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# Treating cockroach phobia using a serious game on a mobile phone and augmented reality exposure: A single case study

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ABSTRACT

In vivo exposure has proved its efficacy in the treatment of specific phobias; however, not all patients benefit from it. Communication and information technologies such as Virtual Reality (VR) and Augmented Reality (AR) have improved exposure treatment adherence and acceptance. Serious games (SG) could also be used in order to facilitate exposure treatment. A line of research on SG is emerging which focuses on health issues. We have developed a SG for the treatment of cockroach phobia that uses a mobile phone as the application device. This work examines results of an $N = 1$ study about whether the use of this mobile game can facilitate treatment of this specific phobia preparing her for the AR exposure. A 25-year-old woman with cockroach phobia participated in the study. Results showed that the use of the mobile game reduced her level of fear and avoidance before a "one-session" AR exposure treatment was applied, following the guidelines by Öst. The participant found very helpful the use of the SG before the AR exposure session and she was willing to use it after the AR exposure session as a homework assignment. Although the results of this study are preliminary, SG appears to be a line of research of high interest in clinical psychology for the treatment of specific phobias.



## 1. Introduction

Specific phobias have a high prevalence rate and can be very disabling for many people (Agras, Sylvester, & Oliveau, 1969; Boyd et al., 1990; Magee, Eaton, Wittchen, McGonagle, & Kessler, 1996). Between 60% and 80% of people who suffer from phobias do not seek treatment (Agras et al., 1969; Boyd et al., 1990; Magee et al., 1996). As untreated mental health disorders become more severe, social and economic costs to society will increase (Kessler & Greenberg, 2002; Kessler et al., 2008).

Currently, the treatment of choice for specific phobias is in vivo exposure (Antony & Swinson, 2000); however, not all patients benefit from this treatment. According to Choy, Fyer, and Lipsitz (2007), it is necessary to analyze the overall effectiveness of in vivo exposure, taking into account aspects such as treatment motivation and adherence; a high treatment rejection or abandon rate is observed (approximately 25%) when patients are informed about the procedure of exposure therapy (García-Palacios, Hoffman, See, Tsay, & Botella, 2001; Marks, 1978; Marks, 1992; Garcia-Palacios et al., 2007). Dropout rates ranging from 0% to 45% have been reported for in vivo exposure for treating specific phobias in adults. A possible explanation for these high rejection and attrition rates is that patients consider it to be too threatening and/or aversive to confront the feared object or situation (Choy et al., 2007).

In addition to frequent rejection by patients, other authors have suggested that in vivo exposure suffers from a "public relations problem" with therapists, that is, there are concerns that it is cruel and at odds with some ethical considerations because it purposefully evokes distress in patients (Olatunji, Deacon, & Abramowitz, 2009). Some practitioners therefore have a negative view of this treatment (Feeney, Hembree, & Zoellner, 2003; Prochaska & Norcross, 1999). Richard and Gloster (2007) conducted a survey of professional members of the Anxiety Disorders Association of America, and found that exposure-based therapies were considered fairly aversive. New technologies, especially Virtual reality (VR) could help to overcome these issues. In fact, in Richard and Gloster's survey, VR exposure therapy was viewed as more acceptable, helpful, and ethical than traditional exposure-based therapies (Richard & Gloster, 2007).

Data about the efficacy of VR for exposure in phobia treatment are already available (e.g., Botella, Baños, Villa, Perpiñá, & García-Palacios, 2000; Choy et al., 2007; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008; Rothbaum et al., 2006) as are data on increasing participants' acceptance of VR exposure over in vivo exposure (Garcia-Palacios et al., 2007). Augmented Reality (AR) is

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a variant of VR that combines the real world with virtual elements, using computer graphics that are blended into the real world in real time. The user sees the real world "augmented" by virtual elements, that is, AR tries to complement or improve the reality not to replace it (Azuma, 1997). A core aspect of AR is that the virtual elements add relevant and helpful information to the physical details of the real world. For instance, in Theme Parks, a therapist can display certain information by imposing virtual images (such as reconstructed ruins or landscapes as they appeared in the past) over real objects and environments. Milgram and Kishino (1994) analyze the qualities of both systems along a continuum from real to virtual environments. In VR systems the user is completely immersed in synthetic contexts, whereas in AR the user sees an image comprising both the real world and virtual elements.

AR applications are already available in the areas of education (Arvanitis et al., 2007; Kerawalla, Luckin, Seljeflot, & Woolard, 2006) and medicine (De Buck et al., 2005). In the field of clinical psychology, some studies have demonstrated the utility of AR for the treatment of insect phobias (Botella et al., 2005; Botella, Bretón-López, Quero, Baños, & García-Palacios, 2010). Botella et al. (2005) evaluated a cockroach phobia case study using an AR system developed for the treatment of this specific phobia. The AR exposure therapy was applied using the "one-session treatment" guidelines developed by Öst (Öst, 1989; Öst, 1997; Öst & Ollendick, 2001; Öst, Salkovskis, & Hellström, 1991). In Botella et al. (2010) the efficacy of the same AR system was tested in the short and long term (three-, six- and twelve-month follow-up) using a multiple baseline design across individuals. Results showed that AR was effective at treating cockroach phobia. The AR system was capable of evoking fear in the participants, and all participants improved significantly in all outcome measures after treatment; furthermore, the treatment gains were maintained at follow-up periods.

These two studies (Botella et al., 2005, 2010) demonstrate that the AR system was efficacious; however, some aspects could be improved. Firstly, as usual, participants came to the "one-session treatment" with high levels of fear. We hypothesize that asking the patients to complete homework assignments involving familiarization with the feared object (cockroach) could help make the "one-session" exposure treatment less aversive. Secondly, following Öst's recommendation (Öst et al., 1991), participants are advised to continue confronting cockroach-related phobic situations after therapy in order to completely surmount the problem. This aspect can be difficult, since the feared object (cockroach) is sometimes not present for the duration that the patient requires. New technologies, such as computer games, could help make post-treatment self-exposure tasks more effective.

Computer games have emerged as a powerful new economic, cultural, and educational force. Their ubiquity with increasingly diverse groups of people (children, adults, and elderly people) suggests that their utility may extend beyond entertainment purposes. Clark Abt proposed the term "Serious Game" (SG) in 1970, long before the introduction of computer and electronic devices into the entertainment arena. From his point of view, the primary goal of an SG should not be simple entertainment; rather, it should have an explicit and carefully thought-out educational purpose. This is precisely what characterizes SGs: they are games that engage users in a purpose and help to achieve a determined goal that extends beyond pure entertainment (Michael & Chen, 2006; Zyda, 2005).

An emerging line of research on SG focuses on health issues such as prevention of disease, healthy lifestyles, physical exercise, and more. Some works combine the use of SG with mobile devices (Fogg & Eckles, 2007); for instance SG designed to help manage chronic disease (Boland, 2007), and to teach about healthy diets and to promote physical exercise in obese children (Baños et al., 2009). Special issues have appeared on this topic emphasizing the great potential of SGs (Barnes, Encarnação, & Shaw, 2009). Specifically, in the cognitive-behavioral field a pioneering SGs have been developed, the "Treasure Hunt" in order to support psychotherapeutic treatment of children with emotional problems using cognitive behaviour therapy principles (Brezinka, 2007; Brezinka & Hovestadt, 2007), however, these studies do not offer data about the efficacy and utility of these SGs. In fact, the impact of these new applications has just begun to emerge, prompting one researcher to state that "mobile phones will soon become the most important platform for changing human behavior" (Fogg, 2007, page, 5).

Because SGs can change behavior, it is worthwhile to investigate whether they can help people overcome phobias. A large number of games incorporating feared objects related to phobias already exist, including those with cockroaches. However, clinical patients with mental disorders should of course only use games that meet strict conditions consistent with exposure therapy as applied in a therapeutic context. As previously mentioned, exposure is the most effective technique for treating anxiety disorders; it involves confronting feared situations in a repeated, gradual, and systematic way. One of the processes that affects the efficacy of exposure is emotional processing (Rachman, 1980). Foa and Kozak (1986) used this concept to explain fear reduction during exposure. This approach incorporates Lang's bio-information theory of emotion, in which fear is considered a cognitive structure that includes representations of stimuli, responses, and their meaning (Lang, 1979). Foa and Kozak (1986) suggested that exposure to feared stimuli activates the pathological fear structure and presents corrective information incompatible with the pathological elements of the fear structure. In order to facilitate change, it is also important to enhance the patient's perception of self-efficacy when confronting the feared situation, context or object (Bandura, 1977) and also to incorporate humor into the therapeutic process (Frankl, 1960).

After surveying currently available games, we could not find any that could be used according to the suitable clinical guidelines for the treatment of specific phobias. Therefore, our research team has developed an SG named "Cockroach Game" which uses a mobile phone as the application device for the treatment of cockroach phobia. Its main objective is to help the user become familiar enough with the feared insect (cockroach) to be able to interact with it. It is hypothesized that the use of SG will help the participant to become more familiar with the feared stimuli and this will diminish the levels of fear and avoidance, helping the participant to confront the "one-session treatment" and preparing the participant to gain more from the exposure session.

This study describes the Cockroach Game SG and presents results obtained in a single case study in which it was applied in combination with AR exposure, concretely the SG was used before and after receiving the "one-session" AR exposure therapy.

## 2. Method

### 2.1. Participant

A 25-year-old woman with cockroach phobia participated in this study. She came to seek help at the Emotional Disorders Clinic at Jaume I University of Castellon (Spain) and met DSM-IV-TR (APA, 2000) criteria for Specific Phobia animal type, specifically Cockroach phobia. She had received no prior treatment for her fear of cockroaches. In order to be included in the study, the participant should fulfil the criteria established in the clinical studies about one-session treatment for specific phobias, that were: having a score over 4 in phobic avoidance (on a scale of 0–8), having no current alcohol or drug dependency, having no diagnosis of major depression or psychosis, not taking any anti-anxiety medication for the duration of the study, not having been or being treated with a similar program, having a minimum of one year duration for the problem and not being able to put her hand inside a container with a cockroach during the behavioral avoidance test.

The woman was divorced and worked as a clerk in an office. Her fear of cockroaches began a few years ago and she did not remember any particular cause; however, she conjectured that perhaps it was related to the fact that she frequently encountered the insects after having moved back to her city of origin alone after her divorce. It was at this time that the participant requested help at our clinic to manage her depressed mood. She was diagnosed with adjustment disorder and received a brief psychological treatment with good results.

One year later, she returned to our clinic for treatment for her cockroach phobia. She reported that her fear had become progressively worse and that she felt less capable of confronting cockroaches than before. Given her high level of fear, we invited her to participate in a pilot study that uses a new SG for confronting cockroaches before the participant receives a one-session AR treatment. The patient agreed to participate.

She rated the interference of her phobia in her life as a 7 on a scale of 0–8 (ADIS-IV; DiNardo, Brown & Barlow, 1994) and the severity of her problem as an 8 on a scale of 0–8. The participant reported a high level of fear when she saw a cockroach. In the first assessment interview, the participant stated that she avoided going anywhere where cockroaches might be found. Her fear was so severe that she felt unable to enter her garage alone, to take out the trash or be out in the street (for example, in the terrace of a bar) if she suspected that she would find a cockroach. When she did see a cockroach, she would run away and suffer from tachycardia. The catastrophic thoughts she reported about cockroaches were that ‘‘*the cockroach will approach me, it is uncontrollable, and it will land on me*’’. Her core belief regarding cockroaches was to be infected by the cockroach ‘‘*It is a dangerous and dirty animal, it will get into my clothes and will infect me*’’.

## 2.2. Measures

### 2.2.1. Diagnostic measure

The *Anxiety Disorders Interview Schedule* (ADIS-IV; DiNardo et al., 1994) specific phobia section was used to make the diagnosis. This instrument also includes other relevant clinical measures such as ‘‘interference as perceived by the participant’’ on a scale from 0 to 8 (wherein 0 is ‘‘Not at all’’ and 8 is ‘‘Very severe’’), and the ‘‘clinician’s severity rating’’, (wherein the clinician rates the severity and interference of the problem on a scale from 0 to 8 where 0 is ‘‘Absent/none’’ and 8 is ‘‘Very severely disturbing/disabling’’). We included these two ratings as outcome measures in our study. The ADIS-IV has shown to have inter-rater reliability from satisfactory to excellent when administered by expert clinicians who are familiar with the DSM diagnostic criteria (DiNardo, Moras, Barlow, Rapee & Brown, 1993). The diagnosis was conducted by an expert clinician who also applied the treatment to the participant. To assess reliability of the diagnosis, a second interviewer also administered this interview. Diagnosis agreement was obtained in this case.

### 2.2.2. Target behaviors (adapted from Marks & Mathews, 1979)

The participant assessed her level of fear and avoidance on a scale ranging from 0 (‘‘No fear at all’’, ‘‘I never avoid’’) to 10 (‘‘Severe fear’’, ‘‘I always avoid’’) for the situations in which she had to confront small insects (e.g., to approach a cockroach). This work includes results for the most significant target behavior chosen by the participant: staying in a place where a cockroach was present. The degree of belief in the catastrophic thought (‘‘*It will land on me, it is a dangerous and dirty animal, it will get into my clothes and will infect me*’’) was also assessed on a 0–10 scale.

### 2.2.3. Behavioral avoidance test (BAT)

An adaptation of Öst et al. (1991) behavioral avoidance test was used to measure the degree of overt avoidance of cockroaches. This kind of test is considered to be the cornerstone of objective assessment for phobias (Meng, Kirkby, Martin, Gilroy, & Daniels, 2004; Mineka, Mystkowski, Hladek, & Rodriguez, 1999). For this study, a container with a live cockroach in it was placed 5 m from the entrance to a room. The participant was asked to enter the room and approach the cockroach as closely as possible. She was informed of the importance of doing the test for the assessment of her problem, and was told that she could terminate the behavioral test at any point if her anxiety became too strong. Her performance in the test was scored, taking into account her final proximity to the insect. The distance measurement was converted to a behavioral score wherein 0 = ‘‘The participant refuses to enter the room’’; 1 = ‘‘The participant stops 5 m away from the cockroach’’; 2 = ‘‘The participant stops 4 m away from the cockroach’’; 3 = ‘‘The participant stops 3 m away from the cockroach’’; 4 = ‘‘The participant stops 2 m away from the cockroach’’; 5 = ‘‘The participant stops 1 m away from the cockroach’’; 6 = ‘‘The participant stops near the cockroach’’; 7 = ‘‘The participant touches the container’’; and 8 = ‘‘The participant opens the container and interacts with the cockroach’’. In addition, the participant rated her level of subjective fear, avoidance and belief in her catastrophic thoughts on a scale of 0–10 before she entered the room with the feared insect, as well as her fear level for the last step completed during the BAT. Results of this BAT for Spanish participants with various small animal phobias (cockroaches, spiders and mice) can be found in Botella et al. (2008, 2010). Also, this BAT has been used in a controlled study demonstrating the efficacy of VR exposure therapy in the treatment of spider phobia (García-Palacios, Hoffman, Carlin, Furness, & Botella, 2002).

### 2.2.4. Fear of spiders questionnaire (FSQ; adapted from Szymanski & O’Donohue, 1995)

This questionnaire assesses the severity of spider phobia and consists of 18 items rated on an 8-point Likert scale ranging from 0 (‘‘I totally disagree’’) to 8 (‘‘I totally agree’’) for situations related to the fear of these creatures (e.g., ‘‘If I found a spider now, I would ask someone to help me to get rid of it’’). The total score ranges from 0 to 126. This measure has excellent internal consistency with Cronbach’s alphas ranging from .88 to .97 (Muris & Merckelbach, 1996; Szymanski & O’Donohue, 1995), as well as good test–retest reliability (Muris & Merckelbach, 1996). An adaptation of this questionnaire (in which all items were referred to as cockroaches) was made for the assessment of cockroach phobia. This adaptation for cockroaches has been used in previous studies (Botella et al., 2008, 2010).

### 2.2.5. Spider phobia beliefs questionnaire (SPBQ; adapted from Arntz, Lavy, Van der Berg, & Van Rijsoort, 1993)

This is a self-report scale comprised of 78 items. It includes the two following subscales: items from 1 to 42 assess the strength of fearful beliefs about spiders (e.g., ‘‘It will attack me’’); items from 43 to 78 measure the strength of fearful beliefs about one’s reaction to encountering spiders (e.g., ‘‘I will lose control’’). All items are rated on a scale from 0 (‘‘I do not believe it at all’’) to 100 (‘‘I absolutely believe it’’). This measure has good internal consistency reported by Arntz et al. (1993) for both the spider-related ($\alpha = .94$) and self-related ($\alpha = .94$) subscales. In addition, acceptable test–retest reliability for both subscales has been found ($r = .68$ for the spider-related and $r = .71$ for the self-related subscale). In order to assess fearful beliefs about cockroaches, an adaptation of this questionnaire was also made by our research team. The only change made to the original questionnaire was introducing the term cockroach instead of the term spider. This adaptation has been used for cockroaches and mice in other studies (Botella et al., 2008, 2010).

*2.2.6. Subjective units of discomfort scale (Wolpe, 1969)*

While using the mobile game and during the exposure session, the participant rated her levels of anxiety on a scale from 0 (''No anxiety'') to 10 (''Extreme anxiety'').

### *2.3. Serious game self-record*

This instrument includes the following variables: date and time the game was used, scenario and level of difficulty, and the maximum level of anxiety (from 0 ''No anxiety'' to 10 ''Extreme anxiety when playing. Finally, the self-report also included a record of the total duration of play (in minutes) and a record of whether or not the target was achieved.

### *2.4. Mobile game*

As indicated in the introduction, in order to meet the suitable conditions for use in a therapeutic context, the design of an SG should follow a series of clinical indications according to the existing knowledge of exposure therapy. Taking this into account, the clinical indications that guided the design of the cockroach SG were:

a) The SG should include different levels regarding the feared stimuli in order to make it possible to develop a hierarchy that would enable systematic and graduated exposure.
b) The SG should also allow players to gradually advance in the game, enhancing the sense of mastery and self-efficacy regarding being able to stay in a place where cockroaches are present.
c) The SG should use a ''neutral'' context; it should not include any reference to ''dirt'' so that the patient can overcome irrational thoughts associated with this.
d) The SG should include elements related to ''game'' and ''challenge''.
e) The SG should include some kind of reward.

''Cockroach Game'' is an application that was developed within the SG framework. Unlike in traditional games, advancement to different levels is not based on the cognitive skills of the player, but rather on the achievement of therapeutic goals. The increasing difficulty of the game is not based on exclusive playability criteria. Instead, the design, information architecture and goals match these clinical guidelines so that the player receives proper exposure to the feared animal. Therefore, the game was designed with possible users in mind: namely, people suffering from phobia of cockroaches.

From the perspective of human–machine interaction, the design, development and evaluation process involved the following: adapting clinical specifications to the game environment, optimizing the different methods of interaction to the parameters of this type of technology (screen size, graphical capability, types of interaction, etc.).

''Cockroach Game'' is a puzzle game using a mobile phone as the application device in which the main objective is to interact with cockroaches while matching the pieces of a puzzle. Several screen shots of the mobile game are shown in Fig. 1. The game has two scenarios with different levels of difficulty. In the first scenario, the screen option, the user can see the cockroaches on various surfaces that are displayed on the phone screen; the virtual insects appear on winter shoes (closed toe) in the first level, on summer shoes (open toe) on the intermediate level, and on a hand on the advanced level. The second scenario, as can be seen in Fig. 1, includes a camera option which allows the users to see the virtual cockroaches on real surfaces (e.g., on their real clothes, on their real hands, etc.).

In order to complete the puzzle, the user must win the pieces that comprise it by ''killing'' cockroaches, after interacting with them. Notably, in Spanish culture, killing a cockroach is considered an appropriate response because it is considered an animal related with dirtiness and is not related with avoidance of the feared insect.

The game also includes options on the mobile phone keyboard that allow the following: creating one or more insects, increasing their size, decreasing their size, and resetting the counter (see Fig. 1). The new insects appear in random positions on the display and can move horizontally and vertically; up to five can be created simultaneously. The user can create, change size and kill an insect at any time. Once the puzzle is complete, the user obtains a graphic ''trophy'' and diploma (see Fig. 1). In addition, the application can make sounds such as applause while the user acquires puzzle pieces during the game. If users want to stop the game for any reason, they can exit the application and their scores will be stored until the next time they play. It is also possible to reset the game to the initial level at any moment during play.

Java 2 Mobile Edition (J2ME) platform was used for the development of the game. The system can be used on any mobile phone with an integrated camera that supports J2ME, specifically the Mobile Information Device Profile (MIDP) 2.0. The phone must also support the Mobile Media API (MMAPI), an optional JAVA package


**Fig. 1.** Mobile game screen shots: camera option, mobile phone keyboard, symbolic reinforcement.

that allows access to the mobile phone camera in order to capture video that is shown in the background of "Cockroach Game". A high-end phone is not needed to play the game; it runs on most mid-range phones, and only requires Java support. To develop and test the system, we used a Nokia 6600 mobile phone. This model meets the specifications above, as do many of the mobile phones currently on the market.

The video capture provides the sensation of interacting with the insects in the real environment. J2ME devices range from mobile phones with simple tone generation to PDAs with advanced audio and video capabilities. MMAPI provides access to all types of multimedia content locally as well as remotely, including images, audio and video. It is also the interface for the audio and video recording. MMAPI supports the following characteristics: (a) tone and sequence production; (b) MIDI sequence display; (c) video display; (d) photo capture, and (e) audio and video recording. "Cockroach Game" only requires video recording and playing, since the game player is usually viewing the video of the real environment that the camera is recording and playing.

MMAPI offers a common interface for reading information from any source and in any format using a Uniform Resources Identifier (URI), which defines the device and the playing parameters. In "Cockroach Game", we need to access the camera in order to read information from it, which is done using the special capture URI "capture: // video". By calling the method "System.getProperty (String key);" we can determine whether a mobile device allows video capture, and in what formats.

Regarding the virtual elements (the insects), the game was developed using the MIDP 2.0 profile (Personal Mobile Information Profile) of J2ME; one of the most important improvements that this profile presents is that its API is designed for developing entertainment applications (Sun Microsystems Inc. 2000).

The main idea of the game's API is that the game's display consists of layers. The screens to show consist of layers. All of these layers can be handled separately and the API handles drawing them. Of the classes offered by the game API of MIDP 2.0 we used the following: GameCanvas, LayerManager and Sprite.

The main screen of the game is GameCanvas, shows us the state of the keys on the phone's touchpad as used in game play. This is very useful, since the user interacts with the game via the keyboard of the mobile phone (by selecting one of the available actions). In addition, GameCanvas synchronizes the appearance of graphics on the display, which helps eliminate the "blinking" that sometimes results from constantly redrawing the graphics.

To achieve movement of the insects, we used the class called Sprite (an animated layer). We created the animations as sequences of movement from a set of same-sized images showing the cockroaches' antennae and leg positions at different moments during movement. These images were captured from models of cockroaches that were as realistic as possible, designed with Autodesk 3ds Max.

The models described above represent the structure, movement and texture of the cockroaches (see Fig. 2). Later, rotations created by the Sprite class (including mirror, 90°, 180° and 270°) were used to display the insects in accurate positions, and to simulate realistic movement.

Each time the user creates a new insect during play, a new Sprite object is created, which represents the new insect moving itself. This Sprite is then eliminated when the insect is removed. The LayerManager class is used to manage the different Sprites that can exist in the game simultaneously (up to five).

The pieces of the puzzle that are recreated in each level are also images, as are some of the drawings used to congratulate users when they earn a piece of the puzzle or complete a level of the game.

Another aspect was the user interaction. Commands provided by J2ME are used to introduce all of this functionality to the game and to determine what players want to do at any given moment. Commands allow users to interact with the application and select functionality; the users thereby introduce "orders" into the game. The commands are modelled using the Command class. When creating a command, users can assign a priority to it, in addition to the tag that will be shown. The priority of a command is important, because it determines how users will access the command. Because mobile phones have a limited number of buttons, only the most important commands are directly mapped to them. Commands assigned with lesser priorities are only accessible from a menu, not directly from a button.

When the first functional prototype of "Cockroach Game" for mobile phones was completed, we conducted an evaluation for usability. The main objective of the evaluation was to guarantee the success of the exposure process via the mobile device according to its therapeutic purpose. The evaluation was conducted by a usability expert with a Nokia N70 mobile phone (with a Symbian operating system). As a result, the following recommendations were made:

1. The device's operating system allows the user to continuously see two keys, which originally corresponded with "Options" and "Save". Maintaining constant visual contact throughout exposure is important; therefore, it was advised that the actions "Save" and "Exit" should correspond with the "Options" key. It was also advised that the key for the main interaction be on the right side of the screen, which is easier for users to access.
2. In order to create a new cockroach ("create a cockroach"), it was recommended to use the key on the right side, so as not to lose visual contact when entering options. Originally, this action was accessed through the "Options" key.
3. In order to change the size of the insect, the system required the user to use the menu options, which broke the user's visual contact with the exposure scenario. To avoid this, it was recommended to use the upper part of the central key to enlarge the size of an insect, and the lower part to reduce it.
4. For the software for mobile phones without a camera, a more realistic wallpaper was recommended. Furthermore, it was recommended to change the wallpaper according to the user's advancement to different levels in the game: (a) first step in the hierarchy (first level in the game): wallpaper with two feet

**Fig. 2.** Sprites (image sequences) for cockroach movement.

wearing running shoes from the first person perspective; (b) second step in the hierarchy exposure (second level in the game): wallpaper with two feet wearing sandals, also from the first person perspective; (c) third step in hierarchy (third level in the game): wallpaper of a hand.

5. As for playability, it was recommended to include sounds, as they would positively reinforce the user: (a) each time a screen is completed, the user receives a piece of a puzzle. It was recommended to include a pleasant sound with an ascending pitch, as well as an animal indicating that the user has received another piece of the puzzle; (b) at the end of each level, there is a trophy indicating that the user has successfully completed it. It was recommended to include an applause sound to reinforce the user.

### 2.5. Augmented reality system

The AR-Insect Phobia system runs on a PC AMD Athlon with 1 Gb RAM on Microsoft Windows 2000. The video stream is captured using a USB camera (Creative NX-Ultra). Mixed Reality images are displayed with a 5DT HMD (head-mounted display). Participants can see the actual world through the HMD; everything they see is real except the feared stimuli (in this case, cockroaches). A significant element of the system is the representation of the cockroach, which can move its feelers and legs and has structure, movements and texture that are similar to real cockroaches. Both the body and the basic movements of the cockroaches were modelled using 3DStudio and exported in VRML format.

The AR-Insect Phobia system includes the following variables. (1) Number of cockroaches. When only one cockroach is required, it appears in the center of the marker; when more cockroaches appear, they do so randomly. (2) Movement of cockroaches. The cockroaches can be static or dynamic, and their movement is repetitive and different for each cockroach. (3) Zoom in/Zoom out. The size of the cockroaches can be increased or reduced (to small, medium and large sizes) with these options. Finally, cockroaches can be displayed on several surfaces (on the table, on the floor, and near users' personal belongings). Fig. 3 shows a person interacting with the cockroaches with her hands. A full description of the system can be found in previous works (Botella et al., 2005, 2010).

**Fig. 3.** A person interacting with the cockroaches with her hands.

### 2.6. Design and procedure

The participant sought help for her cockroach phobia at our emotional disorders clinic. First, she underwent a screening assessment. She satisfied the inclusion criteria and signed a consent form to participate in the study.

The assessment consisted of two 60-min sessions. In the first session, the ADIS-IV for specific phobia was administered and an independent diagnostic assessment to confirm the diagnosis was carried out. In the second assessment session, the participant completed other self-report measures (specific questionnaires about cockroach phobia) and the target behaviors were established.

A single case study design was used. The different phases of the study are presented in Table 1. As shown in Table 1, after the initial assessment, a 14-day baseline period was established during which the participant recorded her degree of fear, avoidance and belief in the catastrophic thought regarding the main target behavior on a daily basis. Before starting the treatment phase, the BAT was applied.

Next, two intervention options (Cockroach Game and Augmented Reality Exposure) were carried out in different phases. In the first intervention phase (“First mobile game interaction”; MG1) the participant was asked to play with “Cockroach Game” throughout 7 days and to register her levels of fear, avoidance and belief in the catastrophic thought according to the different scenarios offered by the mobile game. During this period she could play as much as she wanted. On day six the participant asked the therapist to extend the time of playing to 9 days (three more days) because she felt the game was decreasing her level of avoidance and fear; however, she was still too afraid to advance to the second phase of the intervention, that is, the “one-session” AR exposure (Botella et al., 2005). After this first phase, a new assessment of target behaviors and BAT was made. In the second intervention phase, the participant received the “one-session” exposure treatment using the AR system. The exposure therapy was carried out by an experienced clinician with a Ph.D. degree. After completing this intensive treatment, the main clinical variables (target behaviors, specific questionnaires, and BAT) were assessed again. In the third intervention phase, the patient was encouraged to play with the “Cockroach Game” over another period of 9 days as homework task (“Second mobile game interaction”; MG2) and registered the same clinical variables (levels of fear, avoidance and belief according to the different scenarios). During the two interaction periods with the game (MG1 and MG2) the participant also recorded the following information: date and time the game was used, scenario, maximum level of anxiety while playing, and total time spent playing (in minutes) and whether or not the target was achieved.

After the last phase, a new assessment of target behaviors and BAT was made again. Finally, the main clinical variables were assessed again at 1-, 3-, 6- and 12-month follow-up periods. After the first and second mobile game interaction, the participant was asked about her opinions and satisfaction with the mobile device.

### 2.7. Mobile game procedure

“Cockroach Game” was applied in the form of self-exposure tasks for the participant, who had to confront the different scenarios involving interacting with cockroaches. First, the therapist explained the rationale of exposure and the possibilities the mobile game offered to carry out self-exposure tasks. Next, both therapist and patient created a gradual exposure hierarchy using the appropriate software options of “Cockroach Game” so that the participant could experience gradual and personalized exposure to the levels of difficulty (initial, intermediate and advanced) and options (screen or camera), progressing from the easiest to the most challenging situations.

**Table 1**
Phases of study.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | 14-day BL | A | 9-day MG1 | A | "One-session" AR exposure | A | 9-day MG2 | A | FUs |

A = assessment; BL = baseline; MG1 = first mobile game interaction; MG2 = second mobile game interaction; FUs: follow-up periods.

### *2.8. Augmented reality system procedure*

The exposure session was conducted in a single extended session lasting one hour and sixteen minutes. The treatment includes participant modelling, AR exposure (in this case), reinforced practice and cognitive challenge. The purpose of this exposure treatment is for patients to confront their phobic situation in a controlled manner, thereby allowing them to accept that the negative consequences they fear do not actually occur. During the AR "one-session treatment" the therapist could view the treatment on a monitor and see the same stimuli as the participant, and could also control the application using computer keys. The participant confronted various scenarios, progressing from the easiest to the most challenging situations. The goal was for the participant to remain in the various situations until they experienced a notable decrease in anxiety. Throughout the treatment, the therapist's instructions to the participant were similar to those used in traditional in vivo exposures. Following the instructions recommended by Öst et al. (1991) (adapted for the AR system), that is, the exposure session would be completed in a gradual, planned and controlled way.

## 3. Results

### *3.1. Target behaviors*

Results obtained for the level of fear, avoidance and belief in the catastrophic thought related to the main target behavior are presented in Fig. 4. The data obtained along baseline scores were quite stable for all measures, especially for avoidance. However, although fear and belief scores reported by the participant slightly decreased and increased along the baseline period, before starting the phase one of the intervention, that is, the first mobile game interaction (MG1), the participant's scores in fear, avoidance, and belief were in a high rank. As it can be seen in Fig. 4, the first days of use of the SG, the participant's scores in fear, avoidance and belief in catastrophic thoughts were high. However, with the use of the SG a progressive decrease of the levels of fear and avoidance, but not of the degree of belief in the negative thought occurred. Moreover, as is marked with an arrow in Fig. 4, a more notable reduction was produced in these two variables from day six to day nine (after the participant asked for extended play with the mobile game). After the "one-session" AR exposure treatment, all three clinical variables decreased notably. The second mobile game interaction (MG2) produced an additional reduction of fear, avoidance and belief with regard with the registered scores after the "one-session" AR exposure. Furthermore, all therapeutic gains were maintained at one-, three-, six- and twelve-month follow-up periods; some (specifically for fear and belief) even continued to improve over time.

Results on the interaction of the participant with the SG are shown in Fig. 5. As shown in the figures, the participant played each day during the two game periods and utilized all of the scenarios with different levels of difficulty, as agreed upon with the therapist. During the game periods, the game activated the anxiety response. As the days passed anxiety was decreasing. The duration of play varied from 15 to 35 min. During MG1 (Fig. 5), there were 6 days in which the target was reached and there were 3 days in which the target was not reached, specifically regarding the scenarios "no camera shoes" (day 2) and "no camera hand" (days 4 and 5). The patient replayed the scenarios on the following day, thereby reaching the target. During MG2 (Fig. 5), and after the participant received the one-session AR treatment, she reached the target each day; in other words, she only needed one day to reach the target for each scenario.

### *3.2. Other outcome measures*

Regarding the remaining outcome measures, scores reported by the participant along the different phases included in the study are shown in Table 2. If we compare the BAT results before and after the first interaction with the SG (MG1) a slight improvement is observed in performance, fear and avoidance; whereas there was a slight increase in the belief in the catastrophic thought. After the "one-session" AR exposure treatment there were improvements in all BAT measures: performance, fear, avoidance and belief. After the second mobile game interaction (MG2), a drastic reduction was produced in all these measures and these gains were maintained at four follow-up periods. For example, with regard to performance the participant obtained a score of 7 after the "one-session" treatment; she was able to touch the container (but only for a few seconds and with a high level of anxiety), after the second mobile game interaction (MG2), she was able to touch the container with no anxiety for a longer period of time; and her performance in the BAT improved even more (maximum score of 8) at one-, three-, six- and twelve-month follow-up periods.

As for the specific cockroach phobia questionnaires, a notable reduction in the FSQ was observed after the "one-session" AR exposure treatment, and an additional reduction was produced at one-, three-, six- and twelve-month follow-up periods. The scores obtained for the two subscales included in the SPBQ likewise improved; a notable reduction was produced after the "one-session" exposure treatment and an additional decrease was observed at four follow-up periods (see Table 2).

Finally, as can be seen in Table 2, both the clinician's rating and the interference of the problem perceived by the participant decreased notably after the second mobile game interaction, and these gains were maintained or even improved at four follow-up periods.

## 4. Discussion

Results obtained in this study support the utility of a combination of a SG and a one-session AR exposure therapy program for the treatment of cockroach phobia. The findings related to the "one-session" AR exposure therapy are consistent with those obtained in previous studies (Botella et al., 2005, 2010). Furthermore, results regarding the mobile game point out its possible utility for improving the feasibility of exposure therapy for cockroach phobia. The participant was able to play every day throughout the two game periods (MG1 and MG2). Anxiety levels were highest on the first day, and were progressively reduced throughout the game periods as the participant reached the programmed targets.

The AR-Animal Phobia system applied using the guidelines developed by Öst et al. (1991) was able to elicit anxiety in the participant and produced a notable decrease in all outcome measures: levels of fear, avoidance and belief in the catastrophic thought related to the main target behaviour, scores obtained in the BAT (for

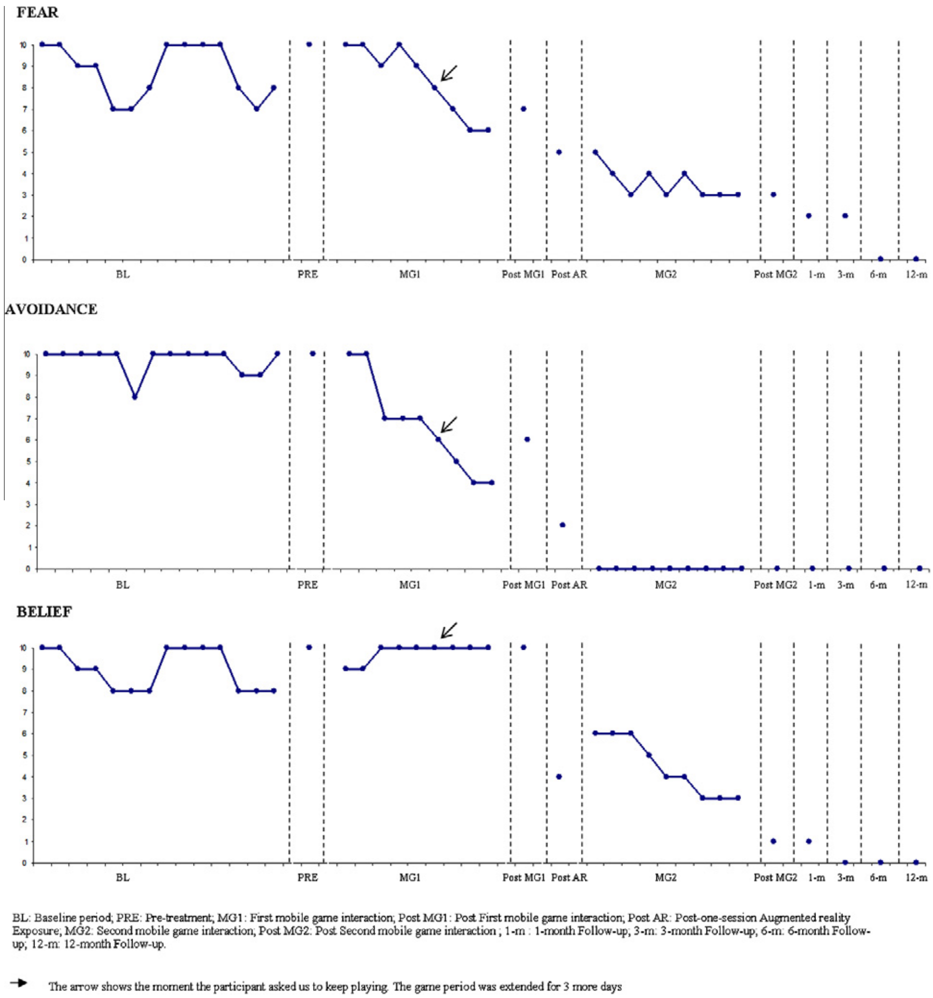


**Fig. 4.** Scores of fear, avoidance and belief along the different phases of the study.

performance and subjective levels of anxiety, avoidance and belief in the catastrophic thoughts), scores for the specific questionnaires (FSQ and SPBQ), and for the interference and severity measures (clinician's rating and interference of the problem perceived by the participant). Furthermore, all of these gains were maintained or even showed a larger improvement at one-, three-, six- and twelve-month follow-up periods. The score obtained by the participant in the FSQ after "one-session" AR exposure treatment was lower than the mean score for phobic individuals after treatment reported by Muris and Merckelbach (1996) ($M = 39.9$, $SD = 25.4$). In addition, the participant's score in this questionnaire at all four follow-up periods was similar to the mean score reported by the same authors for non-phobic controls ($M = 3.0$; $SD = 7.8$) (See Table 2). As for the cockroach-related belief subscale of SPBQ, the score obtained by the participant after "one-session" AR treatment and at four follow-up periods was similar to the mean score of phobic individuals reported by Arntz et al. (1993) after treatment ($M = 10.15$, $SD = 13.6$). For the self-related beliefs subscale of the SPBQ, similar results were found after "one-session" AR exposure treatment; that is, the score obtained by the participant was similar to the mean score obtained by Arntz et al. (1993) in spider phobics after treatment ($M = 8.00$, $SD = 3.15$). Moreover, the score obtained by the participant in this study was even lower at four follow-up periods (see Table 2).

The findings regarding the mobile game point out its possible utility for the treatment of cockroach phobia. After the first 9-day mobile game interaction, the participant showed a decrease in the majority of the clinical variables that were assessed (main target behavior and BAT), being avoidance the most affected variable. However, this did not occur for the degree of belief in the catastrophic thought. In this particular case, the participant reported that she required the additional cognitive challenge work provided by the therapist during the AR exposure session in order to replace her irrational thoughts for more productive ones. Only after the exposure session did she report a decrease in her belief in her negative thoughts. Therefore, we can conclude that the mobile game helped the patient to confront the "one-session" AR exposure treatment reducing fear and avoidance in this participant before starting the one-session exposure therapy. As previously mentioned, on day six the participant asked the therapist for more days of game play because she still experienced a level of fear that was too high to start exposure treatment and reported that the game was very useful in decreasing her anxiety. In fact, she stated, "If I had started the exposure treatment right away, I would have probably panicked; I don't know if I could have tolerated it". Related to this, it should be emphasized that the exposure treatment was applied using AR. Significantly, when the participant was asked to choose between virtual reality exposure and in vivo exposure before treatment, she preferred virtual reality exposure. Furthermore, she reported that she would not have been able to confront a real cockroach at the start of the treatment.

With regard to the second mobile game interaction, a notable additional decrease was observed for the main target behaviors (fear, avoidance and belief) and BAT after 9 days of play. These

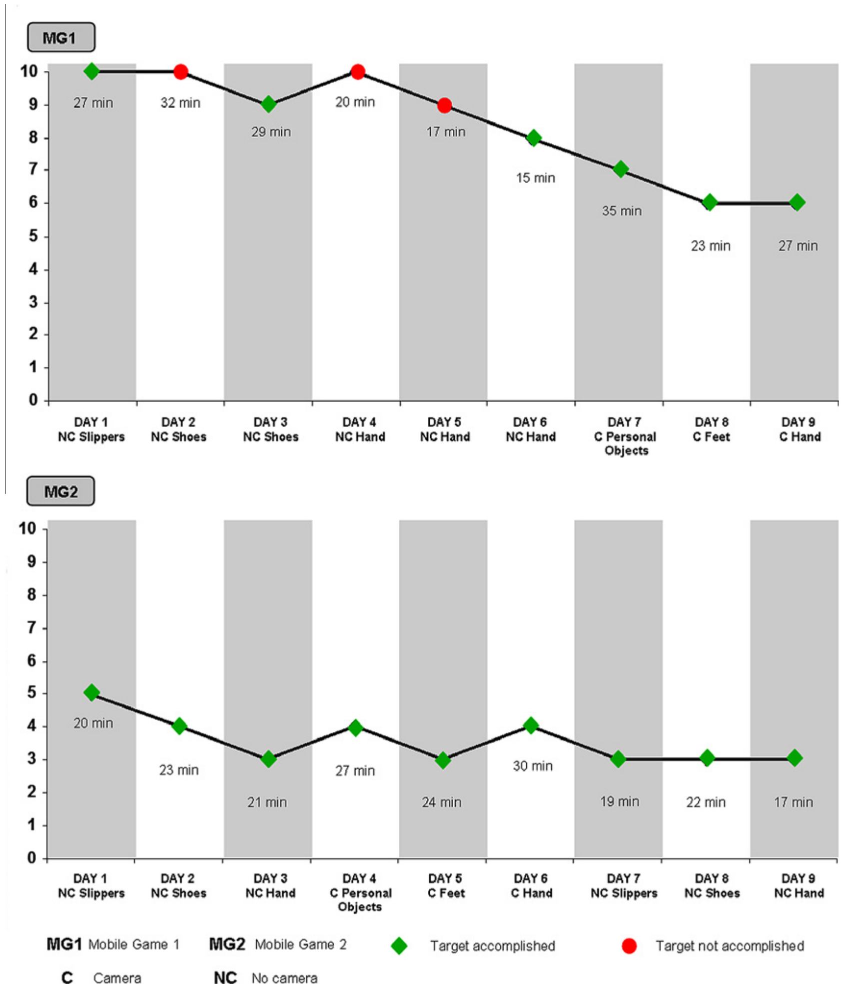


**Fig. 5.** MG1 and MG2 periods. Maximum anxiety levels, time playing (minutes), and target accomplished vs target not accomlished.

**Table 2**
Scores obtained for outcome measures.

| | Pre | Post-MG1 | "One-session" AR exposure | Post-MG2 | 1-month FU | 6-month FU | 6-month FU | 12-month FU |
|---|---|---|---|---|---|---|---|---|
| *BAT* | | | | | | | | |
| Performance | 0 | 2 | 7* | 7** | 8 | 8 | 8 | 8 |
| Fear | 10 | 7 | 6 | 0 | 0 | 0 | 0 | 0 |
| Avoidance | 10 | 8 | 5 | 0 | 0 | 0 | 0 | 0 |
| Belief | 8 | 10 | 4 | 0 | 0 | 0 | 0 | 0 |
| FSQ | 104 | | 21 | | 3 | 5 | 8 | 0 |
| *SPBQ* | | | | | | | | |
| Cockroach-related beliefs | 66.67 | | 14.29 | | 10.72 | 15.48 | 9.52 | 4.76 |
| Self-related beliefs | 50 | | 8.33 | | 2.08 | 2.08 | 3.47 | 1.39 |
| Clinician's rating | 7 | | | 3 | 3 | 2 | 0 | 0 |
| Interference by participant | 7 | | | 2 | 2 | 1 | 0 | 0 |

Pre: pre-treatment; MG1 = first mobile game interaction; AR: augmented reality; MG2 = second mobile game interaction; Post: post-treatment; FUs: follow-up; BAT: behavioral avoidance test; FSQ: fear of spider questionnaire; SPBQ: spider phobia beliefs questionnaire.
* The participant was able to touch the container but only for a few seconds and with a high level of anxiety.
** The participant was able to touch the container with no anxiety for a longer period.

findings indicate the possible utility of the SG for homework practice given that it could have helped the participant consolidate treatment gains by offering her a way to complete self-exposure tasks easily, since she could interact with the feared object at will. In fact, the participant reported that this helped her to improve and consolidate the changes in her level of fear, avoidance and belief in the catastrophic thoughts. However, we have not data comparing the results of the "one-session" AR exposure with and without the use of the SG. In any case, the present work points out that the use of SGs on mobile devices can be useful at increasing treatment motivation and acceptance (the mobile application was well accepted by the participant and was considered very attractive).

It should be highlighted that before treatment, the participant could not go to places where she suspected cockroaches could be found. She never took the garbage out (her partner did it for her), she never went down to her garage alone, and if she saw a cockroach in the terrace of a bar, she made her group of friends go to another place. As the therapy progressed the patient was more and more able to tolerate the presence of cockroaches in the same places where she was. After completing treatment she could take the garbage out, and on one occasion she picked a dead cockroach up off the floor of her garage with her partner, and could also tolerate being in the garage alone.

The present study has some limitations; the most significant is that it is a single case study which compromises external validity. Therefore, the preliminary data obtained should be replicated in other studies with larger samples and control groups in order to draw firmer conclusions about the efficacy of using mobile devices in clinical psychology.

Nevertheless, this is the first single case study that uses an SG on a mobile phone to improve clinical utility of evidence-based treatments (specifically, AR exposure).

Because the SG was designed for using on mobile phones, users can play it at any time and in any place. Therefore, this kind of system could be employed in diverse ways throughout the different phases of the therapeutic process. For instance, it could be used to collect information regarding specific aspects of the assessment (such as registering clinical variables like degree of anxiety and avoidance); the therapist could remind patients of the convenience of doing homework assignments and encourage them to complete them; therapists could help patients between sessions if they were having difficulty with self-exposure tasks (for example, by sending them encouragement and supportive messages); or it could simply be used to achieve a specific useful therapeutic goal (as with the "Cockroach Game"). Additionally, this kind of system could also aid in targeting certain treatment aspects; for example, an enhanced version of this SG could include additional features that would help participants challenge catastrophic thoughts related to cockroaches. It is convenient to highlight that the "Cockroach Game" did not have the same effect in the different outcome measures. The largest effect was found in avoidance and then in fear; however, the SG had not an impact in the modification of the irrational thoughts related with cockroaches. Because of this we are developing a new SG with a module focusing on cognitive challenge of irrational thoughts related to cockroaches. In this same line, and taking into consideration cultural differences about the convenience of killing or not killing the cockroach, this new SG will include different ways of interacting with the animal without killing it.

In summary, development and application of these types of SGs appears to hold much promise. These new developments may spark a revolution, not only in the way exposure therapy is applied, but also in the therapeutic process itself. This perspective could be seen as a return to earlier forms of practice in behaviour therapy when photographs and images were used to conduct exposure, but also as a new challenge for the future clinical procedures creating new helpful "realities". For thousands of years, humans have used games to transfer knowledge and to transmit certain types of skills. This is not surprising; games are engaging, and therefore they are of great help in the natural learning process in human development (Kim, Park, & Baek, 2009). Furthermore, their effectiveness has increased with the development of computer technologies that make SGs targeting different goals possible.

Mobile devices interventions ("mobile persuasion") have appeared which assist with management of chronic diseases such as asthma or diabetes (Boland, 2007); others are designed to encourage physical activity (Damen, 2007; Baños et al., 2009), or for supporting the treatment of children with emotional problems using cognitive behaviour therapy principles (Brezinka, 2007; Brezinka & Hovestadt, 2007). However, as already mentioned, these works included descriptions of the SG but not efficacy or clinical utility data. Increasing numbers of such applications are expected to be developed in coming years, and SGs designed for mobile persuasion will be important tools for changing people's attitudes and behaviors.

In therapeutic contexts, these kinds of systems and devices should always be conceived, designed and used to help others. Expectations for these new information and communication technologies should take both their potential and limitations into account. As mentioned previously, exposure therapy is no doubt very effective, but it has some issues. These new strategies might help to solve some of the problems of the "cruelest cure" (Olatunji et al., 2009). VR exposure therapy has already been deemed more acceptable to users than traditional exposure-based therapies (Garcia-Palacios et al., 2007; Richard & Gloster, 2007), and about the same can be said about AR therapy (Botella et al., 2005). In order for such a useful strategy as AR therapy to reach more people, it is important for it to become more accepted and perhaps also more amusing. However, it is a formidable challenge to develop new elements and devices that enable and improve clinical utility of evidence-based treatments. For children, the possibilities are infinite, and perhaps it is an ethical imperative to develop programs specifically for them. Each new technological development must be rigorously assessed and tested. Only then can we hope to achieve the objective stated by Lewis (2007), "to move the field of serious games from 'looks promising' to determine where such interventions will be effective and where they will not" (page 918). That is, SGs and other persuasive devices will cease being merely a possibility in the future and become a useful reality.

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