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Mixing Realities? An Application of Augmented Reality for the Treatment of Cockroach Phobia

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ABSTRACT

Augmented reality (AR) refers to the introduction of virtual elements in the real world. That is, the person is seeing an image composed of a visualization of the real world, and a series of virtual elements that, at that same moment, are super-imposed on the real world. The most important aspect of AR is that the virtual elements supply to the person relevant and useful information that is not contained in the real world. AR has notable potential, and has already been used in diverse fields, such as medicine, the army, coaching, engineering, design, and robotics. Until now, AR has never been used in the scope of psychological treatment. Nevertheless, AR presents various advantages. Just like in the classical systems of virtual reality, it is possible to have total control over the virtual elements that are super-imposed on the real world, and how one interacts with those elements. AR could involve additional advantages; on one side it could be less expensive since it also uses the real world (this does not need to be modeled), and it could facilitate the feeling of presence (the sensation of being there), and reality judgment (the fact of judging the experience as real) of the person since the environment he or she is in, and what he or she is seeing is, in fact the "reality." In this paper, we present the data of the first case study in which AR has been used for the treatment of a specific phobia, cockroaches phobia. It addresses a system of AR that permits exposure to virtual cockroaches super-imposed on the real world. In order to carry out the exposure, the guidelines of Öst with respect to "one-session treatment" were followed. The results are promising. The participant demonstrated notable fear and avoidance in the behavioral avoidance test before the treatment, and not only was an important decrease in the scores of fear and avoidance observed after the treatment, but also the participant was capable of approaching, interacting, and killing live cockroaches immediately following the treatment. The results are maintained in a follow-up conducted 1 month after the termination of the treatment.

INTRODUCTION

AUGMENTED REALITY (AR) refers to the introduction of virtual elements into the real world. That is, the user is seeing an image composed of the visualization of the real world and virtual elements that are superimposed over it. The most important aspect in AR is that the virtual elements add relevant and helpful information to the scene that is not included in the real one.

There exist differences between AR and virtual reality (VR). One difference is the immersion of the

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user inside the system. VR achieves an involved environment for the user. Vision, and in some systems, other perceptive channels, are controlled by the system. Contrarily, an AR system complements the real world being necessary that the user maintains his or her sense of presence in that world. The virtual images mix with the real world to create AR. So, there exists inside AR a mechanism that combines the real and the virtual that is not present in VR settings. In an AR system, the virtual objects generated by computer must be completely fused to the real world, in all of the dimensions. If errors exist in adjustment, the user will not have the perception of seeing both images, virtual and real, fused. Also, the adjustment of the images must be adequate at all times, including when the user is moving, the changes in vision due to movement must be taken into account, and to carry out the opportune operations for the placing of the virtual objects.

In short, the VR systems submerge the user inside a totally synthetic environment. In contrast, AR permits the user to see the real world, except that in this real world virtual objects are placed or superimposed, forming part of what the user is seeing. Therefore, AR complements reality, in place of substituting it completely. Ideally, the user would have the sensation that virtual objects and real objects coexist in the same space, that is to say, without distinguishing the difference between real and virtual objects.

Why is AR of interest? Why would it be useful to combine real and virtual objects in three-dimensions (3-D)? It is thought that AR can improve the perception and interaction of the user with the real world. The virtual objects offer information that the user cannot see directly with his or her own senses, and this information supplied by the virtual objects helps the user to carry out the tasks in the real world. AR is a specific example of what Fred Brooks calls *amplification of intelligence*: to use a computer to do tasks that humans must perform, more easily.[1–3]

AR has several applications. It has been used in many fields, but it can be applied to any field where the information is superimposed over the real world, and can help the user in different ways. Some areas where AR has been used are: medicine, the army, entertainment, engineering design, robotics and telerobotics, manufacturing, maintenance and repair, consumer design, navigation systems, and/or face recognition,[2–4] but until now very few applications of AR exist in psychology. One of the first applications in this field, assuming that the relationship of human beings with nature is beneficial for their emotional behavior, cognitive, and physical well being, demonstrated the usefulness of placing a plasma monitor in an office showing the countryside (in real time) as though it were a real window.[5,6] Also, AR has been used to develop pedagogical applications. For example, the *Magic Book* and *Kidsroom* projects. *Magic Book*[7] is like a children's story, with colored pages and text. The readers use a head mounted display (HMD) to look at the book and the images on the pages transform into virtual animated 3-D scenes. If a button which is included in the HMD is pressed it is possible to navigate inside the virtual scene, and freely explore this environment. *Kidsroom*[8] is a place of games for children. It uses images, music, sound effects, narrations, and lights to convert a normal child's room into a fantasy world, where children live various adventures. *Kidsroom* transports the child through diverse worlds inspired by stories for children.

Up to now, several applications of VR for the treatment of different psychological disorders have been developed[9,10]; nevertheless, there exists no application of AR in this field. From our point of view, AR could be shown as useful for the development of treatment procedures. On one hand, AR counts with the same advantages as VR, that is, possibilities to dominate and have control over the object or fearful situation, security for the person, possibility of access of fear causing stimuli/contexts, confidentiality, and possibility of repetition and of self-training.[9,11] But also, it counts on other added advantages. The person does not stop perceiving the "reality" from aspects of the real world, to his or her own movements, or parts of his or her body. From a practical point of view, this could without a doubt mean an enormous advantage since being able to design and show in VR a grade of realism similar to the real one means much effort. This would also involve a cheaper cost of design and modeling of virtual environments, limiting it only to modeling and programming some objects. On the other hand, the fact that the scenario that is perceived by the person would be the image of the real scenario, it could have a great impact with respect to the grade of presence and reality judgment that the person confers upon the experience. An elevated sense of presence in the environment ("I feel that I am here") and an elevated reality judgment of the objects ("I feel that this is real") could increment the efficiency of the treatment of virtual exposure. Presence and reality judgment, key aspects in this field, also make AR a subject of enormous interest, not only from a practical point of view, but also from a theoretical point of view.[12–14]

The aim of this work is to present the first AR system designed for the treatment of a psychological disorder, the phobia to small animals, specifically

cockroaches. Already there exist systems of VR designed for the treatment of the phobia to small animals which has demonstrated its efficacy. For example, the VR system for the phobia to spiders,[15,16] and systems of telepsychology are also using VR techniques for the treatment of the phobia to small animals (cockroaches, rats, and spiders).[17] But for the moment, there exists no system of AR designed with this purpose.

MATERIALS AND METHODS

Participants

Maria is a 26-year-old single woman. She asked for help at Jaume I University Anxiety Disorders Clinic. Maria met DSM-IV[18,19] criteria for phobia to small animals, specifically, fear of cockroaches. At the moment of the first interview, she indicated that she was not capable of being in a place where cockroaches might appear, and she completely avoided going anyplace in which there could be cockroaches. For example, she refused to go to her family's country house until she was completely sure that the other members of the family had had completely cleaned the house, and that they assured her that they had not seen any cockroaches.

She indicated that she had always experienced a notable fear of cockroaches (and also that she had some fear of small bugs in general), though she was incapable of identifying a clear source of her phobia. She only pointed out that it could have been her mother that influenced her, given that her mother was also afraid of cockroaches. She believed that lately the fear had become worse, she felt less capable of confronting cockroaches. In the presence of these animals (which, conversely, she had encountered very few times in her life), her reaction could be varied, from being completely paralyzed with horror, to running away from the place of the encounter. The constant is the avoidance. What she fears, fundamentally, is that the cockroach will come close, and that it might jump towards her, and land in her clothing. Maria experienced tachycardia and sweating before the fact of thinking about cockroaches.

She evaluated the severity of her problem as an 8 on a scale of 0–10. Until now she had neither looked for, nor had she applied any type of treatment to overcome this fear.

Maria indicated that her mood is not very good at this time, she felt sad and discouraged due to the fact that she was looking for work and still had not found anything, but she did not fulfill any of the criteria for a mood disorder, nor did there seem to be present any other mental disorder. She felt hopeful before the treatment, that it could reduce her fear, and she also indicated that in order to feel better she hoped she did not have to see any cockroaches.

Methods

The instruments and measures used were the following:

Diagnosis. We used an adaptation of the Anxiety Disorders Interview Schedule (ADIS-IV), specific phobia section.[20] This is a semi-structured interview designed to carry out a differential diagnosis of the anxiety disorders included in the DSM. This instrument gathers clinical data such as the history of the problem, as well as cognitive and situational factors that could play a role in the phenomenology of the anxiety response. Several studies show interreliability from satisfactory to excellent when it is used by expert clinicians who are familiar with the DSM diagnostic criteria.[21]

Treatment effectiveness measures. (1) Behavior Avoidance Test (Bat). This test was adapted from Öst,[22] and it was used to measure the degree of overt avoidance of cockroaches. We put ordinary house cockroaches (about 5 cm) in a plastic bowl (17 cm wide, 13 cm high, and 10 cm deep) closed with a lid. The terrarium was placed on a table in the far end of a room (4 × 5 m) next to the room in which the therapy was given. The distance from the door of the room to the bowl was 5 m. The participant was asked to enter the room, walk to the bowl, remove the lid, and interact with the cockroaches using a postcard for at least 20 sec. The importance of doing these things was highlighted to the participant, but it was also indicated to the person that she was free to stop the test at any point. The behavioral score obtained from this BAT ranged from 0 to 12 where 0 = refuses to enter the test room, 1 = stops 5 m to the terrarium, 2 = 4 m, 3 = 3 m, 4 = 2 m, 5 = 1 m, 6 = stops close to the table, 7 = touches the terrarium, 8 = removes the lid, 9 = puts a hand on the terrarium, 10 = touches the cockroach with the post card, 11 = interacts and holds the cockroaches using the postcard less than 20 sec, 12 = interacts and holds the cockroaches using the postcard for at least 20 sec. *(2) The Fear of Spiders Questionnaire.*[23] This questionnaire has 18 items that refer to a restricted time period (e.g., "If I encounter a spider *now,* I would have images of it trying to get me.") Items are evaluated on 8-point Likert scales (0 = strongly dis-

agree, and 7 = strongly agree). Accordingly, scores range between 0 and 126, with higher scores reflecting greater fear of spiders. Internal consistency is good, with Cronbach's alphas ranging from 0.88 to 0.97 across studies and samples. The test-retest of the FSQ is also good, with a correlation of 0.91 in a nonclinical sample, and it is sensitive to the effects of treatment.[23,24] *(3) The Spider Phobia Beliefs Questionnaire (SBQ).* Adapted from[25] is a 78-item scale. The SBQ comprises two scales that assess the strength of negative beliefs about spiders, that is, Beliefs About Spiders (e.g., "The spider will attack me") and about reactions of the individual during confrontation with a spider, that is, Beliefs About Self (e.g., "I will lose control"). Items of both subscales range from 0 (absence of negative beliefs) to 100 (very strong beliefs). Internal consistency (Cronbach's alpha) was good for the spider-related scale (α = 0.94) and for the self-related scale (α = 0.94). Test-retest reliability was acceptable, with r = 0.68 for the spider beliefs subscale and r = 0.71 for the self-related beliefs subscale.[25] *(4) Fear and avoidance scales.* These scales were adapted from elsewhere,[26] the patient, and the therapist, who establish the target behaviors or situations that the patient avoids and that he or she would like to overcome by the end of the treatment. The patient rates the daily level of avoidance on a 0–10 scale, where 0 is *I never avoid it* and 10 is *I always avoid it*; the level of fear is rated in another 0–10 scale, where 0 is *No fear* and 10 is *Extreme fear*. The first target behavior was "To approach the animal"; the other one was "To kill the animal and to throw it away." Coping with these situations was the treatment goal. *(5) Degree of belief in catastrophic thoughts.* The main catastrophic thoughts related to target behaviors or situations regarding cockroaches are specified. The degree of belief in those thoughts is assessed daily on a scale from 0% to 100%, where 0% means that the patient does not believe the content of the thought at all, and 100% means that the patient believes that the thought is totally true. The catastrophic thoughts that Maria had were: "It will climb on top of me," and "It will climb between my clothes." The grade of firmness in which she maintained these thoughts were 50. *(6) Measures regarding expectations and satisfaction with the treatment.* We were interested in obtaining information about the patients' expectations with regard to the treatment before starting it and after it was completed. We included two questions adapted from elsewhere,[16] specifically the willingness of getting involved in a treatment program that includes *in vivo* exposure and the willingness of getting involved in a treatment program that includes AR exposure. The patients rated these questions on a 1–7 scale, where 1 was "I would never do it" and 7 was "I would absolutely do it." The patient answered these questions during the pre-treatment assessment after being given a rationale about both exposure techniques. We also included several questions[27] to measure the satisfaction about the AR exposure treatment. The questions were about the logic of the treatment, the grade of satisfaction obtained, if it would be recommended to other people, if it would be useful to treat other problems, the utility for solving the problem of the person, and in what measure it had resulted aversely. *(7) Presence and reality judgment*. We posed three questions with the purpose of tracking the participant's evaluation concerning the degree of presence experienced in the AR session: "In what measure did you feel present in the situation" and "In what measure did you feel that you were in the place where the cockroaches appeared" and the reality judgment concerning the virtual cockroaches: "In what measure did the cockroaches appear to be real." *(8) Subjective units of discomfort scale (SUDS)*. Following[28] we asked the participant to rate her maximum level of anxiety on a 0–10 scale (0 = no anxiety; 10 = high anxiety). We also used this measure during the exposure sessions. *(9) Consent form.* The participant read and signed a consent form accepting the treatment that she was going to receive, allowing us to videotape the sessions, and allowing us to use her data in our research.

Procedure

It was announced at the university that a study was going to be done in which a psychological treatment would be applied for phobia to cockroaches using new technologies. Maria went to our clinic soliciting help. Once the diagnosis was confirmed, and informed consent was given, Maria was asked to complete the above mentioned instruments, the BAT was administered, and she was also asked to daily register the degree of fear, avoidance, and belief in the catastrophic thoughts related to cockroaches during a baseline period. Initially, we thought that this period would last two weeks, but due to the time that was spent to have the AR system definitively ready, the baseline time in which the participant was registering was 2 months.

She was given an appointment for the treatment session, and before beginning the exposure she was again administered the BAT. Once the session of exposure was complete, she was once again administered the BAT. We asked her to again complete the instruments of evaluation; she completed the instruments at home and sent them to us. Two months

after finishing the treatment Maria was called in, and was asked how she felt with respect to the degree of fear avoidance and fear related to cockroaches. Again she was administered the BAT, and afterwards she was asked to interact during 5 min with the AR system, and we asked again the questions concerning presence and reality judgment, and the questions related to her satisfaction with the treatment.

Treatment

AR-cockroaches system. The AR-cockroaches system is running on a PC AMD Athlon with 1 Gb Ram under Microsoft Windows 2000. The video stream is captured using a USB camera (Creative NX-Ultra). Mixed Reality Image is shown using 5DT HMD. The camera is attached to the HMD. So the camera is focusing on where the patient is looking.

AR-cockroaches system has been developed using ARToolkit 2.65 software with VRML support and Visual C++ version 6.0 as a development environment. ARToolkit was developed at the University of Washington by Kato and Billinghurst.[29] ARToolkit is an open source library in C that allows programmers to develop easily Augmented Reality applications.[30] It uses computer vision techniques in order to obtain the position and orientation of the camera respect to markers. It draws virtual objects over these markers. The creation of the AR image in our system has the following steps: (a) The system obtains the video stream captured by the camera using ARToolkit. (b) It identifies four different markers in the video stream using ARToolkit. (c) If the system recognizes the marker associated with the appearance of cockroaches, it overlays one or several cockroaches on it (from one to 60). It depends on the selection the user has chosen.

A basic element of the system is the cockroach. Both the model and the basic movement of the cockroach have been modeled using 3DStudio and exported in VRML format. The animal moves the feelers and the legs.

The system includes the following options in a menu, and it also works when the user touches associated keys: (a) number of cockroaches, (b) movement of cockroaches, and (c) zoom in/zoom out. Cockroaches increase/reduce their size with these options. Apart from these options, the system includes the possibility that the patient kills one or several cockroaches. It can be done using two different typical instruments to kill small animals. The first one is a fly swatter. We have put a marker on it. The program identifies when the flyswatter marker and the cockroach marker are near and then it kills. When the user kills cockroaches, the program plays a sound similar to when you flatten a real cockroach. The second instrument is a typical cockroach killer. Again, the program identifies when the insecticide marker and the cockroach marker are near and then it kills one or several animals. In this case the sound is similar to when you use a real insecticide.

All these options are combined so the patient's treatment can be progressive. The therapist can choose at any time how many cockroaches are to appear, if they have to move or not, their size, to kill a cockroach when the patient is prepared, and to throw it in a dustbin.

Psychological approach. The AR-cockroaches system is applied using the logic and the guidelines of "one-session treatment" from Öst treatment[1] that, at this moment, is recommended for the treatment of many phobias. The "one-session treatment" implies utilizing intensive exposure, and it is carried out in only one session in a maximum of 3 h, or in more sessions, but the total time for therapy cannot surpass 3 h. In the treatment for the phobia to animals, the exposure is usually combined with modeling.

The purpose of the exposure treatment in only one session is to expose the patient to the phobic situation in a controlled form, that allows the patient to notice that the consequences that he or she fears so much do not happen. Also, treatment in only one session must be understood as a starting point. It is recommended to the patient to continue exposing him or herself to the phobic situations in his or her daily life after the therapy. Nevertheless, as is pointed out by Öst,[1] this session permits the patient to start and continue a program of self-exposition that will allow for the definite disappearance of the problem.

Maria was given the instructions recommended by Öst[1] concerning what is implicated by the treatment and what will happen during the session, although adapted to the AR program: (a) that the treatment requires a close collaboration between patient and therapist (it deals with carrying out work in a team, and the treatment will only be successful if the patient carries out his or her work); and (b) that the therapist will never complete an action not previously planned (to the contrary, what will happen will be described to the patient, it will be proven, many times doing it him or herself, and permission from the patient is granted before it is carried out); (c) that even though the treatment presumes to confront many more aspects of the phobic situation than what he or she has done in his or her life, this will not presume "to break their personal record of anxiety," since the exposure in the treatment session is completed in a gradual form, planned and controlled; and (d) that a high level of anxiety is not a

goal in itself, but can be considered as something normal in the treatment process. If the person can overcome his or her phobia with a maximum anxiety level of 50 USA instead of 90 or 100, it is somewhat acceptable, always when no type of cognitive avoidance is produced, and the emotional processing of the fear is carried out.

Regarding the treatment goals, we planned that Maria would be able to face the presence of the cockroaches (first virtual, and then live ones) and react in the presence of them as would a person that does not have that phobia, that is, actively look for the cockroaches in the situation, approach them, kill them, and not believe anymore that the feared catastrophic consequences can occur. Following Öst[1] recommendations, we did not previously inform Maria of the details of what we expected her to be able to do in relation to the manipulation of the cockroaches.*

RESULTS

Our data supports the effectiveness of the AR system for the treatment of animal phobia in this participant. The data from BAT manifest the improvement that was produced with respect to fear and avoidance towards cockroaches. On the first BAT before the baseline, Maria obtained a score of 2. On the BAT that she was administered before the beginning of the treatment session she also obtained a score of 2. On the BAT that was administered at the end of the exposure she obtained a score of 12. At this moment, Maria was not only capable of getting close to the terrarium, look at the cockroach, open the lid, and interact with the cockroach, but also she allowed the cockroach to leave and run freely on the floor around her feet, and later she was able to get close to the cockroach and kill it, remove it with a piece of cardboard, and throw it in the trash bin. On the BAT that she was administered in the follow-up, she also scored a 12. At this moment, Maria was able to kill four cockroaches.

The data that appears in Figure 1 are also along these same lines. During the period of observation during the baseline of 2 months, high levels of fear and avoidance were observed with respect to the target behavior in relation to cockroaches (get close to a cockroach and kill it). She also scored a 10 before the exposure session, while the level of fear and avoidance with respect to the target behavior fell to 2 after the exposure. These values were maintained in the follow up 2 months later. As for the belief in the catastrophic thoughts that Maria maintained in relation to cockroaches, she scored 50 during the entire baseline period and before the exposure session. Also, important decreases were observed in the degree of belief after the session and this result was also maintained in the follow up.

The AR-cocoroaches system was able to activate her anxiety and she experienced high levels of anxiety during the AR exposure session. As can be seen

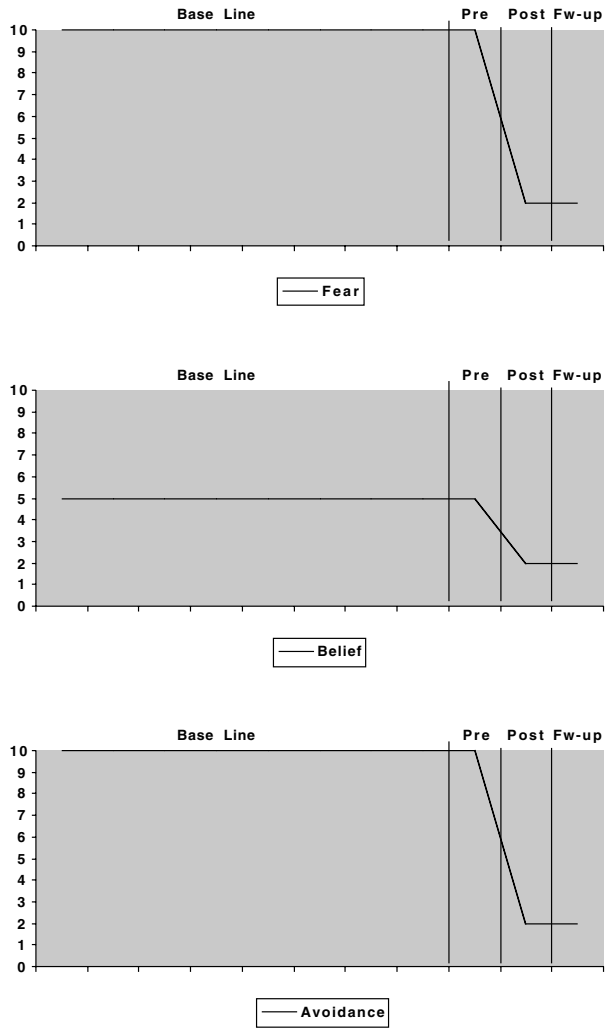

FIG. 1. Ratings in fear, avoidance, and belief in catastrophic thought regarding the target behavior throughout all the base-line (8 weeks), before and after the exposure session (1 h), and at the follow-up (2 months).

*According to Öst,[1] it is not useful to inform the person of all of the goals before the session since, in his experience, 90% of people will reject the treatment. Also, the fact of knowing what he or she will have to do could give rise to the patient thinking it over in a negative way during the entire session, and that this impedes him or her from focusing on the exposure task that he or she is realizing in each moment. Öst reflects on to what extend this could be ethical, but concludes that after 60 studies no patient has complained about it, to the contrary, the people thanked the therapist for demonstrating to them that they are capable of doing much more than they would have ever imagined.

TABLE 1. DEGREE OF ANXIETY THROUGHOUT THE EXPOSURE SESSION

Time	*Anxious element*	*Degree of anxiety*
12.00	Initial moment	7
12.02	The first cockroach appears	9 (notable reaction of start)
12.05	A cockroach	9
12.10	A cockroach	5
12.15	A cockroach	3
12.20	Three cockroaches	5
12.25	Three cockroaches	2
12.30	Many cockroaches	4
12.35	Many cockroaches	2
12.36	Therapist kills a cockroach	4
12.37	Participant kills a cockroach	2
12.40	Surprise element, boxes in which cockroaches appear	7 (notable reaction of start)
12.45	Surprise element, boxes in which cockroaches appear	5
12.50	Surprise element, boxes in which cockroaches appear	2
12.55	Many cockroaches	1
12.17	Many cockroaches	1
13.00	Many cockroaches	0

in Table 1, at the beginning of the session the anxiety was situated at the level of 7 on SUDS, later at the moment when the first cockroach appeared Maria experienced an important start. She said she had thought that the cockroach could climb on her, and she indicated a degree of anxiety of 9. Subsequently, all through the process of exposure variations were observed in the degree of anxiety that she experienced. The increment in anxiety was related to the different AR levels and the anxiety provoking elements introduced. For example, depending on the number of cockroaches, or on the element of surprise of not knowing when or where they were going to appear, or of the fact of killing the cockroaches, or of having to collect them with cardboard and throw them in the trash. All through the process, a tendency to decrease the degree of anxiety experienced was observed, to the point of reporting a 1 for anxiety on the SUDS at the 55th minute of exposure to the virtual cockroaches super-imposed by the system on the real world, and finally, arriving at 0 in the 60th minute. Moreover, Maria explained that she felt a notable sensation of personel self-efficacy with the fact of having to interact with cockroaches. In Figure 2a,b, two moments of the exposure can be seen in (a) the hands of the therapist and (b) the hands of the therapist and of the participant. In Figure 3a,b, the moment in which there is an interaction with virtual dead cockroach can be seen.

With respect to the self-reports specific to the fear of cockroaches, before the treatment the scoring of the FSQ was a 98, and after the treatment a 54. In the case of the SBQ, before the treatment it was a 42 in the scoring of the "Spider-beliefs subscale," and

FIG. 2. Two images of the hands of the therapist **(A)** and the hands of the therapist and of the participant **(B)**.

FIG. 3. There is an interaction with a virtual cockroach dead.

a 48 in the "Self-related beliefs," whereas after the treatment the scoring on both scales was a 25 and a 22, respectively.

With respect to the measures related with the opinion of the participant regarding the treatment, Maria valued it with a 6 (on a 1–7 scale), the willingness of getting involved in a treatment program that includes AR exposure and with a 2 (on a 1–7 scale), her willingness of getting involved in a treatment program that includes *in vivo* exposure. As for the valuation of the treatment after it was applied, Maria (using a scale of 1–10) valued it very positively: She found the procedure very logical (10), she was very satisfied (10), she would recommend it to a friend (10), she found that it could be useful for treating other psychological problems (10), she did not find it to be excessively averse (2), and indicated that it had been very useful in treating her problem (10). The same results were observed in the follow-up. For another part, as much before as after the treatment, Maria showed verbally her clear preference to the AR system as opposed to the *in vivo* exposure procedure to real cockroaches. After the treatment she indicated that she possibly would also have been able to be exposed to a procedure of this type, but that without a doubt would have resulted much more aversely.

With respect to the degree of presence and reality judgment manifested by Maria, in Table 2 it can be seen that, according to her subjective valuation (carried out after interacting with the AR system for 60 min), during the session of exposure she experienced a high degree of presence. When asked the question "In what measure have you felt present in the situation you have lived," she answered 10; and when asked the question "In what measure have you had the sensation of being in a place where the cockroaches appeared," she answered with a 9. With respect to reality judgment, when asked "In what measure did the cockroaches seem real," she answered 6. Whereas after an interaction of 5 min with the system in the follow-up session, to these same questions she answered in the three cases with a value of 8.

DISCUSSION

The aim of this work was to present the first AR system designed for the treatment of a psychological disorder, the phobia to small animals. The results make manifest the utility of the AR system for the treatment of the phobia to cockroaches. Using the guidelines of Öst[1] of the one-session treatment, but using as a stimulus for the exposure virtual cockroaches super-imposed on to reality by means of the system, was achieved (with an exposure time of 60 min) not only a very notable decrease in the degree of fear and avoidance experienced by the participant faced with the virtual cockroaches, but that she approached them, looked, and interacted with a real, live cockroach that she later killed and threw in the trash bin. In the two months follow up she maintained the improvement. At that moment the partici-

TABLE 2. SENSE OF PRESENCE AND REALITY JUDGMENT

	Post AR 1	*Post AR 2*
"To what degree have you felt present in the situation"	10	8
"To what degree have you felt that you were in a place in which cockroaches appeared"	9	8
"To what degree did you think the cockroaches were real"	6	8

Post-AR 1: Post AR exposure session (60 min of exposure).
Post-AR 2: Post AR interaction with the system in the follow-up (5 min of interaction).

pant was able to interact with four live cockroaches, kill them and also throw them in the trash bin.

The data obtained with respect to the degree of anxiety experienced by the participant throughout the session of exposure fit with what would be expected if an *in vivo* exposure procedure had been applied, that is, elevated anxiety when a person confronts a feared stimulus, and a gradual decrease as the time of exposure advances. This makes evident that the virtual cockroaches were capable of activating the participant's anxiety, and that subsequently this anxiety was decreased as the time of exposure progressed. In regards to the data of the FSQ self report, the data indicate that before the treatment the scoring of the participant is elevated and is situated in the range of scores obtained by the clinical population.[16,24] After the treatment the score of our participant was similar to those obtained in the study by García-Palacios et al.[16] Something similar occured in the case of the SBQ scales. Regarding these results, it is important to mention that the participant indicated in the post treatment, that the fear had decreased but the disgust that these animals produced was very similar, above all, the fact of seeing the white liquid that she saw when smashing a cockroach.

Also, very satisfactory results were obtained with respect to the acceptance of the participant of this type of AR system, and clearly manifested her preferences with respect to exposure to real live cockroaches.

The result with respect to presence and reality judgment deserves highlighting. After the treatment session the participant manifested to have experienced very elevated degrees of presence. It must be remembered that, in fact she was in the real situation. Reality judgment regarding the cockroach in that same session is less elevated, and it also has to be remembered that the cockroaches were virtual ones. Now, in the follow-up session, and after interacting again with the AR system during 5 min, the participant indicated the same scores, both for the fact of feeling present in the situation as well as regarding the degree in which she found the cockroaches real. The question raised here is, how is it possible that these two aspects are rated in the same way? The patient was there and the environment was real, while the cockroaches were virtual ones. Although they are very preliminary, since they are subjective evaluations in a case study, this data points out the possibility of juggling between the "real" and the "virtual." We could think about information processing "games." As indicated by constructivist theoreticians,[31–33] or as it would be defended from a "critical realism" approach[34] we do not know how reality is in fact, we only know reality as we construct it. It is evident that the planet Earth is not the same for a person that suffers from a panic disorder and agoraphobia as it is for a person that does not have these problems. The important question here is that maybe we can use these AR systems, which have the advantage that they allow the provision of additional information to the user to modify in a more efficient and effective way the pathological fear structures[35] than what can be accomplished with current psychological treatments. The topic is important, it is about helping the person see that reality (the cockroaches, open spaces, or heart palpitations) and the self ("I'm weak and cannot confront it"), that he/she took as something definitive and finished are not more than interpretations, constructions that (at least in same degree) can be altered.

If these results are confirmed in other works, with other problems and with bigger samples, it could be assumed that RA can have numerous applications in the field of psychological treatments. For now, however, a great degree of caution should be maintained since it is a mere case study with all of the threats regarding internal and external validity[36,37] that this implies.

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