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Cue-exposure software for the treatment of bulimia nervosa and binge eating disorder

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Abstract

Background: Cue-exposure therapy (CET) has proven its efficacy in treating patients with bulimia nervosa and binge eating disorder who are resistant to standard treatment. Furthermore, incorporating virtual reality (VR) technology is increasingly considered a valid exposure method that may help to increase the efficacy of standard treatments in a variety of eating disorders. Although immersive displays improve the beneficial effects, expensive technology is not always necessary. **Method:** We aimed to assess whether exposure to food related virtual environments could decrease food craving in a non-clinical sample. In addition, we specifically compared the effects of two VR systems (one non-immersive and one immersive) during CET. We therefore applied a one-session CET to 113 undergraduate students. **Results:** Decreased food craving was found during exposure to both VR environments compared with pre-treatment levels, supporting the efficacy of VR-CET in reducing food craving. We found no significant differences in craving between immersive and non-immersive systems. **Conclusions:** Low-cost non-immersive systems applied through 3D laptops can improve the accessibility of this technique. By reducing the costs and improving the usability, VR-CET on 3D laptops may become a viable option that can be readily applied in a greater range of clinical contexts.

Keywords: Food craving, virtual reality, cue-exposure, low-cost VR systems.

Resumen

Programa de exposición a señales para el tratamiento de la bulimia nerviosa y del trastorno por atracón. **Antecedentes:** la terapia de exposición a señales (TES) se ha mostrado eficaz en el tratamiento de pacientes con bulimia nerviosa y trastorno por atracón. Por otra parte, la incorporación de tecnologías de realidad virtual (RV) se considera cada vez más un método de exposición válido que puede ayudar a aumentar la eficacia de los tratamientos. Aunque los dispositivos inmersivos mejoran los efectos beneficiosos, no siempre es necesario el uso de tecnología costosa. **Método:** el objetivo de este estudio es evaluar si la exposición a entornos virtuales relacionados con la comida puede disminuir el deseo de comer en una muestra no clínica. Además, se comparan los efectos de dos sistemas (uno no inmersivo y otro inmersivo) durante la TES. Se aplicó un modelo de TES en una única sesión a 113 participantes. **Resultados:** los resultados indicaron una disminución del deseo de comer como efecto de la exposición. No se encontraron diferencias significativas entre los dos sistemas. **Conclusiones:** los resultados sugieren que con sistemas de bajo coste y alta facilidad de uso, la TES mediante RV puede llegar a ser una opción aplicable en un mayor rango de contextos clínicos.

Palabras clave: deseo de comer, realidad virtual, exposición a señales, sistemas económicos de RV.

This study is part of a wider research project whose main objective is to develop a new, empirically validated treatment procedure for binge eating behaviour in patients with bulimia nervosa (BN) and binge eating disorder (BED) based on cue-exposure therapy (CET) and the incorporation of virtual reality (VR). While cognitive-behavioural therapy (CBT) is an effective treatment for these eating disorders (Fairburn & Harrison, 2003), a substantial percentage of patients do not improve despite treatment, and thus remain chronically symptomatic. CET has been found effective with patients resistant to conventional treatments, but there are several logistical drawbacks associated with in vivo exposure to real cues (food) when conducted in a consultancy. The use of VR to apply CET overcomes those drawbacks and seeks to enhance its efficacy by increasing the possibilities of generalization.

Virtual Reality (VR) technology is used in clinical psychology to integrate and enhance traditional assessment and therapeutic approaches for a variety of conditions (Riva, 2005). Specifically, CET that uses VR (i.e., VR-CET) has been proposed as a novel tool for the study and treatment of bulimia nervosa and binge eating episodes (Gutiérrez-Maldonado, Ferrer-García, & Riva, 2013). VR exposure has been demonstrated to be efficacious not only for the treatment of eating disorders, but also for anxiety disorders, psychotic disorders, addictions, and so on, offering several advantages such as a high ecological validity, high acceptability, and increased control over variables (Ferrer-García, Gutiérrez-Maldonado, Caqueo-Urízar, & Moreno, 2009; Gutiérrez-Maldonado, Ferrer-García, Caqueo-Urízar, & Letosa-Porta, 2006). Significantly, VR allows the therapist to maintain

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ecological validity by making it possible to recreate real-world environments, thus ensuring that the results are more generalizable and reliable. Moreover, VR is a relatively safe process for patients and is generally more acceptable than full exposure. Finally, the strict control over variables that it allows facilitates the provision of interventions tailored to the patient's specific needs.

VR works by recreating an artificial reality that reflects real situations more closely and also reduces the sensation of being observed (Riva, 2003). Traditionally, immersion has been considered central to the quality of a VR system (Slater, Steed, & Chrysanthou, 2001); immersive VR is considered a special and unique experience that it is not achieved by three-dimensional (3D) interactions on desktop PCs. In other words, high levels of immersion increase the realism of the experience, which can improve the effectiveness of psychological treatments (Bowman & McMahan, 2007). Previous research has focused on the factors that contribute to the level of immersion in virtual environments (McMahan, Gorton, Gresock, McConnell, & Bowman, 2006; Narayan, Waugh, Zhang, Bafna, & Bowman, 2005; Ni, Bowman, & Chen, 2006; Bowman & McMahan, 2007). However, authors are also interested in looking for situations in which highly immersive systems are unnecessary. Although specific immersive technology displays can improve outcomes in psychological treatments, other factors may be equally or more beneficial (McCreery, Schrader, Krach, & Boone, 2013; Simone, Schultheis, Rebimbas, & Millis, 2006). Indeed, Baños et al. (2000) suggested that if the content design is emotionally engaging, immersive systems are not always necessary (Baños et al., 2004).

Typical VR systems for exposure involve different graphical user interfaces for human–computer interaction that vary with the required level of immersion. The most basic level involves exposure to virtual environments on computer screens, with peripheral input devices (e.g., a keyboard or a computer mouse) used to interact with them. At the other extreme are innovative and technologically advanced systems such as Head Mounted Displays (HMD) which simulate binocularly overlapped images and create the illusion of a three-dimensional world (Mon-Williams, Warm, & Rushton, 1993). Although HMDs can increase the user's immersive experience, their use has several drawbacks. For example, they can be impractical in clinical settings (Simone et al., 2006); clinical centres are often reluctant to include VR interventions in their daily practice if it involves the use of expensive or technically complex instruments. Another concern is that HMD may have side effects such as simulator sickness, which is estimated to affect 20% of the healthy population (Nichols & Patel, 2002), or visual fatigue. In addition to these practical issues, the price of immersive HMDs with a good tracker system is generally prohibitive, which has delayed the development of advanced virtual environments for routine clinical practice (Godbersen, 2008). Low-cost immersive HMDs have appeared on the market over the last year, including the Oculus Rift and Samsung Gear VR which allow greater immersion at relatively economical prices. However, despite the development of low-cost HMDs, some technical knowledge is still needed to use them properly, and may present a barrier to their wider clinical use. Thus, although low-cost HMDs overcome economic drawbacks, the technological difficulties remain.

VR technology has been proposed as a valid exposure method for the treatment of eating disorders and other related disturbances (Cottone, Sabino, Steardo, & Zorrilla, 2008; Ferrer-García & Gutiérrez-Maldonado, 2012; Koskina, Campbell, & Schmidt, 2013). Moreover, previous research has provided evidence that VR can elicit emotional responses, such as anxiety, and changes in body image in patients with eating disorders (Ferrer-García et al., 2009; Gorini, Griez, Petrova, & Riva, 2010; Gutiérrez-Maldonado, Ferrer-García, Caqueo-Urízar, & Moreno, 2010; Gutiérrez-Maldonado et al., 2006). Some of the most recent applications of this technology in eating disorders use CET, which has been also widely used with success in the treatment of addictions. In VR-CET for addictions, the patient is systematically and repeatedly exposed to drug-related virtual environments to reduce or extinguish the cue-elicited response of craving that triggers consumption and is associated with relapse (Lee, Kwon, Choi, & Yang, 2007; Moon & Lee, 2009; Park et al., 2014; Pericot-Valverde, Secades-Villa, Gutiérrez-Maldonado, & García-Rodríguez, 2014).

The rewarding effects of palatable foods and abused drugs appear to overlap substantially in their neurobiological mechanisms. Rats given long-term access to palatable food (a sugar solution) develop a constellation of behavioural and neurochemical symptoms resembling those that occur after repeated exposure to addictive drugs, thus supporting the notion of "food addiction". Most studies of reinstatement of food seeking have been performed by addiction researchers interested in the selectivity of their experimental manipulations for drug versus food reward. In a review of those studies, Nair, Adams-Deutsch, Epstein, & Shaham (2009) discuss the degree of overlap in the mechanisms underlying reinstatement of food versus drug seeking. Cue-induced reinstatement is procedurally similar regardless of whether the reinforcer being studied is food or a drug. The cues may be discrete, discriminative, or contextual. Together, the data suggest an overlap in the mechanisms underlying cue-induced reinstatement of food and drug seeking. These mechanisms include activation of group II metabotropic receptors (mGluR2 and mGluR3), D1 dopamine receptors, CB1 receptors, and mu opioid receptors, all of which contribute to reinstatement of heroin, cocaine, alcohol, and food seeking induced by several types of cues. There is also evidence for a role of mGluR1 and 5-HT1A and/or 5-HT1B receptors in discrete cue-induced reinstatement of both food and cocaine seeking. Additionally, there is evidence that activity in the accumbens core mediates discrete-cue-induced cocaine, heroin, and food seeking and that activity in the lateral hypothalamus mediates context-induced reinstatement of both alcohol and food seeking.

Given the similarities between cue-induced craving in bulimia nervosa and drug addiction, CET has been proposed as a treatment for bulimia nervosa and related disorders (Jansen, van den Hout, de Loof, Zandbergen, & Griez, 1989). Indeed, both food and drug intake establish strong Pavlovian associations with consumption-related stimuli (Cason et al., 2010; Kelly, Schiltz, & Landry, 2005). Therefore, CET may be effective for extinguishing the food craving that is associated with bingeing by breaking the link between the conditioned stimuli (i.e., high calorie foods) and the unconditioned stimulus (i.e., the binge behaviour) (Yela-Bernabé, Gómez-Martínez, Cortés-Rodríguez, & Salgado-Ruiz, 2013). Though few studies have been carried out to date, CET has shown promise for the treatment of bulimia nervosa (Koskina et al., 2013), even in patients who did not improve with cognitive behavioural or pharmacological therapy (Martínez-Mallén et al., 2007). In a recent study conducted by Schyns, Roefs, Mulkens, & Jansen (2016) to investigate whether a one-session cue exposure intervention decreases eating in the absence of hunger, and whether the hypothesized decrease in intake is specific for exposed food items or would generalise to other food items that were not present during exposure, it was found that the intake of the one exposure food item (chocolate mousse) was significantly lower in the exposure condition than in controls. However, total consumption did not significantly differ between the conditions. These data showed that inhibitory learning takes place during one session of food cue exposure, as participants successfully inhibited themselves when confronted with an exposed food item, but the inhibitory learning did not generalise to food items that were not present during the cue exposure. These results show that there is room for improvement regarding the generalizability of CET, and that VR technology might achieve this improvement since it allows the therapist to maintain ecological validity by making it possible to recreate real-world environments, thus ensuring that the results are more generalisable.

Recently, a few groups have studied the application of VR in order to elicit food craving. Ferrer-García, Gutiérrez-Maldonado, and Pla (2013) found that high calorie food cues produced greater food craving than low-calorie food in a non-clinical sample when exposed to VR environments associated with food. In another study, Ferrer-García, Gutiérrez-Maldonado, Agliaro-López et al. (2014) found that participants with higher scores on the Food Craving Questionnaire (Cepeda-Benito et al., 2000) had higher levels of craving when exposed to food using VR environments. At the same time, Ledoux, Nguyen, Bakos-Block, and Bordnick (2013) investigated whether food cues delivered via VR environments could elicit higher levels of food craving than neutral VR cues, photographs of foods, or real food. They concluded that real food produced higher levels of food craving than VR, but that no significant differences were found between VR and photographic exposure.

The main purpose of the present study was to assess the validity of a novel VR-CET procedure for the reduction of the craving response. To achieve this, a one-session VR-CET was applied to a non-clinical sample. Participants were exposed to different virtual foods in different virtual environments with the aim of producing habituation of the craving response (reduction of food craving by means of repeated presentations of the virtual food stimuli). A reduction in craving for food reported during exposure, compared with the craving reported during a previous assessment, was expected to support the validity of VR-CET. In addition, two VR systems offering different levels of immersion were compared in order to explore the possibility of obtaining significant levels of craving reduction without using immersive systems.

Method

Participants

We enrolled 113 undergraduate students from the University of Barcelona, who received extra credits for their participation. The sample comprised 90 women (79.6%) and 23 men (20.4%), with a mean age of 23 ± 3 years (range 20-36 years). Although our study was conducted with healthy participants, our aim was to generalise the results obtained to patients with bulimia nervosa or binge-eating disorder. Bulimia nervosa is far less common in males than in females, with an approximately 10:1 female-to-male ratio. The gender ratio is far less skewed in binge-eating disorder than in bulimia nervosa; nevertheless, the twelve-month prevalence of binge-eating disorder among U.S. adult (age 18 or older) females and males is 1.6% and 0.8%, respectively (American Psychiatric Association [APA], 2013).

By body mass index (BMI), 86 were normal weight (BMI, 18.5-24.99), 10 were underweight (BMI ≤ 18.5), and 17 were overweight (BMI = 25-29.99). Participants who reported a diagnosed eating disorder or severe psychiatric disorder (dementia or psychosis) were excluded. Before inclusion, all participants provided signed informed consent.

Instruments

Hardware. This study was conducted under two exposure conditions: one using a non-immersive VR system and the other using an immersive VR system. The non-immersive virtual environments were displayed on an Intel™ Pentium™ T4400 IV (2.2 GHz, 800 MHz FSB) laptop with 4 GB RAM, ATI Mobility Radeon™ HD 4570 (up to 2301 MB HyperMemory™) graphics card, and a 15.6 inch 3D monitor. Earphones and polarised glasses were also used. The immersive virtual environments were displayed on an Oculus Rift VR HMD DK1 system. The Oculus provided immersive 3D virtual environments in a wide field of view (90 degrees horizontal, 110 degrees diagonal) with low head-tracking latency. This system uses two lenses in a ski mask style HMD that combine to form a 1280 × 800 display (each eye sees 640 × 800 pixels). In addition, the hardware includes a break out control box for connection to a computer, featuring DVI, HDMI, micro-USB and power input. Furthermore, the device included interchangeable lenses that permitted simple diopter adjustments to be made for users with different refractory errors. Adjustment for different inter-pupillary distances was accomplished with the software provided.

Food CET software. The software comprised a library with four contexts to simulate situations where patients with eating disorders usually binge (kitchen, dining room, bedroom, and café) and 30 foods frequently consumed during binge episodes (figure 1). Before initiating CET, users were exposed to all 30 foods and asked to indicate the level of food craving elicited per item on a visual analogue scale (from 0 to 100). Participants were also asked to indicate the level of food craving experienced for each of the four contexts. Using this information, the software then created an exposure hierarchy. Early in the hierarchy, participants were exposed to the foods and contexts that elicited lower levels of craving; later in the hierarchy, participants were exposed to the ones that provoked higher levels of craving.

In a given situation, participants were asked to find their table and to sit down, at which point food appeared according to the predetermined, individualised hierarchy. Using the mouse, users could manipulate the food without being able to eat it.

In the present study, an abridged version was prepared for the validation of the software. In this version, only the 10 foods assessed by the participant as provoking the highest levels of craving were selected and presented to the participant in the four different contexts. Thus, during CET participants were exposed to 40 virtual environments resulting from the combination of the 10 foods rated with higher levels of food craving and the four contexts assessed.

Eating Disorder Inventory-3, Bulimia subscale (Garner, 2004; adaptation by Elosua & López-Jáuregui, 2012). This is a self-report questionnaire comprising 91 items divided into 12 subscales rated on a 0–5 point Likert scale. In the current study, we only used the bulimia subscale to assess bulimic symptomatology. By administering the EDI-3 to 394 women in Spain who had already been diagnosed with an eating disorder and were receiving treatment, Elosua and Lopez-Jauregui (2012) were able to confirm the inventory's psychometric qualities. The results confirmed the internal structure, the temporal stability (r_{xx}= .85-.99), and the high internal consistency (eating disorder scales α = .90-.92; psychological scales α = .75 -.93).

Information about gender, age, history of psychopathology or eating disorders and BMI was also collected. BMI (weight [kilogram] / height [metre] ^{2}) was calculated from measures with participants standing in stockinged feet.

Procedure

First, basic demographic data (gender, age) and history of psychopathology or eating disorders were collected and exclusion criteria were applied. Participants who reported a diagnosed eating disorder or severe psychiatric disorder (dementia or psychosis) were excluded. Once informed consent forms had been signed, each participant was randomly assigned to the immersive VR group (using the Oculus Rift HMD) or the non-immersive VR group (using the 3D laptop). Eighty-two participants were assigned to the non-immersive group and 78 to the immersive group. All participants in the non-immersive group completed the study but only 31 of the 78 participants in the immersive group; the remaining 47 dropped out at some point. In all cases, the reason for discontinuation was the occurrence of simulator sickness in the form of dizziness or nausea. This high dropout rate in the immersive condition has important implications regarding the use of these systems in everyday clinical practice, which will be assessed in the discussion section.

There were two phases in both groups. In phase 1 (assessment) all participants were exposed to 30 representations of different foods, as well as to four representations of different environments (kitchen, dining room, bedroom and café). The level of craving elicited by each food and environment was assessed using a visual analogue scale that ranged from 0 (not at all) to 100 (extreme). In phase 2, the participants were subjected to VR-CET for approximately 30 minutes. In this phase, the participants were exposed to the 10 different virtual foods assessed as eliciting the highest levels of craving in each of the four virtual environments (kitchen, dining room, bedroom, and café) for a total of 40 virtual situations from lowest to highest craving scores as previously registered in phase 1. Once in the virtual situation, the participant was asked to sit at a virtual table where the food is placed. Once the participant sits, the time was measured. During 45 seconds, the participant was able to handle the virtual food by means of the laptop's mouse but could not eat the food. When the time ran out (45 seconds), the level of craving was assessed by means of visual analogue scales that range from 0 (none at all) to 100 (extreme).

In phase 1 (assessment), 34 measures of craving were collected (30 virtual foods plus four virtual environments). In phase 2 (exposure), 40 measures of craving were collected.

Participants then completed the EDI-3 and, finally, measurements were recorded for BMI calculations. To ensure that the administration of questionnaires and the measurements to calculate the BMI did not influence participants' expectations regarding the experiment and might thus contaminate the results, this information was recorded after performing the virtual exposure. Before taking this decision, the research team debated whether this procedure might constitute a risk to the participants, but finally dismissed this possibility in view of the characteristics of the task.

Non-immersive procedure. Participants in the non-immersive condition sat in front of a table with a 3D laptop that provided 3D vision via the polarised glasses. Exposure was conducted in a quiet room with the lights off. Headphones were used to recreate the typical sounds of the environments. The experimenter was located behind the participant to ensure minimal interference on exposure. Interaction with the virtual environment was via the keyboard and the mouse.

Immersive procedure. Participants in the immersive condition wore the Oculus Rift HMD (DK1), adjusted to each participant's specific requirements. The Oculus Rift HMD allowed the participant to be completely immersed in the VR environment and isolated from the real world. Headphones were also used to recreate the typical sounds of the environments. As in the non-immersive condition, interaction with the virtual environments was conducted using a keyboard and mouse.

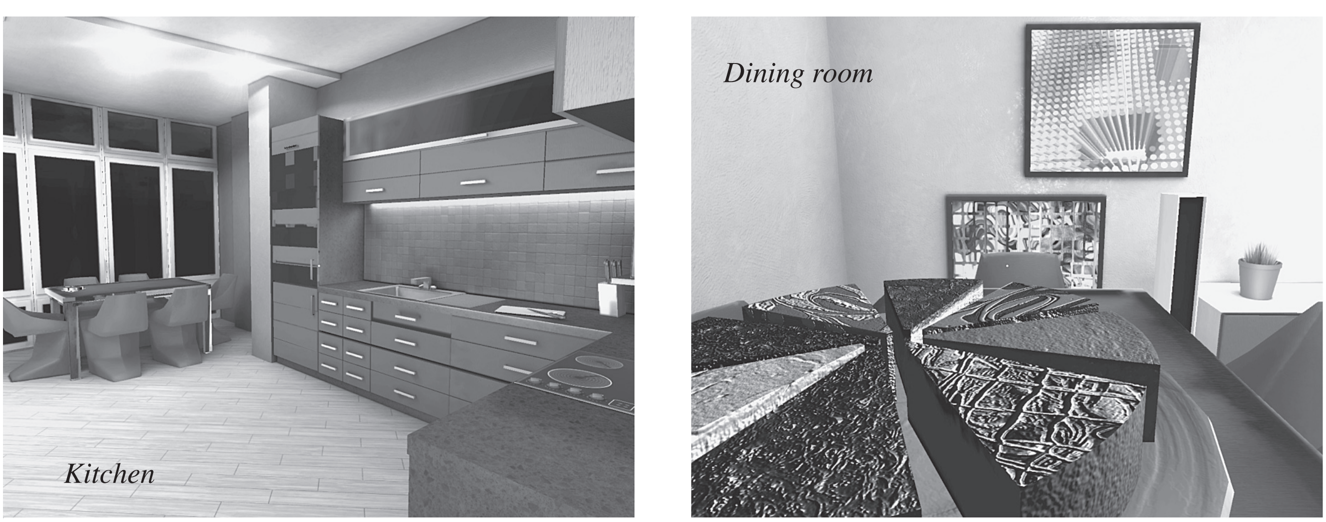

Figure 1. *Images of the virtual reality environments*

Data analysis

To assess the reduction of the food craving response during exposure to the VR environments in the two low-cost VR systems, we used analysis of variance (ANOVA) with Bonferroni corrections for multiple comparisons. We used both within-subject (craving reported before and during the VR-CET) and between-subject (immersive VR system vs. non-immersive VR system) variables. Similar analyses were also conducted to explore whether gender, the presence of bulimic behaviours, and BMI influenced craving reported before and during VR-CET, and between the two VR systems (immersive vs. non-immersive VR systems). To achieve this, the sample was divided into three equal groups according to low (from 0 to 1), moderate (from 2 to 3), and high (from 4 to 17) raw scores on the bulimia subscale of the EDI-3 ($M_{Low\text{-}B} = 0.52 \pm 0.5$, n = 46; $M_{moderate\text{-}B} = 2.53 \pm 0.5$, $n = 30$; $M_{High\text{-}B} = 6.84 \pm 3.51$, $n = 37$). According to Garner (2004), scores over 5 in the Bulimia scale of the EDI-3 in non-clinical population may point to an overeating tendency which may be clinically significant in some cases. Likewise, scores above 11 in non-clinical samples may suggest a non-detected ED.

To explore differences in BMI, the sample was divided into three groups based on the World Health Organisation (2006) classification, which considers that a BMI between 18.5 and 24.99 indicates normal weight, a BMI under 18.5 underweight and BMI of 25 or higher overweight (underweight = 17.71 ± 0.53, $n = 10$; healthy weight = 21.49 ± 1.79, $n = 86$; and overweight = 28.21 ± 3.33, $n = 17$).

Results

Results showed a significant main effect for the food craving measurement time (see table 1). Mean food cravings at assessment were higher than those reported during exposure in both VR systems (F (1, 111) = 71.682, p<.0005, $\eta^2 = 0.392$). The main effect for exposure condition (F (1, 111) = 0.699, $p = 0.405$, $\eta^2 = 0.006$) and the interaction between the two variables (F (1, 111) = 0.709, $p = 0.402$, $\eta^2 = 0.006$) did not reach statistical significance. The immersive condition produced greater reductions in food craving than the non-immersive condition, although the difference was not significant. The effect size for craving levels between the immersive and non-immersive systems during exposure was small (Cohen's $d = 0.22$).

The effect of gender, bulimia nervosa related behaviours and BMI was also analysed. Mixed ANOVA (between- and within-subject) calculated as 2[mean craving during assessment vs. mean craving during VR exposure] × 2[immersive vs. non-immersive VR systems] × 2[male vs. female] showed that neither the simple effect of gender (F(1,109) = 1.074, $p = 0.302$, $\eta^2 = 0.01$) nor the interactions between variables were significant: Craving measurement time × gender (F(1,109) = 0.157, $p = 0.693$, $\eta^2 = 0.001$), exposure condition × gender (F(1,109) = 0.265, $p = 0.607$, $\eta^2 = 0.002$), and craving measurement time × exposure condition × gender (F(1,109) = 0.235, $p = 0.629$, $\eta^2 = 0.002$).

Similar results were obtained when assessing the effects of bulimia nervosa-related behaviours and BMI. Mixed ANOVA (between- and within-subject) calculated as 2(mean craving during assessment vs. mean craving during VR exposure) × 2(immersive vs. non-immersive VR systems) × 3(bulimia nervosa low scores vs. bulimia nervosa moderate scores vs. bulimia nervosa high scores) revealed that the simple effect for bulimia nervosa-related behaviours (F(2,107) = 0.611, $p = 0.545$, $\eta^2 = 0.011$) was not statistically significant. Equally, interactions between variables were not significant: craving measurement time × bulimia nervosa-related behaviours (F(2,107) = 0.965, $p = 0.384$, $\eta^2 = 0.018$), exposure condition × bulimia nervosa-related behaviours (F(2,107) = 0.742, $p = 0.479$, $\eta^2 = 0.014$), and craving measurement time × exposure condition × bulimia nervosa-related behaviours (F(2,107) = 0.160, $p = 0.852$, $\eta^2 = 0.003$).

Finally, mixed ANOVA (between- and within-subject) calculated as 2 (mean craving during assessment vs. mean craving during VR exposure) × 2(immersive vs. non-immersive VR systems) × 3(underweight vs. normal weight vs. overweight) showed that the simple effect of BMI was not significant (F(2,107) = 1.512, $p = 0.225$, $\eta^2 = 0.027$). No significant interactions were found for craving measurement time × BMI (F(2,107) = 1.397, $p = 0.252$, $\eta^2 = 0.025$), exposure condition × BMI (F(2,107) = 1.815, $p = 0.168$, $\eta^2 = 0.033$), and craving measurement time × exposure condition × BMI (F(2,107) = 0.816, $p = 0.445$, $\eta^2 = 0.015$).

Table 1
Mean food craving before and during exposure to immersive and non-immersive systems

	VR system	M	SD
Mean food craving at assessment	Non-immersive (n = 82)	64.47	18.70
	Immersive (n = 31)	65.96	19.80
	Total (N = 113)	67.05	18.93
Mean food craving during exposure	Non-immersive (n = 82)	51.93	21.58
	Immersive (n = 31)	46.98	24.10
	Total (N = 113)	50.57	22.30

Discussion

This study had two main objectives: first, to assess whether exposure to food-related virtual environments could decrease levels of food craving in a non-clinical sample, and second, to assess whether the specific VR system used during exposure (the Oculus HMD immersive system vs. the 3D laptop non-immersive system) affected the reduction in craving.

Several authors have found that food craving can trigger binge eating behaviours in some individuals (Cepeda-Benito & Gleaves, 2001), and that CET can be used to improve the treatment of binge eating behaviours (Martínez-Mallén et al., 2007) due to the habituation of the craving response. Indeed, if it is possible to reduce the craving induced by food cues via CET, subsequent binges may be reduced, because the link between food cues (conditioned stimuli) and binge behaviours is broken (Jansen, 1994, 1998; Wardle, 1990).

As expected, participants reported decreased food craving during exposure to the VR environments compared with levels prior to exposure. This result is consistent with previous literature regarding the use of in vivo CET for bulimia nervosa (Jansen, Broekmate, & Heymans, 1992; Jansen et al., 1989), as well as with the application of VR-CET to treat addictions such as gambling (Park et al., 2014), nicotine (Choi et al., 2011; Pericot-Valverde et al., 2014) or alcohol (Lee et al., 2007).

The results of this study also provide valuable information about the use of immersive versus non-immersive VR systems.

Although the Oculus Rift HMD immersive system produced a slightly higher reduction in food craving than the non-immersive condition during exposure, the difference was not statistically significant. Thus, it is probably true that the use of HMDs in clinical psychology can focus the attention of individuals on the task and provide a more real-life experience, leading to successful and effective interventions (Bowman & McMahan, 2007; Simone et al., 2006). However, we can also conclude that low-cost non-immersive systems, such as 3D laptops, are equally useful. Furthermore, by incorporating more user-friendly VR devices and clinical applications that do not require significant technical knowledge, we could reduce the current usability concerns (Simone et al. 2006). Indeed, not only do stereoscopic 3D laptops allow non-immersive simulations to be used without the technical complexities of HMDs but it also represents a more economical option which can be easily applied to a wide range of clinical contexts.

Other notable usability concerns, such as simulator sickness or visual fatigue (Nichols & Patel, 2002), were also reduced by using non-immersive systems. A major difference between our two groups was reflected in the number of dropouts, which was zero in the non-immersive group but 60% in the immersive group. In all cases, dropouts were due to varying degrees of simulator sickness such as dizziness, nausea, fatigue or disorientation that prevented participants from continuing to perform the task. This dropout rate of 60% was significantly higher than the 20% estimated in the normal population (Nichols & Patel, 2002), though similar to that found in other studies which (like ours) used the first version (DK1) Oculus Rift as the immersive system. In the study by Davis, Nesbitt, and Nalivaiko (2015), for example, eight out of 12 participants reported mild levels of nausea, two moderate levels, and two high levels. In the same study, another condition, also using Oculus Rift DK1, produced even worse simulator sickness symptoms: all participants reported some degree of nausea, with seven experiencing moderate levels and five high levels. Eight (66%) of the participants were unable to complete the simulation.

In a later version (DK2) Oculus has partially corrected this problem by replacing the LCD screen with an OLED screen and by incorporating positional tracking. In any case, despite technical improvements, the use of immersive devices such as HMDs is still associated with simulator sickness in a larger proportion of people than other less immersive devices. This point should be taken into consideration, especially when (as in our study) the application of exposure techniques using virtual reality requires long periods of time, thus raising the likelihood of the occurrence of simulator sickness or other similar sources of discomfort. However, negative side effects of this kind are extremely rare when the virtual exposure is carried out by non-immersive devices such as laptops with stereoscopic display.

In the current study, we found no gender differences in food craving between the immersive and non-immersive conditions or in the reduction in food craving during exposure to different VR environments. Similarly, our results did not show any statistically significant differences according to bulimic behaviours and BMI; this was the case both for the immersive and non-immersive VR systems and for food craving reductions during exposure to different VR environments. However, the results may have been limited by the small group of male subjects included, the lack of variability observed for bulimia EDI-3 subscale scores (which were mostly low, given that we used a non-clinical sample), and the large number of normal weight participants (76% of BMIs were classified as normal). Therefore, further studies with larger male subgroups as well as subclinical and clinical samples are required. Another limitation of the study is associated with the exclusion criteria used, which were based on self-reports of a diagnosed eating disorder or severe psychiatric disorder (dementia or psychosis) rather than on assessments made by the experimenters.

In conclusion, our study suggests that VR exposure to cues associated with food reduces craving. This technology is associated with fewer logistical complications and greater external validity than the traditional *in vivo* exposure performed in consultancy. The degree of immersion of the VR systems does not appear to be decisive for reducing craving. The more immersive systems must evolve to overcome certain important issues related to their usability, particularly the tendency to produce simulator sickness.

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