Eye-Tracking and Virtual Reality-based Attentional Bias Modification Training to Improve Mirror Exposure Therapy: preliminary findings from a multiple case study with Anorexia Nervosa patients

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Abstract. Attentional bias modification training (ABMT) is an effective technique for reducing the dysfunctional body-related attentional bias (AB) that may be responsible for reducing the effectiveness of mirror exposure therapy (MET), which has been proposed as an effective treatment for anorexia nervosa (AN). This multiple-case study provides evidence of the usefulness of incorporating ABMT into virtual reality (VR) and eye-tracking (ET)-based MET to improve its efficacy in the treatment of four female adolescents with AN. Over five exposure sessions, patients were immersed in a virtual environment and were embodied in a real-size body virtual avatar reflected in a mirror that gradually increased body mass index (BMI) until reaching a healthy BMI in the last session. In every session, the participants completed the ABMT followed by the MET. This augmentation of MET using VR-ET-based ABMT achieved promising results for targeting AN symptomatology by reducing body dissatisfaction, drive for thinness, weight-related body parts anxiety, body checking behaviors, fear of gaining weight, and anxiety, and increasing body appreciation. Two patients who did not show a reduction in fear of gaining weight during the sessions also showed high anxiety levels, which could have affected its reduction. To advance this preliminary study and evaluate the effectiveness of incorporating ABMT into MET, a controlled clinical trial will be conducted.

Keywords. Anorexia nervosa, attentional bias modification training, mirror exposure therapy, virtual reality, eye-tracking

1. Introduction

Patients with Anorexia Nervosa (AN) show a phenomenon known as body-related attentional bias (AB), i.e., the tendency to focus more attention on self-reported unattractive body parts and weight-related body parts than other body parts [1-3].

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The presence of dysfunctional body-related AB may be responsible for reducing the effectiveness of mirror exposure therapy (MET) [2], which is frequently used to intensify traditional cognitive behavioral therapy (CBT) and has been proposed as an effective treatment for AN by reducing eating disorder (ED) symptomatology [3,4]. MET involves the patient systematically observing their body reflected in a mirror for a certain amount of time expressing their emotions and thoughts about their body [5]. Patients with AN who tend to focus more on weight-related body parts and ignore non-weight-related body parts (interfering with the exposure-based task) could benefit less from MET [2].

By means of attentional bias modification training (ABMT) it is possible to reduce AB by altering selective attention patterns [6]. A previous study developed an effective ABMT based on a combination of virtual reality (VR) and eye-tracking (ET) by balancing attention between weight-related body parts and non-weight-related body parts in healthy subjects, thus achieving equilibrated attention to the whole body [7]. The combination of VR and ET devices allows accurate and objective control of the attentional patterns in settings simulating real-life situations in highly controlled situations, overcoming the limitations of the traditional ABMT techniques [8].

This multiple-case study aims to provide preliminary evidence of the usefulness of incorporating ABMT into a VR and ET-based MET to improve its results in the treatment of four female adolescents with AN.

2. Method

2.1 Participants

Four female adolescents diagnosed with restrictive AN, according to the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) [9], at the ED Unit of Hospital Sant Joan de Déu of Barcelona, participated in this study. Patient 1 was 14 years old, presented with an adjustment disorder with anxiety, received pharmacological treatment based on antidepressants and antipsychotics and underwent 11 hours of intensive day-patient treatment. Patient 2 was 16 years old, underwent 5 hours of day-patient treatment, did not present any comorbidity, and did not receive any pharmacological treatment. Patient 3 was 17 years old, presented with a major depressive disorder and anxiety disorder, received pharmacological treatment based on antidepressants and occasional anxiolytics and underwent 11 hours of intensive day-patient treatment. Patient 4 was 17 years old, presented with a major depressive disorder, received pharmacological treatment with anxiolytics and antidepressants and underwent outpatient program treatment.

The outpatient program was for patients with good treatment compliance and lower biopsychological risk, whereas the day-patient treatment (sleeping at home) was for those whose weight restoration and eating behaviors were not improving. The treatment at the ED Unit consisted of individual and group CBT, nutritional rehabilitation, and individual and group parent counseling.

2.2 Instruments

Participants were exposed to an immersive virtual environment using a head-mounted display (HMD HTC VIVE Pro Eye®) with an integrated ET device (Tobii®) and were embodied in a real-size body virtual avatar. In addition to the head-mounted display, two hand controllers and two-foot trackers were used to achieve full-body motion tracking of the patients. The VR environment was designed using Unity 3D 5.6.1 software and consisted of a room with a large mirror on the wall placed 1.5 virtual meters in front of the patient, and two boxes placed on the floor next to the avatar's feet. The patients could see themselves, through their avatars, in the first-person perspective and the third-person perspective, reflected in a mirror, even when they were moving. The virtual avatar was designed using the Blender v. 2.78 software. The avatar wore a simple top with jeans, which could be changed in color to match the participants' clothing, black trainers, a head-mounted display, like the patient during the task, and a grey hat to reduce any influence of hairstyle.

2.3. Measures

The following measures were assessed before starting the treatment (pre-treatment) and at the end of the treatment (post-treatment):

- The change in body weight was assessed using body mass index (BMI).
- Body dissatisfaction was assessed using the Spanish version of the body dissatisfaction subscale of the Eating Disorder Inventory-3 (EDI-BD) [10].
- Drive for thinness was assessed using the Spanish version of the drive for thinness subscale of the Eating Disorder Inventory-3 (EDI-DT) [10].
- State weight-related body parts anxiety was assessed using the weight subscale of the Physical Appearance State and Trait Anxiety Scale (PASTAS) [11].
- Frequency of body-checking behaviors was assessed using the Body Checking Questionnaire (BCQ) [12].
- Body appreciation was assessed using the Body Appreciation Scale (BAS) [13].

Full body ownership illusion over the virtual avatar, i.e., feeling the virtual bodies as their own, fear of gaining weight and anxiety were assessed in each of the treatment sessions, as well as before and after the overall intervention through Visual Analogue Scales (VAS) from 0 to 100.

2.4. Procedure

The ethics committees of the Universitat de Barcelona and Hospital Sant Joan de Déu of Barcelona approved this study. Before treatment, written informed consent was obtained from the patients and their parents. The treatment was conducted over five sessions, once a week, with a pre-treatment session and a post-treatment session.

During the pre-treatment session, the virtual avatar was created by taking a frontal and a lateral photo of the patient. The photos and the silhouette of the virtual body were manually matched by adjusting the avatar's body parts to the patient's silhouette. In the meantime, the patients completed pre-treatment questionnaires and then were immersed in the virtual environment. After inducing the full body ownership illusion, using a 5-minute procedure, including visuo-motor and visuo-tactile stimulation techniques [14], the full body ownership illusion, the fear of gaining weight and the anxiety levels were assessed using the VAS.

Each clinical session was carried out in the virtual environment and was characterized by inducing the full body ownership illusion, completing the ABMT followed by the MET and assessing the full body ownership illusion, fear of gaining weight and anxiety levels using the VAS. At the end of each session, the patients were exposed to a relaxing VR environment for 5 minutes. In the first session, each patient was exposed to a virtual body with her real BMI. During subsequent sessions, the BMI of the avatar progressively increased until it reached a healthy BMI.

The ABMT was based on an adaptation of the AB induction procedure proposed by Smeets et al. [6] and was developed through the visual selection of geometric figures with different colors that fitted with specific body areas. Patients were instructed to detect and identify the figures that appeared on different parts of the avatar's body reflected in the mirror. Specifically, participants were asked to stare for 4 seconds at the specific body part where the figures appeared, while it was progressively illuminated. Afterwards, the figure appeared on another part of the body. In 45% of the trials, the geometric figures appeared on weight-related body parts, in another 45% of the trials the figures appeared on non-weight-related body parts and in the remaining 10% of the trials the figures appeared on two neutral stimuli located next to the avatar (Figure 1a-c).

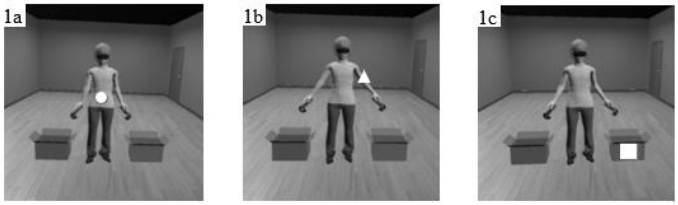

Figure 1. Geometric figures appear on a weight-related body part (1a), on a non-weight-related body part (1b), and on a neutral stimulus (1c).

During MET, the patient was asked to focus on different parts of the virtual body and to orally report her thoughts and feelings about them. The level of anxiety experienced was evaluated every 120 seconds using a VAS. Each of the following treatment sessions began with an avatar with a progressively increasing BMI following the hierarchy only if anxiety had fallen by 40% in the last session.

In the post-treatment session, the patients answered the post-treatment questionnaires and then were immersed in the virtual environment. After inducing the full body ownership illusion, the levels of fear of gaining weight, full body ownership illusion and anxiety were assessed using the VAS.

2.5. Statistical analysis

Reliable changes were calculated for the post-treatment measurements only for the measures with available clinical and community means and standard deviations, provided by the sources for each measure: EDI-DT, EDI-BD, PASTAS, BAS and BCQ. The analyses were conducted following the guidelines of Jacobson and Truax [15] and using the Leeds Reliable Change Index (RCI) calculator in Excel [16] for single cases. An RCI that is greater than 1.96 denotes a reliable change, i.e., a statistically significant difference.

3. Results

Scores from the questionnaire administered pre- and post-treatment for the body dissatisfaction, drive for thinness, body anxiety, body appreciation, and body-checking behaviors variables and their related RCI are given in Table 1 below.

Table 1. Patients' pre-treatment and post-treatment scores and RCIs for body dissatisfaction, drive for thinness, weight-related body parts anxiety, body appreciation and body checking behavior variables.

	PATIENT 1			**PATIENT 2**			**PATIENT 3**			**PATIENT 4**		
	Pre treatment score	**Post treatment score**	**RCI**	**Pre treatment score**	**Post treatment score**	**RCI**	**Pre treatment score**	**Post treatment score**	**RCI**	**Pre treatment score**	**Post treatment score**	**RCI**
EDI-BD	29	14	2.97*	34	31	0.59	34	30	0.79	27	16	2.18*
EDI-DT	25	3	5.68*	28	28	0	28	25	0.77	14	5	2.32*
PASTAS	22	5	9.64*	20	11	5.1*	23	21	1.13	1	4	-1.7
BAS	18	48	-6.82*	15	18	-0.68	24	28	-0.91	24	46	-5*
BCQ	76	46	3.27*	102	90	1.31	90	73	1.85	49	36	1.42

Note: RCI= reliable change index; EDI-BD: body dissatisfaction subscale; EDI-DT: drive for thinness subscale; PASTAS: Physical Appearance State and Trait Anxiety Scale; BAS: Body Appreciation Scale; BCQ: Body Checking Questionnaire. Significant differences *RCI >1.96.

Pre- and post-treatment BMI values and VAS scores for full body ownership illusion, fear of gaining weight and anxiety assessed in each of the treatment sessions, as well as before and after the overall intervention, are given in Figure 2 and Figure 3a-c, respectively.

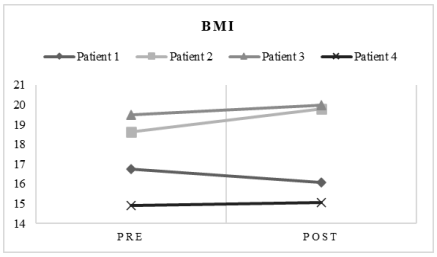

Figure 2. Body mass index (BMI) values pre-treatment (PRE) and post-treatment (POST).

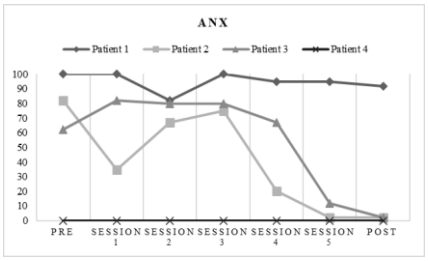

Figure 3a. Anxiety (ANX) scores pre-treatment (PRE), during the five-exposure sessions and post-treatment (POST).

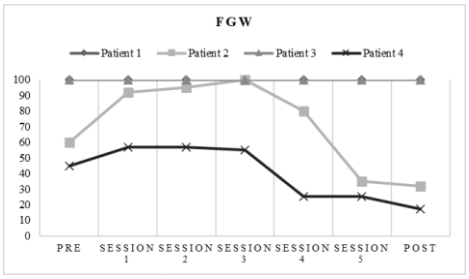

Figure 3b. Fear of gaining weight (FGW) scores pre-treatment (PRE), during the five-exposure sessions and post-treatment (POST).

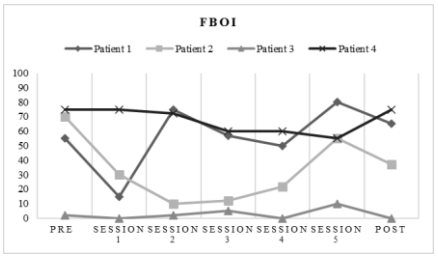

Figure 3c. Full body ownership illusion (FBOI) scores pre-treatment (PRE), during the five-exposure sessions and post-treatment (POST).

Patient 1 showed a significant reduction in body dissatisfaction, drive for thinness, body anxiety, and body-checking behaviors and a significant increase in body appreciation. Across all sessions, the patient maintained a medium-high full body ownership illusion level and a very high level of fear of gaining weight and anxiety, which was not reduced by 40% during any session. Patient 2 showed a significant reduction in body anxiety and a very slight non-significant improvement in body dissatisfaction, body appreciation and body-checking behaviors. There was no change in drive for thinness. In the first few sessions, this patient showed a low level of full body ownership illusion and a high level of anxiety with no reduction in fear of gaining weight. During the last few sessions, the level of full body ownership illusion became higher, the level of anxiety declined by 40%, allowing her to progress through the BMI hierarchy, and the fear of gaining weight levels decreased. Patient 3 showed a very slight non-significant improvement in body dissatisfaction, drive for thinness, body anxiety, body appreciation and body-checking behaviors. This patient showed very low full body ownership illusion, high anxiety levels that were only reduced by 40% during the last session and post-treatment, and very high levels of fear of gaining weight. Patient 4 showed a significant improvement in body dissatisfaction, drive for thinness and body appreciation and a non-significant improvement in body-checking behaviors. The level of body anxiety pre-treatment was zero and this level was maintained even post-treatment. A medium-high level of full body ownership illusion and absence of anxiety were maintained across all sessions, allowing her to progress through the BMI hierarchy until she reached the minimum healthy weight of the avatar in the last session. Fear of gaining weight levels decreased from the 4th treatment session onwards.

Most participants' BMI increased slightly during the sessions (except for patient 1 whose BMI decreased slightly) but none of the patients reached the minimum healthy weight.

4. Conclusion

This augmentation of MET using VR-ET-based ABMT achieved promising results for targeting AN symptomatology, improving body dissatisfaction, drive for thinness, body anxiety, body-checking behaviors and body appreciation even if not significantly for all

patients. In addition, BMI levels were slightly improved at the end of the intervention, except in one patient.

ABMT before VR-ET-MET aims to enhance the reduction of ED symptoms and fear of gaining weight through exposure to a gradual increase in BMI [3]. Two patients did not show a reduction in fear of gaining weight during the sessions. Patients 1 and 3, both reporting anxiety disorders, showed a very high level of anxiety, which was not reduced by 40% during the sessions, thus preventing them from progressing through the BMI hierarchy. Patients who were not exposed to a virtual body with an increased BMI could not have developed a habituation process to the anxiety response that gaining weight could activate, therefore, this could explain the failure to reduce fear of gaining weight levels [17]. However, patient 1 showed a high level of full body ownership illusion that increased identification with the avatar with her real weight during the ABMT and MET sessions, probably helping to improve the effectiveness of the treatment. In contrast, patient 3 reported the absence of full body ownership illusion during all sessions and did not identify herself with the virtual avatar, which could explain the lack of effect of the treatment [3].

The current study assessed the incorporation of a pioneering ABMT procedure into MET, taking advantage of VR and ET technologies that might open up a wide range of possibilities for new body-related interventions in patients with AN that could help improve their symptomatology. A controlled clinical trial should be conducted to advance this preliminary study and evaluate the effectiveness of incorporating ABMT into VR-ET-based MET. Our group has already started a randomized controlled clinical trial (clinicaltrials.gov, NCT 04786951) in which we are comparing three experimental conditions: ABMT before VR-ET-MET with added CBT, VR-ET-MET with added CBT, and CBT alone.

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