applied sciences

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Attentional Bias Modification Training in Virtual Reality: Evaluation of User Experience

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Abstract: Recent technological advances have paved the way for incorporating virtual reality (VR) into attentional bias modification training (ABMT) for the treatment of eating disorders. An important consideration in this therapeutic approach is ensuring the ease and comfort of users of the hardware and software, preventing them from becoming additional obstacles during treatment. To assess this, 68 healthy participants engaged in an ABMT experiment aimed at evaluating various factors, including usability as well as the participants' comfort while using the VR equipment, task-induced fatigue, and attitudes towards the technology. Our results indicated a favorable usability level for the ABMT proposed in this study. While their discomfort, anxiety, and fatigue increased during the task, these did not significantly impact its execution. However, heightened anxiety and fatigue were linked to lower evaluations of software usability. Other variables considered in the experiment did not notably affect the task.

Keywords: attentional bias modification training; virtual reality; user experience; eye-tracking; eating disorders

Citation: Mendoza-Medialdea, M.T.; Carballo-Laza, A.; Ascione, M.; Meschberger-Annweiler, F.-A.; Porras-Garcia, B.; Ferrer-Garcia, M.; Gutiérrez-Maldonado, J. Attentional Bias Modification Training in Virtual Reality: Evaluation of User Experience. *Appl. Sci.* **2024**, *14*, 222. https://doi.org/10.3390/app14010222

Academic Editor: Chaman Sabharwal

Received: 11 December 2023
Revised: 22 December 2023
Accepted: 23 December 2023
Published: 26 December 2023

1. Introduction

Virtual reality (VR) has emerged as a transformative technology, offering an immersive three-dimensional environment for diverse applications, including education, training, and psychological therapies [1]. Its integration into psychological treatment has not only eliminated physical limitations to treat a wide range of psychological disorders but has also allowed for the introduction of new techniques and expanded the treatment capacity of existing ones [2,3]. Notably, within this realm, VR has exhibited promising results in addressing eating disorders by enhancing diagnostic accuracy, creating a better relationship between food and its emotional reactions, and modifying body-related experiences [4].

Research has shown that individuals with anorexia nervosa often focus their attention on the more distressing aspects of their bodies [5]. This habitual attentional bias is consistently linked to disruptions in body image and is believed to contribute to intensifying negative emotions related to body image and the adoption of unhealthy behaviors aimed at altering body shape and weight, which are commonly observed in eating disorders [5]. Furthermore, this attentional bias might be amplified during mirror exposure therapy. Some studies indicate that prolonged mirror gazing could lead to distorted thinking and

an exaggerated emphasis on perceived flaws [6], potentially undermining the effectiveness of mirror exposure therapies in certain cases. To reduce this attentional bias, several studies have effectively applied attentional bias modification training (ABMT) involving food-related cues, which reduced the attentional bias towards high-calorie food and, consequently, decreased its consumption in patients with binge eating disorders [7,8]. Other studies have used ABMT to diminish the attentional bias toward negative words associated with body image [9], which could potentially increase dissatisfaction and dietary restrictions [10]. Moreover, exposure to images of participants' body parts improved their body satisfaction if those body parts were considered attractive and enhanced their body dissatisfaction if they were considered unattractive [11]. In more recent studies, ABMT procedures have incorporated VR techniques involving avatars mirroring participants' silhouettes. These methods have been applied to both healthy individuals [12] and patients diagnosed with anorexia nervosa [13]. They resulted in a decrease in attentional bias towards body parts associated with weight in both healthy individuals and patients, and reduced body dissatisfaction in those with anorexia nervosa.

Using VR in ABMT allows for the modification of attentional biases in a more realistic setting, resembling environments closer to real-life scenarios than traditional laboratory or doctor's office setups. However, implementing VR in this kind of training requires user-friendly hardware and software to avoid creating additional barriers during treatment. Studies have shown that poor usability of software is linked to a reduced willingness to use it [14,15]. Specifically, in ABMT, participants may find these tasks monotonous and repetitive, potentially leading to dropout from treatment [16,17]. Discomfort and fatigue from extended use of VR glasses pose another challenge, potentially disrupting ongoing treatment [18]. Additionally, attitudes toward technology play a role in its acceptance [15]. The negative impact of any of these factors can hinder the progress of therapy, diminishing its effectiveness.

The current study aimed to assess various aspects of an ABMT task conducted in VR, like its usability as well as participants' anxiety, fatigue, negative attitudes towards technology, and other factors. These elements could potentially impact how effective this training is for patients with eating disorders.

2. Materials and Methods

2.1. Participants

Sixty-eight healthy college students from the University of Barcelona (four of them men) voluntarily participated in this study. Participants were recruited via social networks and flyers placed around the university campus. The mean age of the participants was 24.91 years (SD: 6.76). The exclusion criteria encompassed self-reported severe mental disorders like psychotic or manic symptoms, eating disorders, epilepsy, or a significant level of visual problems that might interfere with the accuracy of eye-tracking measures.

2.2. Hardware and Software

An HTC VIVE Pro Eye™ head-mounted display (HMD) (HTC Corporation, Taoyuan, Taiwan) was used to immerse the participants in the virtual environment. This device includes dual-OLED 615 PPI displays with a resolution of 2880 × 1600 pixels. Five body trackers were used to monitor the participants' movement: the HMD itself, two VR controllers (one for each hand), and two feet trackers (VIVE trackers V3.0; HTC Corporation, Taoyuan, Taiwan), connected wirelessly with four SteamVR 2.0™ base stations (Valve Corporation, Bellevue, WA, USA). All devices tracked the participants' movements in real time and applied them to an avatar. The setup allowed for a sizable play area of up to 10 m × 10 m. The HTC VIVE Pro Eye HMD was equipped with Tobii™ eye-tracking technology (Tobii Technology, Stockholm, Sweden). This device enabled precise measurement of their eye movements, featuring a binocular gaze data output frequency of 120 Hz and spatial accuracy ranging between 0.5 and 1.1 degrees. Calibration was achieved through a 5-point calibration process. The VR environment, developed using Unity 3D v. 5.6.1

software (Unity Technologies, San Francisco, CA, USA), consisted of a room devoid of furniture. Positioned 1.54 m in front of the participant was a large mirror, and two boxes were placed nearby on the floor. The mirror displayed a full-body image of the participants' avatars, meticulously mimicking all their movements. The avatars, crafted using Blender v. 2.78 software (Blender Foundation, Amsterdam, The Netherlands), were personalized to match each participant's height and silhouette. This customization was based on two participant photos—one frontal and another in profile—that accurately depicted their individual shapes. The avatars' skin tones were adjustable, and their attire, consisting of t-shirts and trousers, could be color-customized to match the participants' actual clothing. Additionally, the avatars featured shoes, an HMD, and a grey cap.

2.3. Measures

Time. The duration of each ABMT series in seconds was measured. Each series consisted of 75 trials, as described in the procedure section, and was completed by participants within the VR environment.

Attitude towards technology. The Media and Technology Usage and Attitude Scale (MTUAS; [19]) was employed to gauge participants' attitudes toward technology. Specifically, three sub-scales were utilized: positive attitude (six items), negative attitude (three items), and anxiety and dependence (three items). These scales used a 5-point Likert-type rating system from 1 (strongly disagree) to 5 (strongly agree). The possible score ranges for each sub-scale were as follows: 5 to 30 for positive attitude, and 3 to 15 for both negative attitude and anxiety/dependence. Sample items from each sub-scale include the following: 'I think it is important to keep up with the latest trends in technology' (positive attitude), 'New technology makes life more complicated' (negative attitude), and 'I get anxious when I don't have my cell phone' (anxiety and dependence). The original studies reported Cronbach's alpha ranging from 0.8 to 0.87 for these three sub-scales [19].

Anxiety, Fatigue, and Comfort. The VR environment included an assessment of their anxiety levels during the session, each individual's fatigue, and their level of comfort wearing the glasses, all measured using visual analogue scales (VASs) ranging from 0 (not at all) to 100 (completely). Participants were asked to rate their current anxiety level with the following question: 'Indicate the level of anxiety you are currently experiencing.' For fatigue, they were asked: 'How tired do you feel right now?' And regarding comfort, the question was as follows: 'To what extent are you satisfied with the comfort of the glasses you are wearing?

User experience. The System Usability Scale (SUS [20] Spanish version [21]) was used to evaluate how users perceived the software's usability. It comprises 10 items measured on a 5-point Likert-type scale. This scale generates a single number ranging from 0 to 100, representing a composite measure of the overall system usability (0 indicating the least usable system, 68 considered normal level of usability, and 100 representing the most usable system). An example item from the SUS is as follows: 'I found the system unnecessarily complex.' The SUS had a Cronbach's alpha of 0.91 in the original studies [22].

Visual problems. Participants were asked if they had any type of visual problem. All participants who answered affirmatively wore either glasses or contact lenses to address these problems.

2.4. Procedure

This study was part of a project that received approval from the Research Ethics Committee of the University of Barcelona. All participants provided written informed consent before participating in the study. They were informed about data confidentiality and their right to leave the study at any time without any repercussions. Participants were informed that this study intended to examine body image disorders using virtual reality methods.

To create the avatar, height and weight measurements were taken for each participant to calculate their body mass index. Additionally, two photos of the participant were

captured—one from the front and another from the side—to accurately represent the participant's silhouette in the avatar.

Before entering the VR environment, participants completed an attitude assessment toward technology using the MTUAS. They were then outfitted with VIVE Pro Eye™ HTC and body trackers and entered the VR setting. Following this, a five-minute visuo-motor and visuo-tactile stimulation aimed to create a strong sense of ownership of their virtual avatar. This process enhances the perception that the avatar reflects their real body [23], which heightens their presence in VR. After this phase, the participants' anxiety, fatigue, and comfort were measured for the first time (pre-session: PrS). Subsequently, the first series of ABMT commenced. We adapted the method from Smeet et al.'s study [11], wherein participants focused on geometric figures appearing over different parts of their body. In our study, these figures were evenly distributed across all body areas, aiming to diminish the attentional bias towards unpleasant body parts, observed in patients with anorexia nervosa and in individuals with high levels of body dissatisfaction. The ABMT involved four series of 75 trials each. Each trial displayed a geometric figure (triangle, square, or circle) in different colors (red, green, or yellow) on a body part. We ensured a balanced distribution of figures across body areas within each series and equally distributed them between the right and left sides of the body for lateralized body parts. Participants identified the shape of the figure in the odd series (first and third), while in the even series (second and fourth), they identified the color. This variation aimed to prevent boredom [11]. The software selected both the color and the shape for each figure randomly. During each trial, as participants paid attention to the figures, nearby body areas were gradually illuminated. Following four-second gaze fixation, a new figure would appear on a different body part. If a participant momentarily looked away, pausing their attention, the software waited for them to refocus on the figure before continuing to illuminate the corresponding nearby body area (refer to Figure 1). Each series took approximately 6 min to complete.

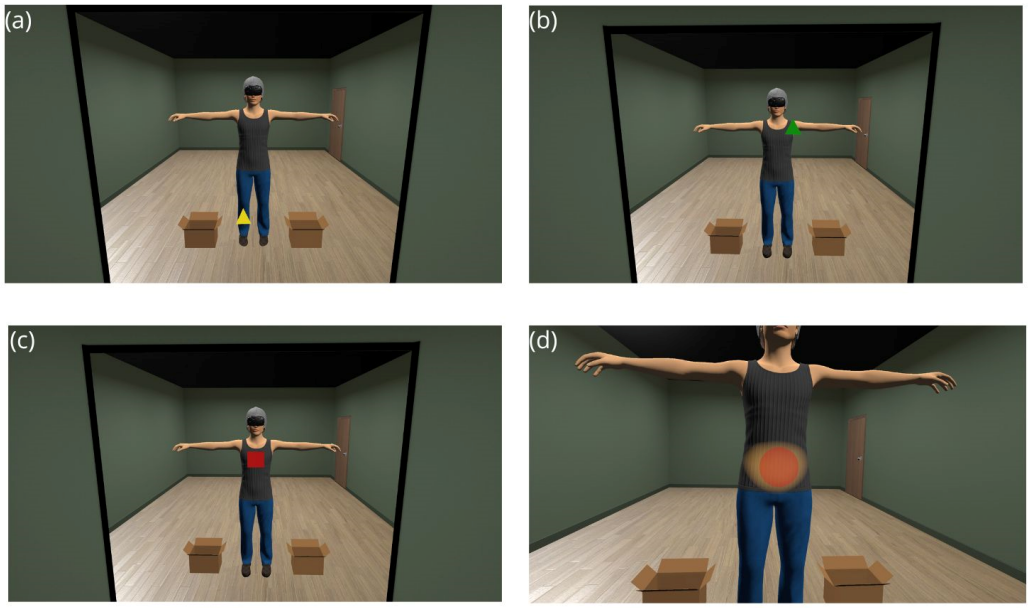

Figure 1. Example of ABMT trials, with the three possible figures and colors: (**a**) Yellow triangle on the right leg; (**b**) Green triangle on the left shoulder; (**c**) Red square on the chest; (**d**) Close-up of the body after the red circle on the stomach disappears and the surrounding body areas are illuminated.

Right after each series, their anxiety, fatigue, and comfort levels were evaluated using the visual analog scales, resulting in a total of five measurements during the intervention: baseline (PrS), and after series 1, 2, 3, and 4 (S1, S2, S3, and S4). Participants were given a 2-min break and seated in a chair after the VAS measurements, before starting the subsequent ABMT series. After completing all series and VAS assessments, the body trackers

and HMD were removed, and participants were administered the SUS questionnaire to evaluate their user experience. Additionally, participants were given necessary rest time while the researcher explained the study's true purpose and addressed any queries.

2.5. Statistical Analysis

The time measure analysis had a sample size of 58 participants due to missing time data from nine participants and the exclusion of two outliers from the sample. For statistical analysis of time, anxiety, fatigue, and comfort levels, one-way ANOVAs were conducted. Time had four levels (series 1 to 4: S1, S2, S3, and S4), while the rest had five levels (PrS, S1, S2, S3, and S4). The data were not normally distributed across all variables according to the Kolmogorov–Smirnov test. Despite this, the decision was made to proceed with the analyses as ANOVAs demonstrated robustness even in cases of deviation from normality [24].

A one-sample *t*-test was conducted to compare the average SUS score of the participants to the standard benchmark for normal usability, which is typically considered as 68 out of 100 [25], in order to assess the software's usability.

Pearson correlations were used to explore the relationships among the measures of usability, the participants' attitudes toward technology, their anxiety, fatigue, and comfort levels, and time to complete each ABMT series.

Furthermore, to explore the potential influence of their technological dependence on their anxiety, a two-way mixed ANOVA was conducted. This analysis included a within-participant factor, anxiety (measured before the first series and after each subsequent series, totaling five levels), and a between-participant factor, dependence, with two levels: low dependence (36 participants) and high dependence (33 participants). The classification criteria for each group were established based on the median value of the sample.

To investigate the potential impact of wearing glasses or contact lenses on usability, time spent in series, and VAS measures, two-way mixed ANOVAs were conducted for each variable. The within-participant factor had four levels for time spent in each series (S1, S2, S3, and S4) and five levels for VAS assessments (PrS, S1, S2, S3, and S4). The between-participant factor in each ANOVA was visual acuity, categorized into two levels: no visual problems (31 participants, 26 for time) and visual problems (38 participants, 32 for time). For SUS, independent-sample *t*-tests were utilized.

The Greenhouse–Geisser correction was implemented to modify degrees of freedom as needed, and Bonferroni-adjusted pairwise comparisons were executed. All p-values resulting from these comparisons were adjusted using the Bonferroni method. The r method for the *t*-test and the partial eta-squared (η^2p) method for the ANOVAs were used to calculate effect sizes. The level of statistical significance was established at $\alpha = 0.05$.

3. Results

3.1. Time

A one-way ANOVA was conducted to examine whether the time allocated to the ABMT task varied significantly across the four series. The outcomes indicated statistically significant differences in the time spent on these different series ($F(3,171) = 3.981$, $p = 0.016$, $\eta^2p = 0.065$), indicating that the time spent on the task was not constant across the series. A deeper analysis of these results showed that the time spent on the S2 series was significantly lower than the time spent on the S1 series ($p = 0.011$), with a medium effect size. No other comparisons between series yielded statistically significant differences.

Table 1 shows the mean values for the time allocated to the task and the data obtained from the self-reported MTUAS and SUS questionnaires.

Table 1. Mean values (and standard deviations) of the MTUAS, SUS, and time spent on each series.

Variable		Mean (SD)
Time	S1	400.38 (68.9)
	S2	384.79 (48.9)
	S3	389.69 (53.86)
	S4	389.41 (58.03)
MTUAS	Positive attitude	22.78 (2.98)
	Negative attitude	9.7 (2.13)
	Dependence	9.74 (2.79)
SUS	--	67.428 (11.4)

Note: S1 to S4 = series 1 to series 4; MTUAS = Media and Technology Usage and Attitude Scale; SUS = System Usability Scale; -- = no subscales.

3.2. MTUAS

Correlation analyses were performed to examine the relationship between the three subscales of the MTUAS and the time spent on each series. There results showed no correlation between the three subscales used in the MTUAS and the time spent in each series. There was no discernible relationship between participants' attitudes and the time dedicated to the task. Regarding the correlation between the VAS measures and MTUAS, a positive moderate association emerged between participants' dependence on technology and their anxiety levels across multiple series (PrS: r = 0.253, p = 0.036; S1: r = 0.364, p = 0.002; S2: r = 0.332, p = 0.005; S4: r = 0.256, p = 0.034), except for S3 (r = 0.179, p = 0.142). These results showed that the participants who reported higher levels of dependence on technology also experienced higher levels of anxiety during the task. No other correlations reached statistical significance.

3.3. SUS

A one-sample t-test was conducted to evaluate the task's usability. The test aimed to determine if the sample's average usability score differed significantly from the established norm of 68, which signifies typical usability [25]. The results indicated no significant difference between the sample's average score and the predetermined benchmark for normal usability (t(68) = −0.417, p = 0.678, r = 0.05), indicating that the usability of this software was similar to the average usability of other software.

The correlations among the SUS, MTUAS, VAS, and time measures indicated a negative moderate association between the SUS and anxiety levels in S4 (r = −0.238, p = 0.049), as well as a negative moderate correlation between the SUS and fatigue levels during the third series (r = −0.306, p = 0.011) and S4 (r = −0.32, p = 0.007). This result shows that the participants who evaluated the software with a lower score also experienced higher levels of anxiety and fatigue during the last series of the task. None of the other correlations reached statistical significance.

3.4. Anxiety, Fatigue, and Comfort

Table 2 displays both the comparison results and descriptive statistics for the self-reported VAS measures.

A one-way ANOVA was conducted to test whether the anxiety during the ABMT task differed significantly across the four series. The results showed statistically significant differences in anxiety levels across the series, with a medium effect size (Table 2), indicating that the anxiety scores varied across the series. Pairwise comparisons revealed a significant increase in anxiety across all series when compared to PrS ($p < 0.05$), except for the comparison between PrS and S2 (p = 0.89). To further investigate the relationship between dependence and anxiety, as previously highlighted, a two-way mixed ANOVA was conducted, with the anxiety levels across the series as a within-participant factor, and high or low dependence levels as a between-participant factor. The results confirmed statistical significance for the within-participant factor with a medium effect size, specifically the

levels of anxiety assessed in each series (F(2.18,146.033) = 7.309, $p < 0.001$, $\eta^2p = 0.098$), aligning with earlier one-sample *t*-test analyses. Additionally, significance was observed in the between-participant factor with a medium effect size for dependence (F(1,67) = 4.111, $p = 0.047$, $\eta^2p = 0.058$), indicating that the high-dependence group experienced higher overall anxiety levels during the task compared to those of the low-dependence group. The interaction between both factors did not reach significance (F(2.18,146.033) = 0.743, $p = 0.488$, $\eta^2p = 0.011$). This lack of significance stemmed from the consistently higher anxiety levels exhibited in the high-dependence group across all series measures when compared to the low-dependence group.

Table 2. Mean values (and standard deviations) obtained by the participants in the three VAS measures, and statistical outcomes of the one-way ANOVAs.

	N	PrS	S1	S2	S3	S4	ANOVA (df = 4272)
Anxiety	69	14.493 (18.838)	19.457 (21.187)	20.217 (20.69)	25.217 (24.859)	22.391 (22.222)	$F = 7.423$, $p < 0.001$, $\eta^2p = 0.098$
Fatigue	69	34.928 (28.697)	49.167 (29.188)	53.732 (27.572)	58.841 (26.962)	61.667 (26.856)	$F = 57.969$, $p < 0.001$, $\eta^2p = 0.46$
Comfort	69	74.913 (19.75)	70.761 (22.785)	64.203 (24.814)	62.681 (22.91)	62.036 (24.257)	$F = 14.963$, $p < 0.001$, $\eta^2p = 0.18$

Note: PrS = Pre-session; S1 to S4 = series 1 to series 4; df = degree of freedom.

A one-way ANOVA showed statistically significant differences in fatigue levels across the four series during the ABMT task, as indicated in Table 2. This suggests that there were variations in anxiety scores across these series, accompanied by a considerable effect size. The pairwise comparisons revealed a notable increase in fatigue throughout all the series ($p < 0.05$), with the exception of the comparison between S3 and S4 ($p = 0.146$), for which the difference did not reach statistical significance.

Finally, the analysis aimed at determining if the participants' comfort levels during the ABMT task varied significantly across the four series showed statistically significant differences with a large effect size (Table 2), indicating that the participants' comfort while wearing the HMD varied across the series. The pairwise comparisons indicated a decrease in comfort for all comparisons ($p < 0.05$), except for those between PrS and S1, S2 and S3, S2 and S4, and S3 and S4.

The correlations among all the VAS measures unveiled a moderate positive association between the anxiety values from the pre-session and series 1 to 4, alongside its corresponding fatigue measure from the pre-session and series 1 to 4 (refer to Table 3). This result shows that the participants who experienced higher anxiety levels also felt higher levels of fatigue during most of the series. Additionally, there was a moderate negative correlation between the anxiety values from series 1 to 4 and their corresponding comfort measures from series 1 to 4, except for the correlation between comfort in PrS and anxiety in PrS (refer to Table 3). Furthermore, a moderate or large negative correlation was identified between each fatigue measure from the pre-session and series 1 to 4 and its corresponding comfort measure from the pre-session and series 1 to 4 (refer to Table 3). This result shows that the participants who experienced lower levels of comfort also felt higher levels of anxiety and fatigue during most of the series.

Table 3. Correlations between Fatigue, Comfort, and Anxiety.

	Comfort					Anxiety				
	PrS	**S1**	**S2**	**S3**	**S4**	**PrS**	**S1**	**S2**	**S3**	**S4**
Fatigue	−0.259 *	−0.399 **	−0.51 **	−0.453 **	−0.398 **	0.277 *	0.311 **	0.37 **	0.419 **	0.417 **
Comfort	--	--	--	--	--	−0.157	−0.304 *	−0.377 **	−0.357 **	−0.324 **

Note: PrS = Pre-session; S1 to S4 = series 1 to series 3; * $p < 0.05$; ** $p < 0.01$.

No correlation was found between the three subscales employed in the VAS and the time spent on each series.

3.5. Visual Problems

Regarding the potential influence of visual problems on the time required to complete each series, as well as on participants' anxiety, fatigue, and comfort levels, the analyses (Table 4) revealed that neither this factor nor its interaction with task duration (Prs and S1 to S4) significantly impacted those variables. The outcomes associated with the within-participant factor (Prs and S1 to S4) were consistent with those found in the previous analyses (Section 3.4).

Table 4. Statistical outcomes of the two-way mixed ANOVAs conducted between participants with and without visual problems, focusing on time and the three VAS measures.

	Within-Participant Factor (Number of Series)	**Between-Participant Factor (Visual Problems)**	**Interaction**
Time	F(2.349,131.557) = 3.71, $p = 0.021$, $\eta^2p = 0.062$	F(1,56) = 0.078, $p = 0.789$, $\eta^2p = 0.001$	F(2.349,131.557) = 1.303, $p = 0.276$, $\eta^2p = 0.023$
Anxiety	F(2.193,146.958) = 7.227, $p < 0.001$, $\eta^2p = 0.097$	F(1,67) = 1.734, $p = 0.192$, $\eta^2p = 0.025$	F(2.193,146.958) = 0.142, $p = 0.885$, $\eta^2p = 0.002$
Fatigue	F(2.345,157.084) = 58.639, $p < 0.001$, $\eta^2p = 0.467$	F(1,67) = 1.707, $p = 0.196$, $\eta^2p = 0.025$	F(2.345,157.084) = 1.305, $p = 0.275$, $\eta^2p = 0.019$
Comfort	F(2.642,176.995) = 14.832, $p < 0.001$, $\eta^2p = 0.181$	F(1,67) = 0.544, $p = 0.463$, $\eta^2p = 0.008$	F(2.642,176.995) = 0.228, $p = 0.854$, $\eta^2p = 0.003$

The independent *t*-test conducted between the participants with and without visual problems in the SUS evaluation revealed no significant differences between the two groups (t(67) = 0.047, $p = 0.962$, r = 0.001). The utilization of contact lenses or glasses did not impact the usability assessment of the software.

4. Discussion

The objective of this study was to explore the impact of VR research tools—both hardware and software—on the execution of an ABMT task. In summary, our findings suggest that while the participants found the ABMT software user-friendly, spending an extended period engaged in this task impacted participants' current state and influenced their evaluation of the procedure.

The participants perceived the ABMT as a task with standard usability, categorizing it as being executed with good software [26]. Overall, the ABMT appeared to be easy to understand, learn, and operate. This was evident in the time taken during each series, as the participants required only one series to learn how to complete the ABMT more efficiently. The use of glasses or contact lenses did not influence the time spent on the task or the assessment of usability. The findings also suggest that negative states like fatigue, discomfort, or anxiety did not impact the time dedicated to the task. Moreover, the absence of differences in time between series 2 and 4 implies that the participants' focus remained undiverted from the primary task objective, since any distraction of the gaze stopped the

counting of the time spent looking at the figure until the participant returned to direct his gaze to that figure. A robust level of sustained attention is essential for tasks focused on altering attentional biases.

As anticipated, their anxiety and fatigue levels intensified across successive series, accompanied by a decline in comfort, albeit with nuanced patterns. Their anxiety levels notably peaked after the initial series and were maintained a stable level thereafter, hinting at their possible adaptation to the VR experience. Their comfort with the VR glasses gradually decreased throughout the series, particularly within the initial 10–15 min, aligning with the established threshold at which discomfort typically arises [27,28]. Towards the final series, their comfort levels reached a plateau that persisted after 45–50 min of wearing the VR glasses. These outcomes echo those observed by Stanney et al. [27], who found that most discomfort levels remained stable even after 45 min of VR exposure. Their fatigue consistently rose across the series, likely due to the prolonged ABMT sessions and the discomfort induced by the VR glasses; the weight of the HMD can also contribute to participants' fatigue [29]. The stability observed in fatigue levels during our study's conclusion could stem from two non-exclusive reasons as follows: firstly, their discomfort levels remained steady at this stage of the experiment, subsequently exerting a lesser effect on participant fatigue; secondly, the participants were aware that the experiment was nearing its end. The escalation of these negative feelings during ABMT raises concerns, especially since ABMT is typically part of a broader, long-term treatment [13]. The increase in dissatisfaction during task performance might discourage patients from returning for subsequent sessions. Fatigue and discomfort have been reasons for dropouts in VR studies [30,31] or ABMT tasks [16].

Fatigue, anxiety, and comfort levels evidenced correlations across all series measures (PrS and S1 to S4). These correlations were positive between fatigue and anxiety, while they were negative between comfort and the other two variables. It is likely that these three factors mutually influenced each other during the experiment. The lack of correlation between anxiety and fatigue during the pre-session might be because participants' initial anxiety was more associated with the novelty of the experience and the anticipation of a VR experiment. An encouraging aspect is that the use of glasses or contact lenses did not impact their anxiety, fatigue, or comfort levels using the VR equipment during the ABMT. This implies that both the software and hardware are suitable for a broad range of users, minimizing exclusions from this type of treatment based on external factors unrelated to the treatment itself.

The relationship between usability and anxiety/fatigue reveals the negative impact of both variables on the usability score. Participants experiencing higher levels of fatigue and anxiety at the conclusion of all series tended to rate the task lower in terms of usability. Using software that amplifies anxiety and fatigue leads to a poorer user experience with that software [32]. Factors like an unattractive environment or a monotonous task could influence participant feelings of anxiety and fatigue [32]. Boredom resulting from extended, repetitive tasks, such as the one used here (four series with 75 trials each), also contributes to fatigue and can alter thoughts, emotions, and behaviors [33,34]. Interestingly, comfort levels did not impact this evaluation. This outcome was expected because the System Usability Scale (SUS) in this experiment assessed software usability, not hardware. Hence, participants focused on rating the software's usability regardless of their comfort levels with the VR glasses. Nevertheless, it is plausible that the comfort provided by VR glasses indirectly affects usability, given the relationship between comfort and fatigue, in which fatigue, in turn, impacts usability scores.

A strength of the ABMT software is its independence from individuals' positive or negative attitudes toward technology and technological dependence, which do not influence the time spent on each series of the ABMT, nor do they affect their fatigue or comfort levels. This is important, as prior attitudes toward technology could impact their adherence to its use [15], and the absence of a relationship between these factors minimizes potential treatment interruptions or dropouts related to software and hardware

use. However, a correlation emerged between anxiety and technological dependence across all series (except for S3). A closer examination of this correlation reveals that participants with higher dependence scores generally experienced higher levels of anxiety compared to those with lower dependence scores. The dependence metric assesses the importance individuals place on continuous internet access and cell phone availability [19]. In this study, the association between dependence and anxiety might be due to the extended duration spent completing all ABMT series without using a cell phone—participants with high dependence levels felt more anxious than those with low dependence levels due to this reason.

This study has some limitations that should be considered, and future lines of research will also be proposed. Firstly, the experiment involved healthy participants rather than individuals with eating disorders. Aspects evaluated here might exert a more pronounced impact on a population dealing with eating disorders. Therefore, reassessing various influencing factors of ABMT within a clinical population is advisable. Secondly, fatigue, anxiety, and discomfort may influence participants' attitude toward ABMT, potentially increasing the likelihood of treatment discontinuation. Factors like an unattractive environment and avatars could contribute to these negative feelings during the intervention [32]. Enhancing the aesthetic elements of VR through more realistic avatars or less neutral environments could mitigate these negative emotions. This improvement should be executed with care, ensuring that it does not negatively impact their sense of presence [35], as this sense of presence is essential for effectively conducting VR therapies [4]. Thirdly, expanding the sample to include a broader range of ages, educational backgrounds, or diverse geographical origins could enhance the heterogeneity of the participants. This approach would provide a more comprehensive understanding of the general population and allow for comparisons among various socio-demographic groups. For instance, different age groups might perceive VR glasses differently—some might find them more user-friendly, while others could have reservations about their usage. [18]. Additionally, addressing fatigue and monotony resulting from repetitive tasks could involve gamifying the task to enhance engagement and reducing the number of trials or series within the ABMT. Introducing breaks between series without VR glasses or spacing the series across different days (e.g., two series per day) might alleviate fatigue and discomfort stemming from the task. It has been observed that gamifying cognitive tasks enhances task engagement without compromising the quality of results [36], provided that the gamification is implemented cautiously to preserve focus on the task, avoiding the introduction of distracting elements. Therefore, future research should explore whether gamifying, modifying the distribution of series across different days, or reducing the number of trials or series could impact the efficacy of the ABMT. While some experiments have shown that changes can occur with a single training session of ABMT [9,37], these findings require further investigation. Reducing fatigue and discomfort could involve exploring lighter models of VR glasses. Currently, most VR glasses with eye tracking weigh around 800–900 g. Hence, advancements in technology that offer lighter options may be necessary in the future. To delve deeper into the effects of anxiety, fatigue, or discomfort, future studies could incorporate more specific inquiries. These might include differentiating between fatigue and boredom, as well as investigating various factors contributing to discomfort while using VR glasses, such as their weight, heat generation, or pressure. Furthermore, a future study could consider a follow-up design to assess if participants' perspectives change over time or with repeated experiences. This could help us understand how usability, comfort, fatigue, or anxiety may alter over the course of multiple exposures or with evolving perceptions of the experience.

In summary, our study findings provide strong evidence to support the feasibility of VR technology for ABMT. The participants consistently demonstrated high levels of attention throughout all the ABMT sessions, regardless of whether they wore contact lenses or glasses. These accessories did not interfere with task performance or worsen their negative feelings during the task. Notably, fatigue, discomfort, and anxiety had a minimal impact on the task duration. These observations can improve patient evaluations of ABMT

techniques and help reduce their potential negative impact on treatment outcomes. While a person's own body is not involved in other ABMT treatments, fatigue, discomfort, and anxiety are common factors in VR-based approaches. By refining specific aspects of the task, it may be possible to minimize the influence of these emotions on treatment outcomes and potentially reduce the risk of patient dropout in VR-based ABMT treatments.

Author Contributions: Conceptualization, J.G.-M., M.F.-G., M.A., F.-A.M.-A. and B.P.-G.; methodology, J.G.-M., M.F.-G., M.A., F.-A.M.-A. and B.P.-G.; software, M.A., F.-A.M.-A. and B.P.-G.; validation, J.G.-M., M.F.-G., M.A., F.-A.M.-A., A.C.-L., B.P.-G. and M.T.M.-M.; formal analysis, A.C.-L. and M.T.M.-M.; investigation, J.G.-M., M.F.-G., M.A., F.-A.M.-A., A.C.-L. and B.P.-G.; resources, M.F.-G. and J.G.-M.; data curation, F.-A.M.-A. and M.T.M.-M.; writing—original draft preparation, M.T.M.-M.; writing—review and editing, J.G.-M., M.F.-G., M.A., F.-A.M.-A., A.C.-L., B.P.-G. and M.T.M.-M.; visualization, M.T.M.-M.; supervision, M.F.-G. and J.G.-M.; project administration, J.G.-M.; funding acquisition, J.G.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This study was funded by the Spanish Ministry of Science and Innovation (Agencia Estatal de Investigación, Ministerio de Ciencia e Innovación, Spain), Grant PID2019-108657RB-I00, funded by MCIN/AEI/10.13039/501100011033. This study also has the support of "Fundació La Marató de TV3", Grant 202217-10.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Bioethics Commission of the University of Barcelona (CBUB) (protocol code IRB00003099, 20 July 2020).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author. The data are not publicly available because the project this study is part of is still ongoing.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Rauschnabel, P.A.; Felix, R.; Hinsch, C.; Shahab, H.; Alt, F. What Is XR? Towards a Framework for Augmented and Virtual Reality. *Comput. Hum. Behav.* **2022**, *133*, 107289. [CrossRef]
2. Cieślik, B.; Mazurek, J.; Rutkowski, S.; Kiper, P.; Turolla, A.; Szczepańska-Gieracha, J. Virtual Reality in Psychiatric Disorders: A Systematic Review of Reviews. *Complement. Ther. Med.* **2020**, *52*, 102480. [CrossRef]
3. Freeman, D.; Reeve, S.; Robinson, A.; Ehlers, A.; Clark, D.; Spanlang, B.; Slater, M. Virtual Reality in the Assessment, Understanding, and Treatment of Mental Health Disorders. *Psychol. Med.* **2017**, *47*, 2393–2400. [CrossRef]
4. Riva, G.; Malighetti, C.; Serino, S. Virtual Reality in the Treatment of Eating Disorders. *Clin. Psychol. Psychother.* **2021**, *28*, 477–488. [CrossRef]
5. Rodgers, R.F.; DuBois, R.H. Cognitive Biases to Appearance-Related Stimuli in Body Dissatisfaction: A Systematic Review. *Clin. Psychol. Rev.* **2016**, *46*, 1–11. [CrossRef]
6. Griffen, T.C.; Naumann, E.; Hildebrandt, T. Mirror Exposure Therapy for Body Image Disturbances and Eating Disorders: A Review. *Clin. Psychol. Rev.* **2018**, *65*, 163–174. [CrossRef]
7. Zhang, S.; Cui, L.; Sun, X.; Zhang, Q. The Effect of Attentional Bias Modification on Eating Behavior among Women Craving High-Calorie Food. *Appetite* **2018**, *129*, 135–142. [CrossRef]
8. Mercado, D.; Werthmann, J.; Antunes-Duarte, T.; Campbell, I.C.; Schmidt, U. A Randomised Controlled Feasibility Study of Food-Related Computerised Attention Training versus Mindfulness Training and Waiting-List Control for Adults with Overweight or Obesity: The FOCUS Study. *J. Eat. Disord.* **2023**, *11*, 61. [CrossRef]
9. Allen, L.; Mulgrew, K.E.; Rune, K.; Allen, A. Attention Bias for Appearance Words Can Be Reduced in Women: Results from a Single-Session Attention Bias Modification Task. *J. Behav. Ther. Exp. Psychiatry* **2018**, *61*, 97–103. [CrossRef]
10. Smith, E.; Rieger, E. The Effect of Attentional Training on Body Dissatisfaction and Dietary Restriction. *Eur. Eat. Disord. Rev.* **2009**, *17*, 169–176. [CrossRef]
11. Smeets, E.; Jansen, A.; Roefs, A. Bias for the (Un)Attractive Self: On the Role of Attention in Causing Body (Dis)Satisfaction. *Health Psychol.* **2011**, *30*, 360–367. [CrossRef] [PubMed]
12. Meschberger-Annweiler, F.-A.; Ascione, M.; Porras-Garcia, B.; Ferrer-Garcia, M.; Moreno-Sanchez, M.; Miquel-Nabau, H.; Serrano-Troncoso, E.; Carulla-Roig, M.; Gutiérrez-Maldonado, J. An Attentional Bias Modification Task, through Virtual Reality and Eye-Tracking Technologies, to Enhance the Treatment of Anorexia Nervosa. *J. Clin. Med.* **2023**, *12*, 2185. [CrossRef] [PubMed]

13. Ascione, M.; Carulla-Roig, M.; Miquel-Nabau, H.; Porras-Garcia, B.; Meschberger-Annweiler, F.-A.; Serrano-Troncoso, E.; Ferrer-Garcia, M.; Moreno-Sánchez, M.; Gutierrez-Maldonado, J. Attentional Bias Modification Training Based on Virtual Reality and Eye Tracking in Anorexia Nervosa Patients. *J. Clin. Med.* **2023**, *12*, 5932. [CrossRef] [PubMed]
14. Funnell, E.L.; Spadaro, B.; Martin-Key, N.; Metcalfe, T.; Bahn, S.M. Health Solutions for Mental Health Screening and Diagnosis: A Review of App User Perspectives Using Sentiment and Thematic Analysis. *Front. Psychiatry* **2022**, *13*, 857304. [CrossRef] [PubMed]
15. Baniasadi, T.; Ayyoubzadeh, S.M.; Mohammadzadeh, N. Challenges and Practical Considerations in Applying Virtual Reality in Medical Education and Treatment. *Oman Med. J.* **2020**, *35*, e125. [CrossRef] [PubMed]
16. Wen, S.; Larsen, H.; Boffo, M.; Grasman, R.P.P.P.; Pronk, T.; van Wijngaarden, J.B.G.; Wiers, R.W. Combining Web-Based Attentional Bias Modification and Approach Bias Modification as a Self-Help Smoking Intervention for Adult Smokers Seeking Online Help: Double-Blind Randomized Controlled Trial. *JMIR Ment. Health* **2020**, *7*, e16342. [CrossRef]
17. Kuckertz, J.M.; Schofield, C.A.; Clerkin, E.M.; Primack, J.; Boettcher, H.; Weisberg, R.B.; Amir, N.; Beard, C. Attentional Bias Modification for Social Anxiety Disorder: What Do Patients Think and Why Does It Matter? *Behav. Cogn. Psychother.* **2019**, *47*, 16–38. [CrossRef]
18. Vlahovic, S.; Suznjevic, M.; Skorin-Kapov, L. A Survey of Challenges and Methods for Quality of Experience Assessment of Interactive VR Applications. *J. Multimodal User Interfaces* **2022**, *16*, 257–291. [CrossRef]
19. Rosen, L.D.; Whaling, K.; Carrier, L.M.; Cheever, N.A.; Rokkum, J. The Media and Technology Usage and Attitudes Scale: An Empirical Investigation. *Comput. Hum. Behav.* **2013**, *29*, 2501–2511. [CrossRef]
20. Brooke, J. SUS: A "Quick and Dirty" Usability Scale. In *Usability Evaluation in Industry*; Jordan, P.W., Thomas, B., McClelland, I.L., Weerdmeester, B., Eds.; CRC Press: London, UK, 1996; pp. 189–195.
21. Sevilla-Gonzalez, M.D.R.; Loaeza, L.M.; Lazaro-Carrera, L.S.; Ramirez, B.B.; Rodríguez, A.V.; Peralta-Pedrero, M.L.; Almeda-Valdes, P. Spanish Version of the System Usability Scale for the Assessment of Electronic Tools: Development and Validation. *JMIR Hum. Factors* **2020**, *7*, e21161. [CrossRef]
22. Bangor, A.; Kortum, P.T.; Miller, J.T. An Empirical Evaluation of the System Usability Scale. *Int. J. Hum. Comput. Interact.* **2008**, *24*, 574–594. [CrossRef]
23. Waltemate, T.; Gall, D.; Roth, D.; Botsch, M.; Latoschik, M.E. The Impact of Avatar Personalization and Immersion on Virtual Body Ownership, Presence, and Emotional Response. *IEEE Trans. Vis. Comput. Graph.* **2018**, *24*, 1643–1652. [CrossRef] [PubMed]
24. Schmider, E.; Ziegler, M.; Danay, E.; Beyer, L.; Bühner, M. Is It Really Robust? *Methodology* **2010**, *6*, 147–151. [CrossRef]
25. Brooke, J. SUS: A Retrospective. *J. Usability Stud.* **2013**, *8*, 29–40.
26. Bangor, A.; Kortum, P.; Miller, J. Determining What Individual SUS Scores Mean: Adding an Adjective Rating Scale. *J. Usability Stud.* **2009**, *4*, 114–123.
27. Stanney, K.M.; Hale, K.S.; Nahmens, I.; Kennedy, R.S. What to Expect from Immersive Virtual Environment Exposure: Influences of Gender, Body Mass Index, and Past Experience. *Hum. Factors* **2003**, *45*, 504–520. [CrossRef] [PubMed]
28. Chang, E.; Kim, H.T.; Yoo, B. Virtual Reality Sickness: A Review of Causes and Measurements. *Int. J. Hum. Comput. Interact.* **2020**, *36*, 1658–1682. [CrossRef]
29. Chen, Y.; Wang, X.; Xu, H. Human Factors/Ergonomics Evaluation for Virtual Reality Headsets: A Review. *CCF Trans. Pervasive Comput. Interact.* **2021**, *3*, 99–111. [CrossRef]
30. Hejtmanek, L.; Starrett, M.; Ferrer, E.; Ekstrom, A.D. How Much of What We Learn in Virtual Reality Transfers to Real-World Navigation? *Multisens. Res.* **2020**, *33*, 479–503. [CrossRef]
31. Larson, E.B.; Ramaiya, M.; Zollman, F.S.; Pacini, S.; Hsu, N.; Patton, J.L.; Dvorkin, A.Y. Tolerance of a Virtual Reality Intervention for Attention Remediation in Persons with Severe TBI. *Brain Inj.* **2011**, *25*, 274–281. [CrossRef]
32. Yakunin, A.V.; Bodrunova, S.S. Cumulative Impact of Testing Factors in Usability Tests for Human-Centered Web Design. *Future Internet* **2022**, *14*, 359. [CrossRef]
33. Milyavskaya, M.; Inzlicht, M.; Johnson, T.; Larson, M.J. Reward Sensitivity Following Boredom and Cognitive Effort: A High-Powered Neurophysiological Investigation. *Neuropsychologia* **2019**, *123*, 159–168. [CrossRef] [PubMed]
34. Westgate, E.C.; Steidle, B. Lost by Definition: Why Boredom Matters for Psychology and Society. *Soc. Personal. Psychol. Compass* **2020**, *14*, e12562. [CrossRef]
35. Pidel, C.; Ackermann, P. Collaboration in Virtual and Augmented Reality: A Systematic Overview. In *Augmented Reality, Virtual Reality, and Computer Graphics*; De Paolis, L., Bourdot, P., Eds.; Springer: Cham, Switzerland, 2020; Volume 12242, pp. 141–156.
36. Vermeir, J.F.; White, M.J.; Johnson, D.; Crombez, G.; Van Ryckeghem, D.M.L. The Effects of Gamification on Computerized Cognitive Training: Systematic Review and Meta-Analysis. *JMIR Serious Games* **2020**, *8*, e18644. [CrossRef]
37. Nelson, B.D.; Jackson, F.; Amir, N.; Hajcak, G. Single-Session Attention Bias Modification and Error-Related Brain Activity. *Cogn. Affect. Behav. Neurosci.* **2015**, *15*, 776–786. [CrossRef]