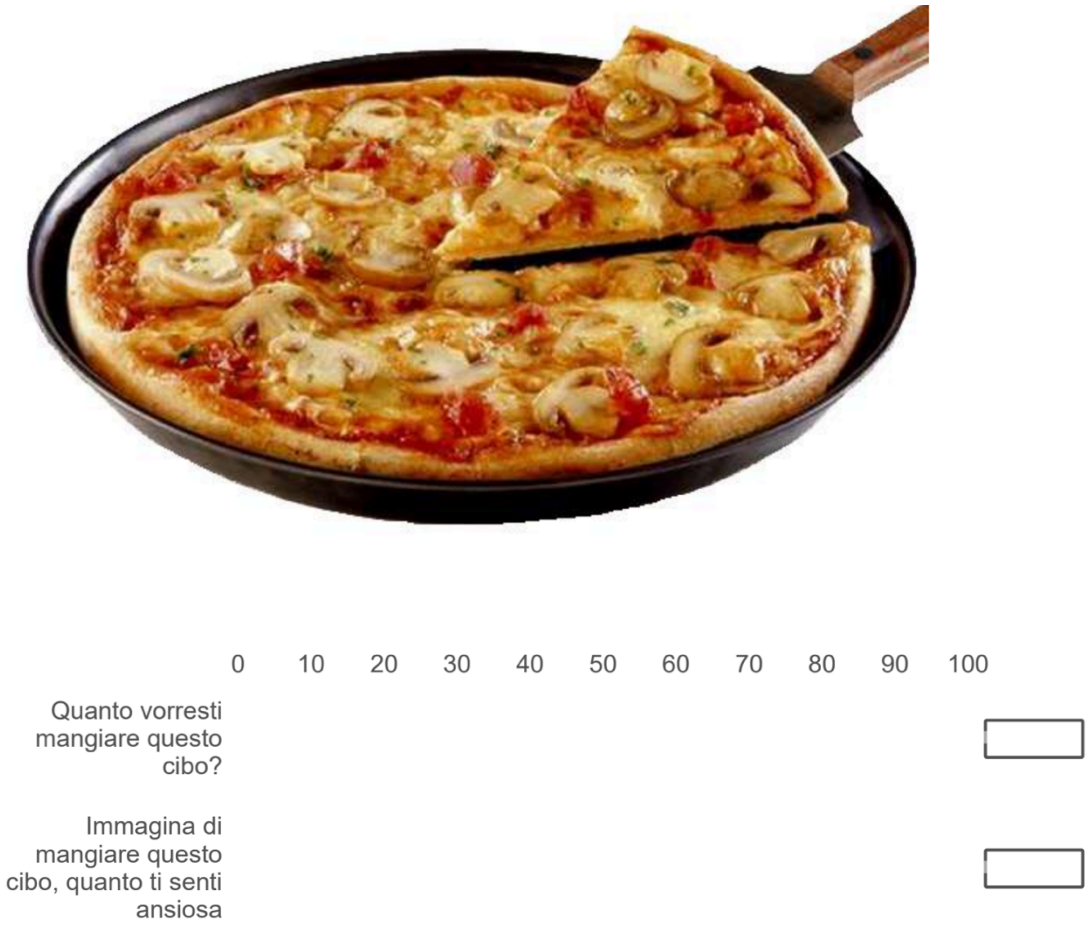


Figure 4. *Example of Food Evaluation Scale (FES).*
Food pictures were rated from 1 to 100 using a Visual Analogue Scale (VAS) according to how much patients wanted to eat the food (Food Wanting, FW, first question), or felt anxious (Food Anxiety, FA, second question) if they imagined eating the food. In the figure, a high-calorie food (pizza) is illustrated as an example.

Virtual Reality

The Oculus Quest 2 headset was used to enter the immersive virtual environment. The headset incorporated a head-mounted display (resolution of 1832 x 1920 pixels per eye) and two joysticks.

Two VR conditions were used: Kitchen environment and Nature environment. Exposure to virtual reality lasted five minutes. The experimenter was present in the room for the whole duration of the exposure.

Kitchen Environment. This environment consisted of a virtual kitchen containing a range of foods with different caloric content (e.g., cookies, pizza, fruit) (Cardi et al., 2019; Natali et al., 2024). Participants were encouraged by the instructor to move, explore, open some of the cupboards and the fridge, pick up and handle the food. Every day, before starting the VR exposure, participants were asked to select one of three conditions, that were structured and evaluated in collaboration with patients with an ED (Natali et al., 2024):

- Kitchen (Kitchen Only, Figure 5).
- Kitchen + positive mood induction (Pet, Figure 6). In this condition, a pink, small elephant was present with the participant in the kitchen. The elephant moved around and emitted noises.
- Kitchen + social support (Avatar, Figure 7) In this condition, an avatar was present with the participant in the kitchen. The avatar encouraged participants to approach the foods in the kitchen and confront the inner voice of their ED.

The application for the procedure used in the study was developed using the Unity3D game engine and the Oculus Software Development Kit (SDK) from the Virtual Reality Lab, a research facility within the Institute of Psychiatry, Psychology, and Neuroscience (IoPPN) at King's College London.

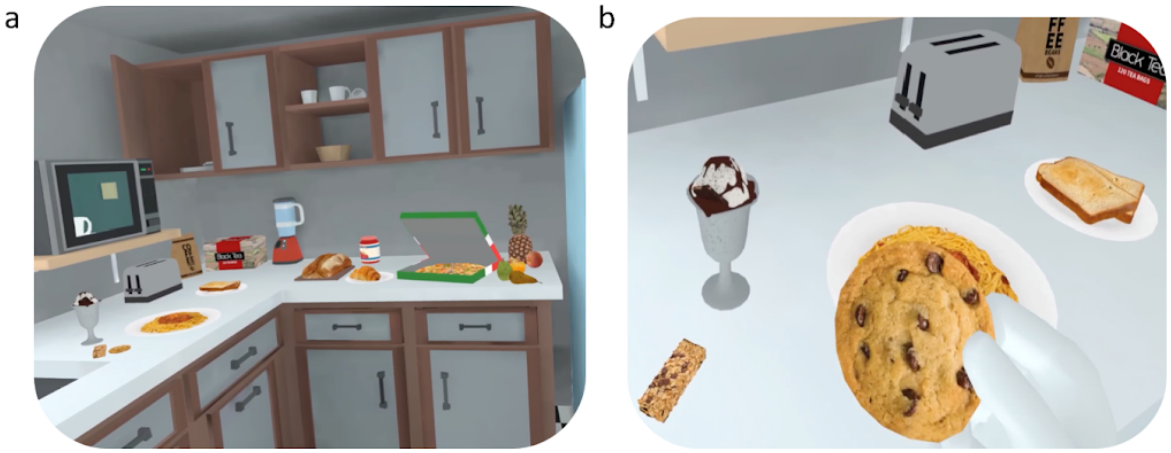


Figure 5. *Virtual Kitchen Only Scenario.*
A) Part of the virtual kitchen containing a range of foods that participants could pick up and handle. B) Detail of the virtual hand of the participant picking up a cookie.

Figure 6. *Kitchen + Pet Scenario.*
A small, pink elephant emitting noises was added to the kitchen environment to induce positive mood.

Figure 7. *Kitchen + Avatar Scenario.*
A choice of four different avatars (A) was given to offer social support. The chosen avatar chosen walked around in the kitchen and spoke supportive words from a script (B).

Nature Environment. The control condition consisted in VR exposure to a natural environment, where participants could move and interact with animals and objects. During exposure, participants sat on a rolling desk chair and were encouraged observe the environment and relax. Every day, before starting the VR exposure participants were asked to select one of three conditions: White Winter, Red Fall, and Blue Ocean (Figure 8). For the

Nature condition, the application Nature Treks VR was used, available for the Oculus Quest 2 headset.

Figure 8. *The Virtual Nature Environment*

Note. Examples of scenarios from White Winter (A), Red Fall (B), and Blue Ocean (C).

Procedure

The procedure took place within three weeks of the patients' admission in the daycare centres. The entire intervention comprised of one day for initial familiarization, demographic collection, and baseline assessment (referred to as day 0, usually Friday), followed by five consecutive days of exposure to virtual reality (referred to as days 1-5, usually Monday to Friday); on day 5, after the final exposure session, participants underwent post-intervention assessments (Figure 9).

On day 0, participants were explained the outline and purpose of the study and were encouraged to ask questions. After that, participants provided written consent, demographic information, and completed the baseline tests (EDE-Q and DAAS-21) and the FES. After being randomly assigned to either the experimental (Kitchen) or control (Nature) group, they were exposed to the selected VR scenario for five minutes to get familiar with the equipment and with the virtual environment. On day 0, immediately before the main meal at the day hospital, participants were also asked how anxious they felt in that moment (PMA).

On days 1-5, participants were exposed to one five-minute VR session every day. Before starting the VR exposure, participants were asked to report their current level of anxiety when thinking of the next meal (NMA, 1-100). Every day, participants within each group were asked to choose one of three scenarios described in the Materials session: Kitchen Only, Pet, or Avatar for the Kitchen condition and White Winter, Red Fall, or Blue Ocean for the Nature condition. At the end of each VR session, participants were asked again to report their current level of NMA (1-100). In addition, they were asked to rate how present they felt in that moment (1-100) and their level of discomfort (1-100).

On day 5, following the final VR exposure session, participants completed the FES again. In addition, they were asked how anxious they felt immediately before the main meal at the day hospital (PMA). At the end of the VR intervention, participants were asked if they had any question and were offered to try scenarios from the other condition (e.g., Nature if they were in the Kitchen condition) in the following days.

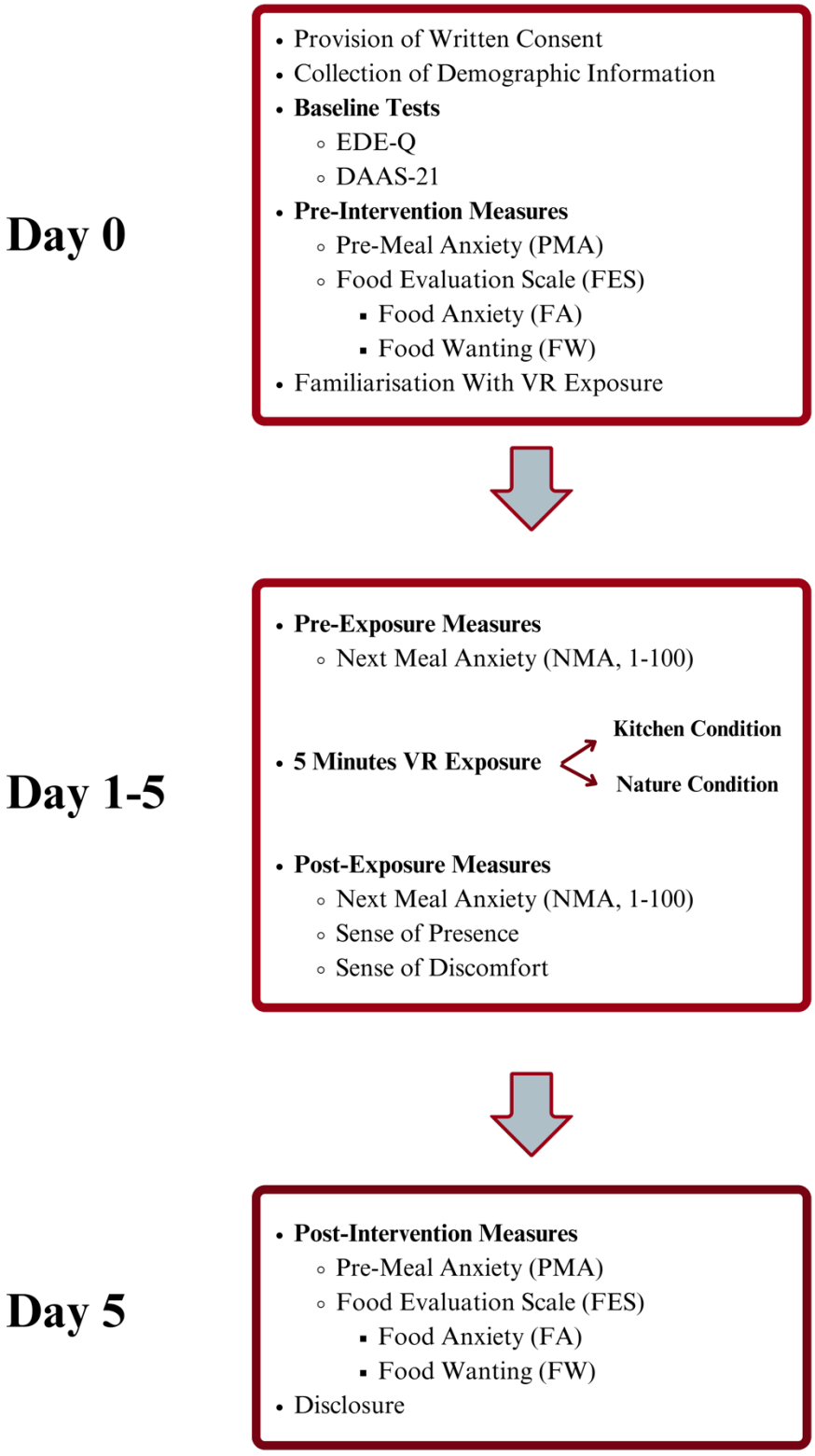


Figure 9. *Schematic Representation of the VR Exposure Intervention.*

Statistical Analysis

Data was analysed using Jasp 0.18.3 software. The following statistical analysis were used to address the aims of the study.

Aim 1. To explore the feasibility of the VR nature scenario.

The reported feeling of physical discomfort (Discomfort, 1-100) and feeling of presence (Presence, 1-100) were measured every day immediately after VR exposure. First, a t-test (or a non-parametric Mann-Whitney test) was run to compare the feeling of discomfort (DV) and the feeling of presence (DV) in the two experimental conditions (IV, Kitchen and Nature). If the data was significant, a one way between factors ANOVA (or a non-parametric Kruskal-Wallis test) was used to compare discomfort across the six scenarios (DV, six levels).

Aim 2. To explore the impact of the VR intervention on eating- and food- related anxiety over time.

Anxiety towards the next meal (NMA; 1-100) was measured immediately before and after each daily VR exposure. To test whether NMA (DV) changed at the beginning (day 1) and at the end (day 5) of the one-week VR intervention, a two-way repeated measures ANOVA was conducted. The within factor IV was the time of measurement and had two levels (Pre vs Post one week of VR intervention), the between factors IV was the VR condition and had two levels (Nature vs Kitchen). PMA (1-10) was measured on day 0, before starting the VR exposure, and on day 5, after the last VR exposure. To test the change in PMA (DV) before and after the one-week VR exposure, a two-way repeated measures ANOVA was conducted. The within factor IV was the time of measurement and had two levels (Pre vs Post one week of VR intervention), the between factors IV was the VR condition and had two levels (Nature vs Kitchen).

Aim 3. To explore differences between kitchen and nature exposure conditions in their impact on eating- and food-related anxiety over time.

Food anxiety (FA) and Food Wanting (FW, used as a measure of avoidance) towards a range of high-, medium-, and low-calorie foods was measured on day 0, before starting the VR exposure, and again on day 5, after the last VR exposure. To test the change in FA (1-100; DV) and FW (1-100; DV) before and after the one-week VR exposure, two separate two-way repeated measures ANOVAs were conducted. The within factor IV was the time of measurement and had two levels (Pre vs Post the one week of VR exposure), the between factors IV was the VR condition and had two levels (Nature vs Kitchen).

Test of Assumptions

Normality of data distribution of all data was verified through inspection of Q-Q plots and homogeneity of variance was tested with Levene's test. If normality or homogeneity of variance was violated in a t-test, a non-parametric Mann-Whitney test was run instead. If normality was violated in a one-way between subjects ANOVA, a non-parametric Kruskal-Wallis test was run instead. If homogeneity was violated in a one-way between subjects ANOVA, Brown-Forsythe correction was applied. In two-way repeated measures ANOVAs with more than two within-subject's levels, sphericity was tested with Mauchly's test. If sphericity was violated, a Greenhouse-Geisser correction was used. If normality or homogeneity were violated, since no correction can be applied in two-way repeated measures ANOVAs, results were interpreted with caution.

Chapter 6 - Results

Descriptive Statistics

Data from 47 participants were collected. Of these, six participants were excluded because they dropped out (2), interrupted one or more VR sessions (1), or because they did less than five exposures of VR (3). In addition, five participants were excluded because they had a diagnosis different from AN (BN = 4; ARFID = 1). The final sample was made of 36 participants. The participants were all female, mostly adolescents or young adults (mean age: 18) attending school or university. The average BMI was 16.2 (1.6) before the VR intervention and 16.2 (1.6) after the VR intervention, classifying participants as having moderate-severity AN. Descriptive statistics of the final sample's demographics are illustrated in Table 1.

Table 1

Demographic Data of the Final Sample.

Variable	*M* (*SD*) / Frequency (%)
Age (years)	18.0 (5.0)
Schooling (years)	10.8 (2.61)
Gender	
Male	0 (0%)
Female	36 (100%)
Occupation	
Student	34 (94.44%)
Employed	1 (2.78%)
No Occupation	1 (2.78%)
BMI	
Pre VR Intervention	16.2 (1.6)
Post VR Intervention	16.2 (1.6)

Period	
Present	3 (8.33%)
Absent	33 (91.67%)

To characterise the eating disorder's psychopathology of the participants and their general level of distress before the VR intervention, the EDE-Q and DAAS-21 questionnaires were used, respectively (Table 2). Scores at the EDE-Q total (M = 3.9, SD = 1.2) and EDE-Q restriction scale (M = 3.3, SD = 1.6) were higher than in the general population, as expected in a sample of EDs' inpatients (Calugi et al., 2017). The average total score of the DAAS-21 (M = 29.6, SD = 13.5) also revealed a general level of distress that was higher than in the general population (Bottesi et al., 2015).

Participants were randomly allocated to the Nature (20) or Kitchen (16) VR intervention's groups. Within each group, participants could choose every day one of three different scenarios. The distribution of the chosen scenarios for each of the two groups is illustrated in Table 2.

Table 2

Distribution of Scenarios Chosen Over the Five Days of VR Exposure.

Nature		Kitchen	
Scenario Selected	Frequency (%)	Scenario Selected	Frequency (%)
White Winter	35 (35 %)	Kitchen Only	28 (35 %)
Red Fall	29 (29 %)	Avatar	34 (42.5 %)
Blue Ocean	36 (36 %)	Pet	18 (22.5 %)

Feasibility of the VR Intervention

To test Aim 1, the dropout rate, sense of presence, and feeling of discomfort were measured. In addition, spontaneous comments of participants were collected. The dropout rate of participants was low (12.7 %). The average sense of presence was 65.3 (SD = 27.0), and was found to be significantly higher (W = 3052.0, p < .006) in participants in the Kitchen condition (M = 71.2, SD = 25.8) compared to participants in the Nature condition (M = 60.6, SD = 27.2). No difference was found in the sense of presence across the different scenarios ($F(5,174) = 1.95$, p = .088). The average feeling of discomfort was 25.7 (SD = 27.5) and was found to be significantly higher (W = 2369.5, p < .001) in participants in the Kitchen condition (M = 37.4, SD = 29.4) compared to participants in the Nature condition (M = 16.4, SE = 21.9). The feeling of discomfort differed across scenarios ($\chi^2(5) = 23.4$, p = < .001) and was significantly higher in the Kitchen Only scenario compared to the White Winter (t = 3.41, p = .012) and Blue Ocean (t = 3.43, p = .011) and significantly higher in the Avatar scenario compared to the White Winter (t = 3.52, p = .008) and Blue Ocean (t = 3.54, p = .008) scenarios (Figure 10). This data suggests that some of the scenarios in the Kitchen condition are associated to a higher feeling of discomfort compared to some of the scenarios in the Nature condition.

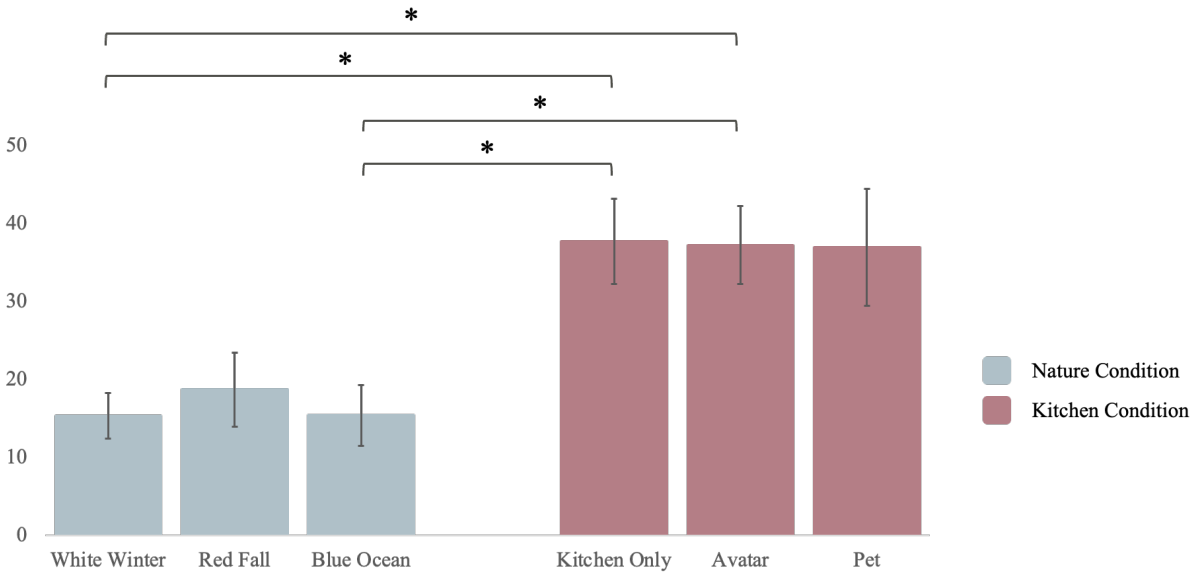


Figure 10. *Difference in the Feeling of Discomfort Across the VR Scenarios.*
Each bar represents the mean feeling of discomfort expressed by participants, while the error bars represent the standard error. The asterisk represents a p-value < .05.

Spontaneous comments that participants made about the chosen scenarios were recorded and are reported in Table 3.

Table 3

Participants' Spontaneous Comments on Their Chosen Scenarios.

VR Condition	Participant's Comment
Nature	"To relax completely, I wish we could interact with animals more"
Kitchen	"I felt discomfort as I tried to move, I was afraid to crash against things. With the joystick, it looks like things will hit me"
	"I tried the elephant on day one and I couldn't bear it anymore after five minutes. Avatars scare me"
	"I felt a bit sick at the beginning"
	"I didn't listen to what it said, after two minutes I became estranged" (referred to the Avatar)
	"I prefer the avatar, it keeps me company"
	"How scary, it's so tall! Does it not stop talking? What if I throw things at him?" (referred to the Avatar. It makes her laugh)
	"The elephant makes too much noise"

Note. The comments were translated from Italian by the experimenter.

Impact of the VR Intervention on Eating- and Food Related Anxiety

To test Aim 2 and Aim 3, the impact of the VR intervention on two measures of eating-related anxiety (NMA and PMA) and on two measures of foods-related anxiety (FA and FW) was tested over time (Aim 2, before vs after the one-week VR intervention) and between conditions (Aim 3, Kitchen vs Nature condition). No change as a consequence of time of measurement ($F(4.72, 160.63) = 1.80$, $p = .119$), VR condition ($F(1, 34) = 0.07$, $p = 0.798$), or their interaction ($F(4.72, 160.63) = 0.62$, $p = 0.68$) was observed in the levels of NMA. This suggests that NMA does not change significantly depending on the day of exposure (Day 1–5), not in the Kitchen condition nor in the Nature condition. NMA of participants in the two VR conditions measured before and after VR exposure over the five days of the intervention is illustrated in Figure 11.

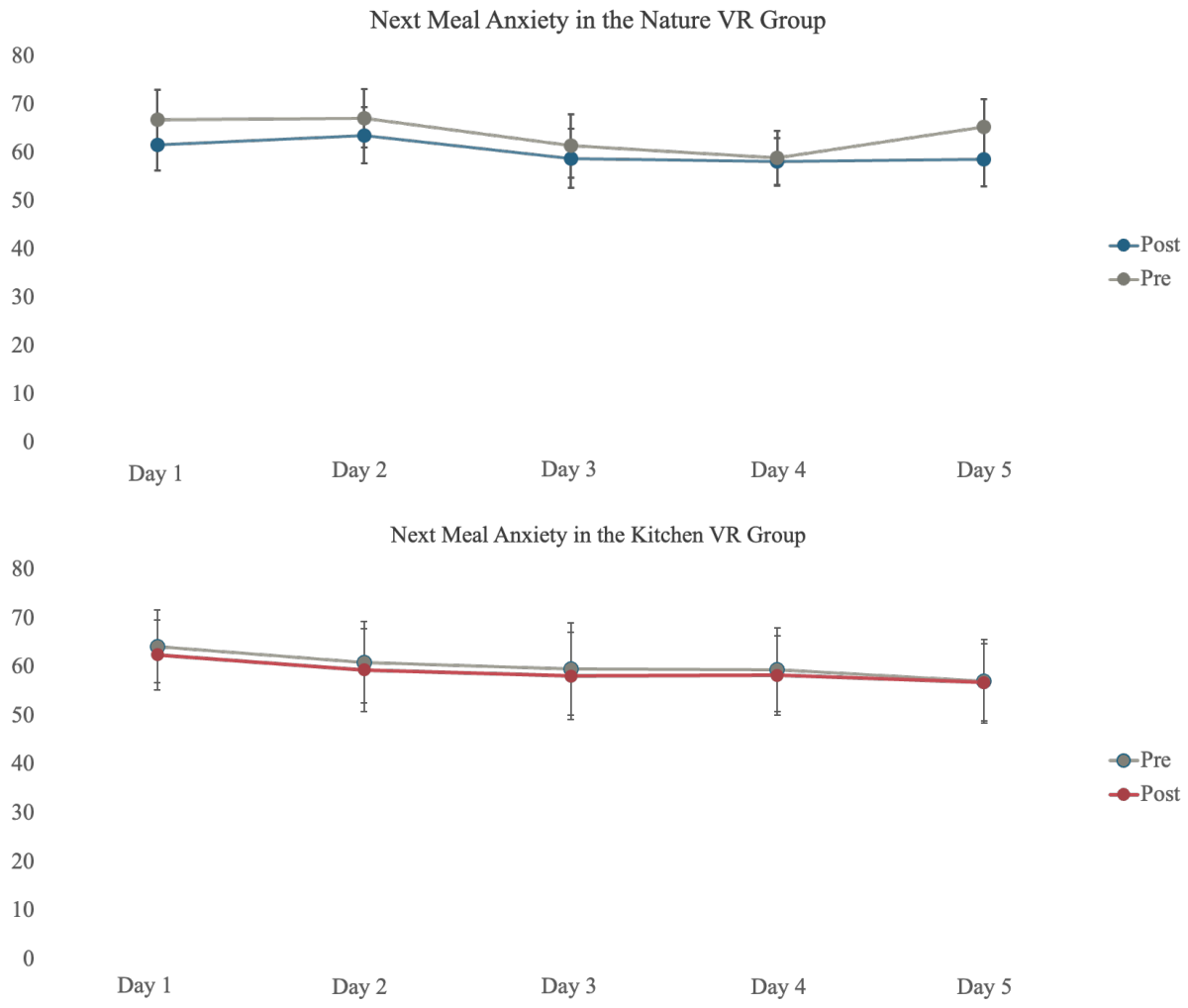


Figure 11. *Next Meal Anxiety Before and After VR Exposure, Over the Five Days of Measurement.*

Each datapoint represents the mean and standard error of anxiety towards the next meal (NMA, 1-100) measured each of the five days of VR intervention, before (pre) and after (post) the five minutes of virtual reality (VR) exposure.

No change as a consequence of time of measurement ($F(1, 34) = 0.43$, $p = .51$, $\eta^2 = 0.002$), VR condition ($F(1, 34) = 2.27$, $p = .141$), or their interaction ($F(1, 34) = 0.12$, $p = .73$) was observed in the levels of PMA. This suggests that PMA does not change significantly whether it is measured before or after one week of VR intervention in neither the two conditions (Kitchen and Nature). PMA of participants in the two groups measured before and after the one week of VR intervention is illustrated in Figure 12.

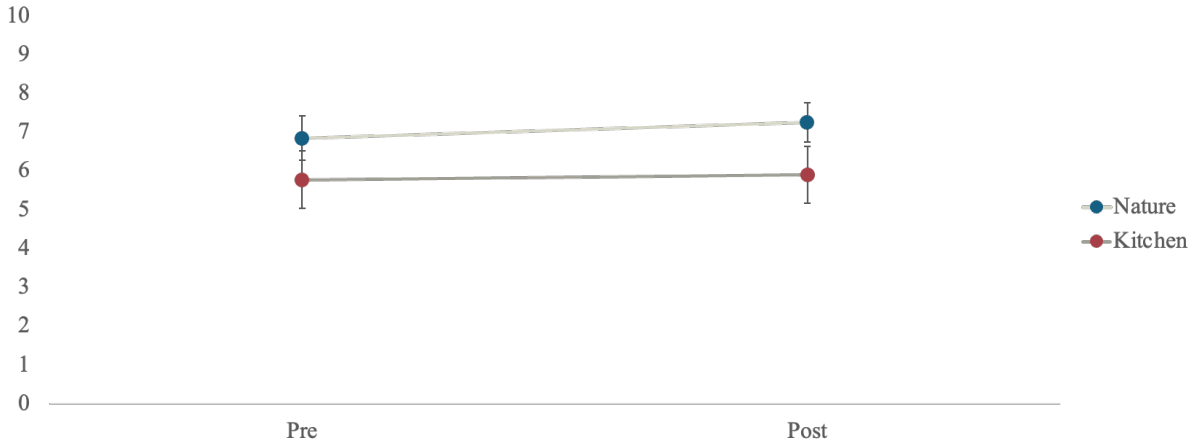


Figure 12. Pre-Meal Anxiety Before and After the One-Week VR Intervention. Each datapoint represents the mean and standard error of pre-meal anxiety (PMA, 1-10) tested immediately before a meal on the Friday before (pre) and after (post) the VR intervention.

To investigate Aim 3, FA and FW were measured before and after the one-week VR intervention. Data for one participant was not collected, therefore the final sample was N = 35. No change as a consequence of time of measurement ($F(1, 33) = 0.06$, $p = .813$), VR condition ($F(1, 33) = 1.8$, $p = .189$), or their interaction ($F(1, 33) = 0.63$, $p = .433$) was observed in FA levels. Likewise, no change as a consequence of time of measurement ($F(1, 33) = 1.27$, $p = .268$), of VR condition ($F(1, 33) = 0.56$, $p = .461$), or of their interaction ($F(1, 33) = 0.02$, $p = .903$) was observed in FW levels. This data suggests that anxiety toward specific foods and avoidance of specific foods does not change significantly whether they are measured before (pre) or after (post) one week of VR intervention in the two VR conditions (Kitchen vs Nature), as illustrated in Figure 13.

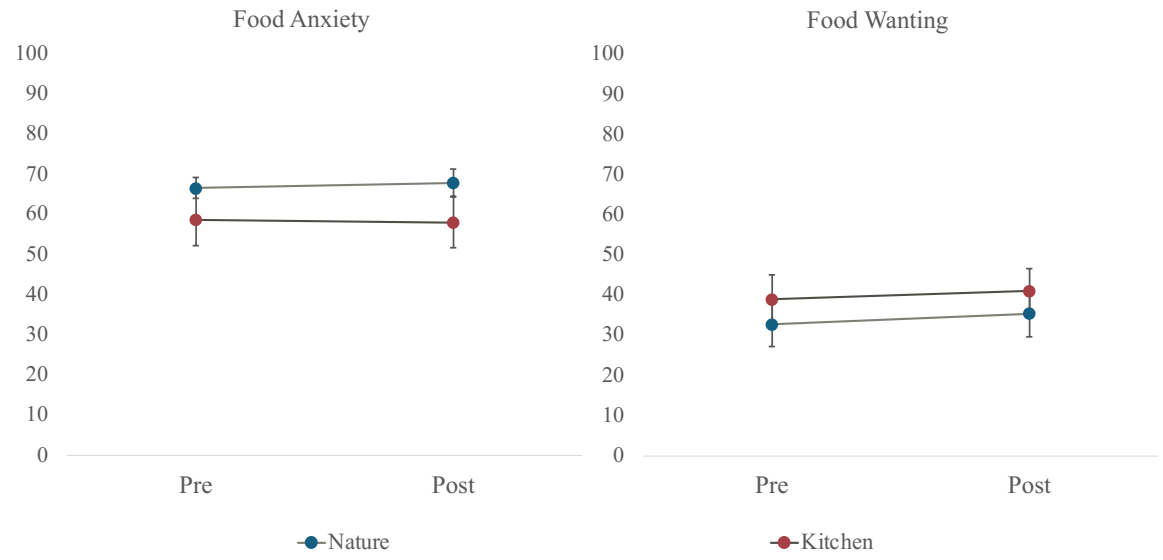


Figure 13. *Food Anxiety and Food Wanting Towards Foods Does not Change After the VR Intervention.*

Each datapoint represents the mean and standard error of Food Anxiety (FA) and Food Wanting (FW, used as a measure of food avoidance) tested on day 0 before starting the VR intervention (pre) and on day 5 after finishing the VR intervention (post). Data from the two VR conditions (Kitchen and Nature) are plotted on different lines.

Discussion

This pilot study investigated the feasibility and impact of a VR exposure intervention on inpatients with AN that were recruited within the first weeks of their arrival in day care structures for the treatment of eating disorders. Before starting the intervention, participants were randomly assigned to one of two groups: an experimental group to be exposed to a kitchen VR environment or a control group to be exposed to a natural environment. The VR intervention lasted five days, and participants were exposed to the VR environment for five minutes every day.

Summary of the Results

Our first aim was to investigate the feasibility of the VR exposure. To explore this aim, the dropout rate from the study was calculated; the sense of presence and feeling of discomfort immediately after VR exposure were measured in participants in both VR conditions; and spontaneous comments of participants about the VR exposure were collected. A low dropout rate, medium-high sense of presence, and medium-low sense of discomfort were observed in our results, suggesting potential feasibility of the VR intervention. Both the sense of presence and the feeling of discomfort were found to be significantly higher in participants in the kitchen VR condition compared to participants in the nature condition. Our second aim was to measure the impact of the VR exposure on anxiety towards eating and food over time. None of the four measures of anxiety analysed in this study changed after the one-week VR intervention. Finally, our third aim was to explore the differences in the impact of the two VR conditions (nature and kitchen) on anxiety towards food and eating. No difference was found in the four measures of eating and food-related anxiety over time and between the two experimental conditions. In this chapter, we will discuss these results as well as suggest some future directions to further investigate the feasibility and use of VRET in the treatment of AN.

Feasibility of the VR Intervention

The first aim of the study was to carry out a preliminary exploration of the feasibility of the VR intervention. First of all, the dropout rate of the participants was low, as only six of the 47 participants from the original sample dropped out, interrupted the intervention, or completed less than five exposure sessions. This suggests that the study was considered acceptable by most participants. After each daily VR exposure, participants were asked to report their sense of presence and their feeling of discomfort. The sense of presence experienced by participants fell in the 65-72 range for both the Nature and the Kitchen condition, suggesting that both environments were evaluated to be moderately immersive by

participants. In addition, the feeling of presence was heightened in participants in the Kitchen condition compared to participants in the Nature condition. The sense of presence is usually determined by both personal characteristics and by the level of immersion provided by the VR instrument, and contributes to the effectiveness of VR experience (Souza et al., 2021; Riva et al., 2022). The reduced sense of presence experienced by participants in the Nature condition could be linked to the low level of interactivity of the Nature condition, where participants were mostly asked to sit down and experience the environment. Consistently, one of the participants reported that they would have appreciated more interaction with animals, that were not responsive to participants immersed in the environment. This finding suggests a possible direction for the improvement of the Nature scenario, introduced for the first time in this study as a control condition. In addition, future studies could consider using more accurate measurements of the sense of presence, that range from subjective scales to objective physiological recordings (Souza et al., 2021).

The feeling of discomfort reported by participants at the end of the VR exposure was in the medium-low range (16-37), and significantly higher for participants in the Kitchen condition compared to participants in the Nature condition. Two of the Kitchen scenarios (Food Only and Avatar) were found to elicit significantly more discomfort than two of the Nature scenarios (White Winter and Blue Ocean). Two interpretations of these results are considered here. The first is linked to the technical aspects of VR, that can cause feelings of dizziness in some participants (Carvalho et al., 2010). The Kitchen scenarios, where participants were asked to stand and actively explore their surroundings, were more interactive than the Nature scenarios, where participants sat on a chair and were asked to relax. It is therefore possible that participants experienced more dizziness and difficulties to handle the VR exposure in the Kitchen condition. Consistently, some of the participants reported dizziness at the beginning of the VR Kitchen exposure, while others reported that it was difficult for them to move using the joystick, as they were scared “to crash against things. With the joystick, it looks like things will hit me.” One solution to minimise this effect would be to encourage participants to physically move in the VR environment, without using the joystick. A second interpretation of the data could be that, when asked to quantify any feeling of physical discomfort caused by VR immersion, participants reported instead a feeling of discomfort caused by the physical symptoms of anxiety, likely heightened in the participants in the Kitchen condition. This interpretation could be especially appropriate given that some AN patients have difficulties to discern their emotions (Oldershaw et al., 2019). To follow up on this possibility, future research could measure physiological

responses of anxiety before and after VR exposure. This could be a more sensitive method to capture signs of anxiety in AN patients, that often present difficulties to express their emotions verbally (Oldershaw et al., 2019).

Finally, some of the participants' comments could be of interest for the improvement of the VR setting. One participant complained about continuous noises that the pink elephant was making, while others described the avatar in the Avatar scenario as "scary" and found their uninterrupted speech annoying. Similar comments were also reported by participants in the study carried out by Natali et al. (2024), suggesting that improvements in the physical aspect and speech of the avatars could increase their acceptability. The Avatar and Pet scenarios were created in collaboration with patients with EDs and added to the Kitchen Only scenario with the goal to maximise the effects of inhibitory learning by adding to the kitchen environment an aspect of social support or of positive mood induction, respectively (Natali et al., 2024). However, comments gathered by this study and research by Natali et al. (2024) suggest that this aim could not have totally met. Future research could follow up on the descriptive comments collected in this study and gather qualitative data on the effects produced by the different scenarios. A qualitative analysis could be used to confirm that the different scenarios were meeting their purpose, and to develop potential directions for their improvement.

Assessing the Impact of a VRET Intervention on Anxiety Towards Eating

The second and third aim of the pilot study investigated the impact of one week of exposure to one of two different VR conditions (Kitchen and Nature) to reduce anxiety towards eating and foods in the participants. To achieve a good sensitivity in the data, anxiety towards food and eating was measured in four different ways. First, anxiety when thinking about the next meal (Next Meal Anxiety, NMA) investigated how anxiety towards an imagined, potentially phobic situation would decrease over the five days of VR exposure. Daily measures before and after VR exposure allowed to closely monitor the changes occurring immediately after VR exposure without burdening the participants with longer, more detailed enquiries. Second, the level of anxiety towards a meal (PMA) was measured immediately before the patients consumed a standardised meal in the day care centre, a critical moment for patients with AN undergoing intensive treatment (Treasure et al., 2012). Finally, a visual food evaluation scale was used to assess both anxiety (FA) and wanting (FW) and towards individual foods (Natali et al., 2024).

These measurements served different purposes. First, our data showed that eating and foods elicited medium-high levels of anxiety in participants. These data is consistent with

previous research that identified food as a phobic stimulus for people with AN (Levinson & Williams, 2020; Murray et al., 2016). In addition, our results showed how wanting for foods is quite low, which is consistent with previous research suggesting that anxiety towards food in patients with AN leads to its avoidance and to the creation of extreme rules that in turn facilitate its avoidance, which results in rigid behaviours and severe caloric restriction that are among the symptoms of AN (Fairburn et al., 2003; Schaumberg et al., 2021; Schroeder et al., 2024).

Although informative to characterise our sample and patients with AN, none of the variables used to measure anxiety towards eating and foods changed after the one-week VR intervention in neither of the two VR conditions. This is not consistent with previous studies that have showed that similar interventions were effective, among other things, to reduce anxiety towards eating and food (Cardi et al., 2012; Natali et al., 2024). A number of reasons are offered to explain these outcomes.

Characteristics of the Virtual Reality Intervention

Duration of VR Exposure

The choice to use VR was rooted in the principles of the inhibitory learning model and of expectancy violation in particular (Craske et al., 2014). According to expectancy violation, aim of the exposure intervention is to maximise the gap between the feared CS, in this case food, and its expected outcomes—in AN, typically loss of control and weight gain. VR is therefore suited for this purpose, as it provides both distal (the kitchen environment) and proximal (the foods present in the kitchen) stimuli that have been shown to elicit similar emotional responses as real foods (Gorini et al., 2010; Wiederhold et al., 2016). At the same time, participants are offered the opportunity to interact with their feared stimulus in a "safe" context, without having to face the feared consequences.

Exposure length was one of the possible limitations on the impact of the VR kitchen exposure on anxiety towards foods and eating. A case study by Cardi et al. (2012), that had similar overall duration (one week) and also used a virtual exposure setting, consisted in seven sessions that were 60-minute long. The exposure time was therefore much longer than the five minutes used in this study, which possibly were not sufficient to create a new, more positive response associated with food. In fact, many effective VRET interventions, as well as exposure interventions, for EDs have longer duration, both in terms of individual sessions and of length of the whole treatment (Butler & Heimberg, 2020; Ferrer-García et al., 2017; Riva et al., 2021). The short length of our exposure is explained by the exploratory nature of our study, and could have affected its outcome (Natali et al., 2024).

Therapeutic Intervention

In our study, the lack of therapeutic intervention in combination to ET is another important difference with ET treatments in EDs, including those using VR (Cardi et al., 2019; Riva et al., 2003). In these studies, the therapist used a number of cognitive restructuration techniques to support the exposure intervention. For example, Craske et al. (2014) suggests eliciting from the patient the feared outcome of the exposure before starting the session, and to recognise and highlight the non-occurrence of the feared outcome after the exposure; to weaken the association between phobic CS and US (expectancy violation). In addition, exploring the patient's feared outcome before planning the exposure intervention would ensure identification of the correct CS and US, thus increasing the effectiveness of ET (Murray et al., 2016).

Therapeutic support could also improve the emotion regulation aspect of the inhibitory learning model, where the patient is asked to explicitly identify their negative emotions (affect labelling) and to challenge them (Craske et al., 2014; Steinglass et al., 2011). Therefore, emotion regulation in ET for EDs could lead to a reduction of the negative valence associated with food and eventually to learning better coping strategies (Reilly et al., 2017). Finally, it is important to highlight that fear of food is closely associated to the consequences of eating: weight gain, loss of control, but also a disruption of self-concept (Murray et al., 2016). Exposure to food without a therapeutic intervention challenging the core negative beliefs around food and eating that characterise AN could reduce the effectiveness of ET and contribute to maintenance of the disorder (Butler & Heimberg, 2020).

Given the role of the therapeutic intervention in ET, other studies have proven effective without the presence of a therapist, in the treatment of specific phobias and EDs (Freeman et al., 2018; Natali et al., 2024). Avoiding mixed forms of interventions in our exploratory study was important to reduce the variables at play; also considering that the participants recruited in our study were already receiving standard treatment (usually in the form of individual CBT-ED sessions) as part of their intensive treatment within the day hospital structures. in addition, one of the aims of our research was to explore the effectiveness of a treatment that could be eventually used self-delivered treatment. A possible option for future research could be to combine VRET with a standardised, self-help protocol that would minimise the inter-therapist variations while still be suitable for a self-directed use of the intervention by patients.

Timing of Delivery

Finally, the timing of the VRET intervention should be considered. Investigating the relationship between ET and AN, Murray et al. (2016) highlighted that exposing AN patients to phobic foods during the phase of weight recovery might be counterproductive, as the expectancy of gaining weight would not be violated but reinforced—as it is part of the treatment itself. According to Murray et al. (2016), instead, weight gain itself should be targeted as the CS during the weight recovery phase, with the US being the fear of criticism from others and the threat to the concept of self. After weight normalisation, exposure to feared foods could be more effective because the expectancy of exaggerated weight gain as a consequence of eating them would be violated.

Following these principles and expectancy violation, the current study used virtual food stimuli because they could not lead to weight gain, therefore breaking the association between CS and feared outcome. However, virtual foods are highly realistic and were shown to elicit similar emotional responses as reals foods (Gorini et al., 2010; Wiederhold et al., 2016). This suggests that an overlap between virtual and real foods could occur and hinder the effects of VRET, especially in a phase of AN where starvation biologically contributes to impair extinction of learning (Murray et al., 2016; Schaumberg et al., 2021). Participants in our exploratory study were patients with moderate AN severity, a low BMI, and had recently started an intensive semi residential treatment. As part of the treatment, patients were required to eat standardised meals in a set amount of time three times a day (two snacks and a lunch). The meals were agreed by patients together with the clinical team, but still represented an important challenge for the patients at this stage of the treatment. It is therefore possible that the disease severity of patients that took part in this study, the early phase of the intensive treatment they were facing, and the limited control they had over the quantity and quality of food were consuming contributed to increasing an aversion and anxiety towards food that could not be counteracted by the VR intervention. Future research could test this VRET intervention at a later stage of the AN treatment, for example during outpatient treatment, when patients have already undergone most of the weight recovery phase and have more control over their nutrition.

The considerations by Murray et al. (2016) and the findings of this exploratory study, however, are in contrast with research showing that VRET can be effective in reducing food-associated anxiety even with patients that are still in the weight recovery phase (Cardi et al., 2012; Natali et al., 2024). One possible explanation for this apparent contradiction is that weight gain is not necessarily the US, or the only US, associated to food; loss of control or

appearing disgusting, for example, are common US in patients with AN that could be targeted with VRET during the weight recovery phase without being affected by weight gain (Cardi et el., 2019; Levinson & Williams, 2020; Murray et al., 2016). In addition, even considering weight gain as a potential US, during therapy a difference could be made by the modality of the feared increase in weight (sudden, exaggerated, unstoppable) compared with the regulated and targeted weight gain occurring during treatment (Cardi et el., 2019). An ideographic approach, when the relationship between CS and associated US is dissected for individual patients before planning the treatment, could be appropriate to device more effective interventions (Butler & Heimberg, 2020; Murray et al., 2016).

Characteristics of the Virtual Reality Setting

Presentation and Handling of Foods

Participants in the experimental group were immersed in a virtual reality kitchen and given the possibility to handle a large range of foods, from low-calorie such as a pineapple to high-calorie such as chocolate ice-cream. This followed the principles of cognitive psychology and inhibitory learning, that suggest that using a variety of feared stimuli improves learning consolidation (Bjork & Bjork, 2013; Bouton, 1993; Craske et al., 2014).

In a classical ET protocol based on the habituation model of extinction, patients are asked to identify a list of phobic stimuli and then place them in order according to the anxiety that each stimulus elicits; after that, patients are exposed to the least phobic stimulus to begin with, and proceed upwards in the hierarchy as their level of anxiety towards each stimulus drops (Choy et al., 2007; Mystkowski et al., 2002). This model has been successfully used in the context of ET for EDs as well (Ferrer-García et al., 2017; Steinglass et al., 2011). According to the inhibitory learning model used in this study, however, phobic stimuli should be presented in a random order to maximise patients' violation of expectations (Craske et al., 2014). If this justifies the setting in our study, future research could add some personalisation of the food stimuli presented in the virtual kitchen. The range of stimuli were chosen based on research using in vivo food exposure by Cardi et al. (2019), and therefore are relevant as phobic stimuli in AN. However, using a selection of foods that are considered phobic by individual participants could make the intervention more relevant for the patients, and therefore more effective (Ferrer-García et al., 2017; Murray et al., 2016).

Finally, it is worth commenting on the instructions delivered by the instructors before starting VR exposure sessions. Participants were asked to explore the virtual kitchen, without receiving any specific indication on which foods to handle of for how long. In addition, the timing and modality of the interactions were not recorded in the study. According to the

principle of attentional focus illustrated by Craske et al. (2014), during ET participants should be encouraged to maintain their attention on the phobic stimulus to potentiate the CS-no US association. In addition, Craske et al. (2014) suggests to encourage the patients to refrain from performing safety behaviours to avoid associating the reduction in anxiety to their enactment. In this study, we did not verify whether participants were actually handling foods or whether they were selectively handling low-calorie foods and avoiding high-calorie foods. In addition, two out of the three Kitchen scenarios contained potential distractors (avatar and pet) that could have been used by the participants as safety behaviours to avoid focussing on the phobic stimulus (Natali et al., 2024). Future research could include more precise instructions for participants and monitor their behaviour in the VR kitchen environment. This could help to establish a connection between the modalities of food handling (timings, caloric content) and the changes in anxiety after the VR intervention.

Generalizability of the Kitchen Scenario

Use of a kitchen environment as the distal stimulus represents one of the advantages of applying VR to ET: exposing patients to settings that are more ecological than a hospital room (Perpiñá & Roncero, 2016; Roncero & Perpiñá, 2015). However, in our study the distal stimulus (the kitchen environment) did not change across sessions. A range of studies have revealed the limitations of carrying out ET studies in just one environment, usually a clinical setting, as they will fail to generalise to future, more ecological, environments: referring again to the inhibitory learning, using only one environment for ET makes it more likely that real-life environments will trigger old, fearful memories (Craske et al., 2014; Treasure et al., 2012). In addition, adding a social element to the exposure could be relevant for AN patients that are particularly vulnerable to criticism by others (Murray et al., 2016). Our study added elements of diversity by offering participant to choose among three scenarios; however, the addition of the avatar or elephant to the same kitchen environment could have not been sufficient. Future interventions could therefore consider including other VR environments, such as restaurant, café, school canteen, to maximise generalizability of fear extinction after VRET.

Strengths and Limitations of the Study

This pilot study aimed to advance research on the feasibility and impact of a VRET intervention on food- and eating-related anxiety in patients with AN. It followed up on the study carried out by Natali et al. (2024), adding a control condition (Nature environment) to improve the study design. One important limitation of the current study was the low number of participants (36 participants versus 145 in the study by Natali et al., 2024). In addition, the

current study did not allocate participants to one of the three scenarios, and participants were asked to choose the scenario at the beginning of each exposure session instead. This choice was made to reduce the number of variables at stake in this exploratory study, also considering the reduced number of participants; but could have acted as a confound on the impact of the intervention on food- and eating-related anxiety levels in the participants. Therefore, this pilot study can be considered as a starting point for future research aimed to evaluate the feasibility and impact of similar interventions, that could use both quantitative measures (e.g., feeling of discomfort after VR exposure, dropout rates, measurements of anxiety towards food and eating) and qualitative measures (e.g., comments and opinions of the participants on the scenarios selected and the VR experience).

Conclusions

Given the need for alternative treatments for AN, the current pilot study aimed to explore the feasibility and impact of a virtual reality exposure therapy intervention on food- and eating-related anxiety of a sample of patients with anorexia nervosa. Modelled on previous research that used similar VR settings, this study added a control condition (Nature environment) to the experimental condition (Kitchen environment) that had been tested in previous studies. Results of the current research suggested that the VRET intervention had a good feasibility, given the low dropout rates and the medium-high sense of presence and medium-low feeling of discomfort experienced by participants after VR exposure. On the other hand, the levels of eating-related and food-related anxiety after the one-week of VR intervention did not differ between the nature and the kitchen VR conditions.

Future research could follow up on the findings of this exploratory study to improve the feasibility and impact of VRET on food- and eating-related anxiety in patients with AN. Among those discussed, some prospects could be to increase the number of participants to acquire more statistical power; to deliver the intervention at a later phase of the AN treatment, when food aversion of patients is likely to be reduced; to lengthen the time of the virtual reality sessions in order to increase exposure time to the phobic stimuli; and to monitor the time and modality of interactions of the participants with the different foods. Finally, we suggest using qualitative analysis to obtain more precise and comprehensive feedback on the intervention and on the VR scenarios used, to be able to improve both their feasibility and therapeutic efficacy.

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