A Novel Treatment of Fear of Flying Using a Large Virtual Reality System

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BACKGROUND: Fear of flying (FoF), a common phobia in the developed world, is usually treated with cognitive behavioral therapy, most efficiently when combined with exposure methods, e.g., virtual reality exposure therapy (VRET). We evaluated FoF treatment using VRET in a large motion-based VR system. The treated subjects were seated on a moving platform. The virtual scenery included the interior of an aircraft and a window view to the outside world accompanied by platform movements simulating, e.g., takeoff, landing, and air turbulence. Relevant auditory stimuli were also incorporated.

CASE REPORT: Three male patients with FoF underwent a clinical interview followed by three VRETs in the presence and with the guidance of a therapist. Scores on the Flight Anxiety Situation (FAS) and Flight Anxiety Modality (FAM) questionnaires were obtained on the first and fourth visits. Anxiety levels were assessed using the subjective units of distress (SUDs) scale during the exposure. All three subjects expressed satisfaction regarding the procedure and did not skip or avoid any of its stages. Consistent improvement was seen in the SUDs throughout the VRET session and across sessions, while patients' scores on the FAS and FAM showed inconsistent trends. Two patients participated in actual flights in the months following the treatment, bringing 12 and 16 yr of avoidance to an end.

DISCUSSION: This VR-based treatment includes critical elements for exposure of flying experience beyond visual and auditory stimuli. The current case reports suggest VRET sessions may have a meaningful impact on anxiety levels, yet additional research seems warranted.

KEYWORDS: phobia, anxiety, virtual reality exposure therapy.

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The prevalence of fear from air traveling, i.e., fear of flying (FoF), is estimated at 7–40% in the western population,[3] of which the majority rely on alcohol and anxiolytics to tolerate it.[4] FoF, which often results in flying abstinence and leads to financial fines, career repercussions, and social embarrassment, is drawing growing attention from therapists.

FoF is usually a part of other specific phobias, e.g., the natural environment type where height and weather conditions are the arousing stimuli, or the situational type deriving from the confinement in an enclosed space. Specifically, subjects who suffer from FoF may also have driving difficulties, claustrophobia, agoraphobia, panic attacks, and general anxiety. In addition, many of these individuals report discomfort or distress many days (sometimes weeks) in "anticipation" for their flight, i.e., anticipatory anxiety. Unfortunately, the most immediate action taken is avoidance, although this only preserves the phobia and even exacerbates it. By constantly avoiding the phobic-producing situations, phobic individuals are not able to habituate (inhibitory learning) to those specific settings.[13]

Cognitive behavioral therapy (CBT) serves as the basis of most psychological interventions implemented in the treatment of FoF in which treatment focuses on the recreation of neutral memories overriding the existing panicking ones.[2] Supplement interventions include psychoeducation, relaxation

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techniques, and exposure therapy, the latter considered the most efficient combination with CBT.[9,10] The various exposure therapies in use include audiovisual presentations, i.e., pictures, sounds, and videos of flights, and, although weak, they were shown to positively affect flying activity and self-reported anxiety.

Among the exposure therapies, in vivo exposure, e.g., an actual interaction with an aircraft or an airport environment, is the most effective; however, this method requires exclusive resources. To the contrary, virtual reality (VR) exposure therapy (VRET) simulates a flight experience by gradually leading the subject into a motivating and challenging environment via dynamic visual, auditory, and motion stimuli.[8] Hence VRET, which is considerably more cost-effective, increases flying activity, and reduces anxiety, is successfully implemented in the treatment of FoF.[1,2] We recently developed a VRET for the treatment of FoF. We used an advanced large-scale VR system, which allows maximal immersion within the virtual environment and applied a novel treatment in three cases.

CASE REPORTS

Three men at the ages of 26, 50, and 51 who suffer from panic attacks and other specific phobias in addition to FoF participated in a pilot evaluation. Patients were free of cardiovascular disease, neurological disorders, and history of epilepsy, psychosis, major depression, suicidal behavior, or substance abuse.

Patient 1 (26 yr) suffers from social phobia, claustrophobia, especially related to elevators and planes, and agoraphobia, which lead him to panic attacks due to the lack of control he has over these situations. This patient survived a severe car accident 10 yr prior to the present intake, with no posttraumatic symptoms. This background caused him flight avoidance of 12 yr prior to his participation.

Patient 2 (51 yr) suffers from panic disorder with agoraphobia and claustrophobia, especially related to elevators and planes. This patient fears losing control over many daily situations, thus he restricted his driving route to home-work and back, and avoided flights for 16 yr.

Patient 3 (50 yr) suffers from panic disorder, driving phobia, and generalized anxiety disorder. He dealt with hazardous situations during his military service and witnessed a terror act, with no posttraumatic symptoms. The patient avoided driving and flying for 4 yr due to lack of control over the plane and catastrophic thoughts.

We used the Computer Assisted Rehabilitation Environment (CAREN; Motek Medical©, Amsterdam, the Netherlands) high-end system (**Fig. 1A**). The virtual visual scenery depicts the interior of an aircraft, where several passengers are seated (**Fig. 1B**). The virtual outside world can be viewed constantly through the window, e.g., on-the-ground airfield sceneries (e.g., terminal, runways). The complete ground scenery is seen in **Fig. 1C**.

The virtual areal path was designed as a circular route, starting at the airport, over fields and countryside, above the clouds, into an urban area, and back to the airport (**Fig. 2**). The treated patient was seated in the middle of a motion platform (**Fig. 1D**). The flight simulation lasted 35 min (6 min of ground pre-takeoff, 24 min for takeoff and airborne, and 5 min of ground

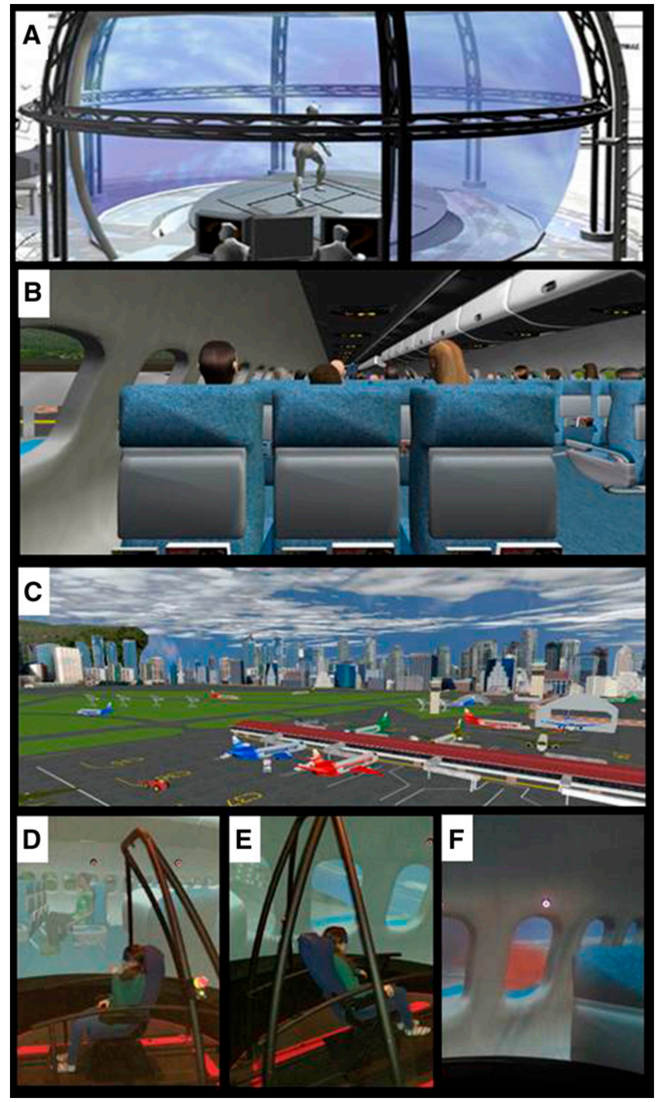

Fig. 1. Virtual reality treatment apparatus, scenery, and flight simulation. A) A schematic drawing of the CAREN high-end system. The system consists of a motion platform (3 m in diameter), which is placed within a dome shape construction. On this interior surface visual scenery is presented using eight projectors which provide a 360° display. Although the projection is not stereoscopic (unlike the case of polarized goggles or head-mounted display), its projection on a spherical screen fully immerses the patient and allows the perception of depth. A surround sound system provides auditory stimuli congruent with the scenery. The platform can be moved (rotations and translations—6 degrees of freedom) in various velocities and inclinations (image courtesy of Motekforcelink©). B) General impression of the visual scenery. The viewpoint is from a passenger sitting toward the rear end of the aircraft. C) A depiction of the complete sequence of environmental scenes viewed through the window by the patient when the aircraft is on the ground (pulling out from the gate and taxiing). D) The passenger aircraft seat was located in the middle of the platform (in the pilot cases we report here, a standard chair was used). E) The patient is seated for takeoff. The platform is inclined backward and the aircraft's wing can be seen through the windows. F) The simulated incidence of one engine catching fire and the smoke following it.

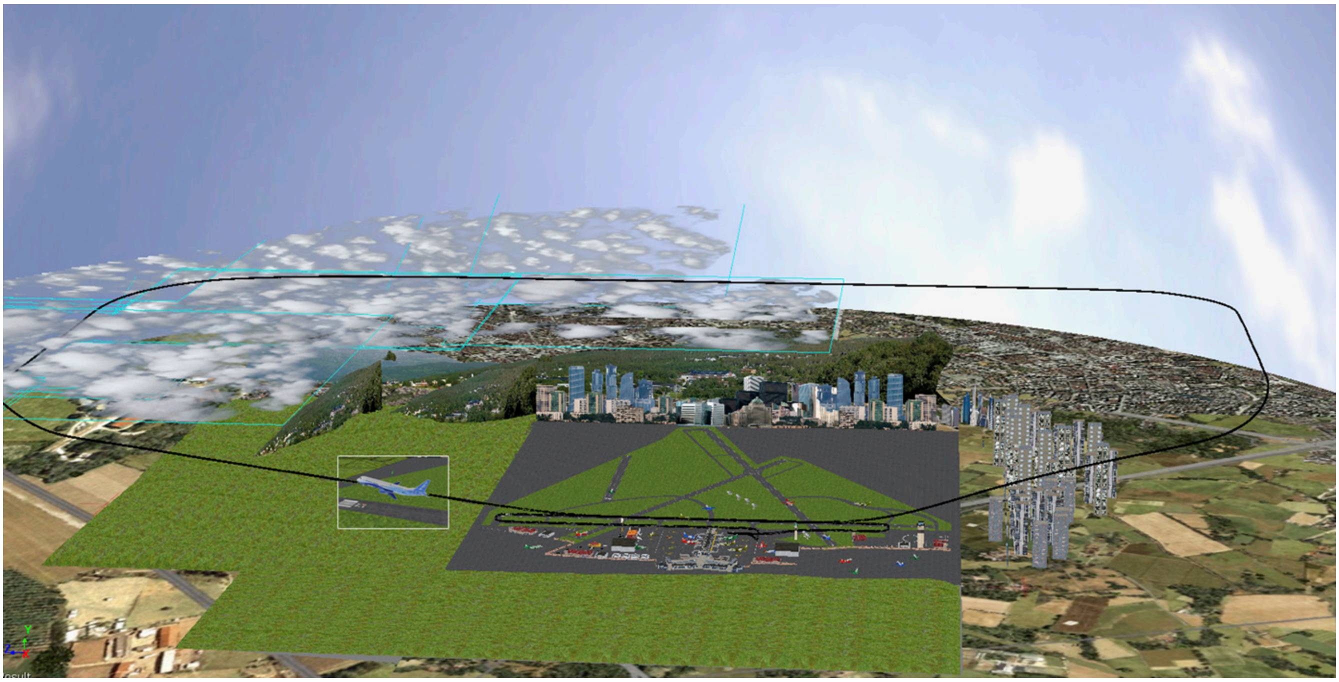

Fig. 2. Simulated flight route and takeoff. The visual illusion of flying was obtained by the creation of a 3D environment (using SoftImage XSI) and then its integration with corresponding sound, platform movements, virtual camera maneuvers, flight conditions, and malfunctions using D-Flow Software (Motekforcelink©). In brief, the virtual plane takes off, flies at 720 km/h, and approaches landing at the speed of 400 km/h—a circular route of 229 km.

post-landing) and included the following stages: taxiing, takeoff (**Fig. 1E**), cruise (including turns), and landing. The inclinations of the platform (2D, pitch, roll) were congruent with the rotations of the visual scenery. The platforms was also linearly accelerated (3D), e.g., for 'vertical drops' (simulating air turbulences).

Corresponding views can be seen through windows either on the same side or on the opposite side of the aircraft based on its virtual location and orientation. A portion of the aircraft's wing is constantly displayed. The auditory exposure includes jet engine sound, i.e., the engines starting and increasing power during takeoff, as well as vocal announcements (i.e., made by the flight crew). Throughout the flight simulation the operator can introduce several exposure levels of simulated unexpected events including: 1) turbulences, 2) fire and smoke (**Fig. 1F**), 3) night flight (not applied in the present cases), and 4) smooth/rough landing.

In the first session the therapist (a clinical psychologist) interviewed the patient regarding his FoF and other specific phobias. The treatment plan was then scheduled accordingly. During the interview the therapist provided the patients with the safety aspects of flights, including emergency procedures and the actions taken by the pilots during technical malfunctions. Next came three consecutive (once a week) VRET sessions in the presence and with the guidance of the therapist. Prior to each VRET, there was a short CBT session confronting the emotions-thoughts-behavior aspects of the patient's core fear, cognitive restructuring, and psychoeducation for providing anxiety-coping skills, as well as breathing and relaxation techniques.

In order to evaluate the emotional, cognitive, and behavioral aspects of FoF, we used the Flight Anxiety Situations (FAS) questionnaire for generalized, anticipatory, and in-flight anxiety, and the Flight Anxiety Modality (FAM) questionnaire for somatic and cognitive modalities.[11] We looked at the total score on the FAS (max 160 pts) and FAM (max 80 pts), where a higher score means higher anxiety. During VRETs anxiety level was assessed using the 0-10 Subjective Units of Distress (SUD) scale[14] every few minutes (managed in real time by the therapist according to the session's evolvement). Several months from completion of treatment patients were contacted and interviewed regarding their flight experience and their current attitude.

All three patients showed satisfaction regarding the procedure and did not skip or avoid any of its stages. None of them experienced motion sickness. Patients' scores on the FAS and FAM questionnaires showed inconsistent trends in weekly sessions across patients. Meaningful reduction was achieved in patients' SUD scores within sessions and across sessions (**Fig. 3**).

The top panel of Fig. 3 depicts the ongoing level of anxiety Patient 1 experienced based on the SUD records. During the first VRET, Patient 1 reported a relatively low initial level of anxiety, reached peak at 21 min, and had only slightly reduced anxiety levels 4 min later while still airborne. Immediately after landing (28 min), anxiety dropped to zero. Since during this exposure there was no satisfactory (to the therapist's view) spontaneous reduction in the anxiety level while still airborne, VRETs 2 and 3 were lengthened to 35 min. In the next VRET the patient started with a lower initial

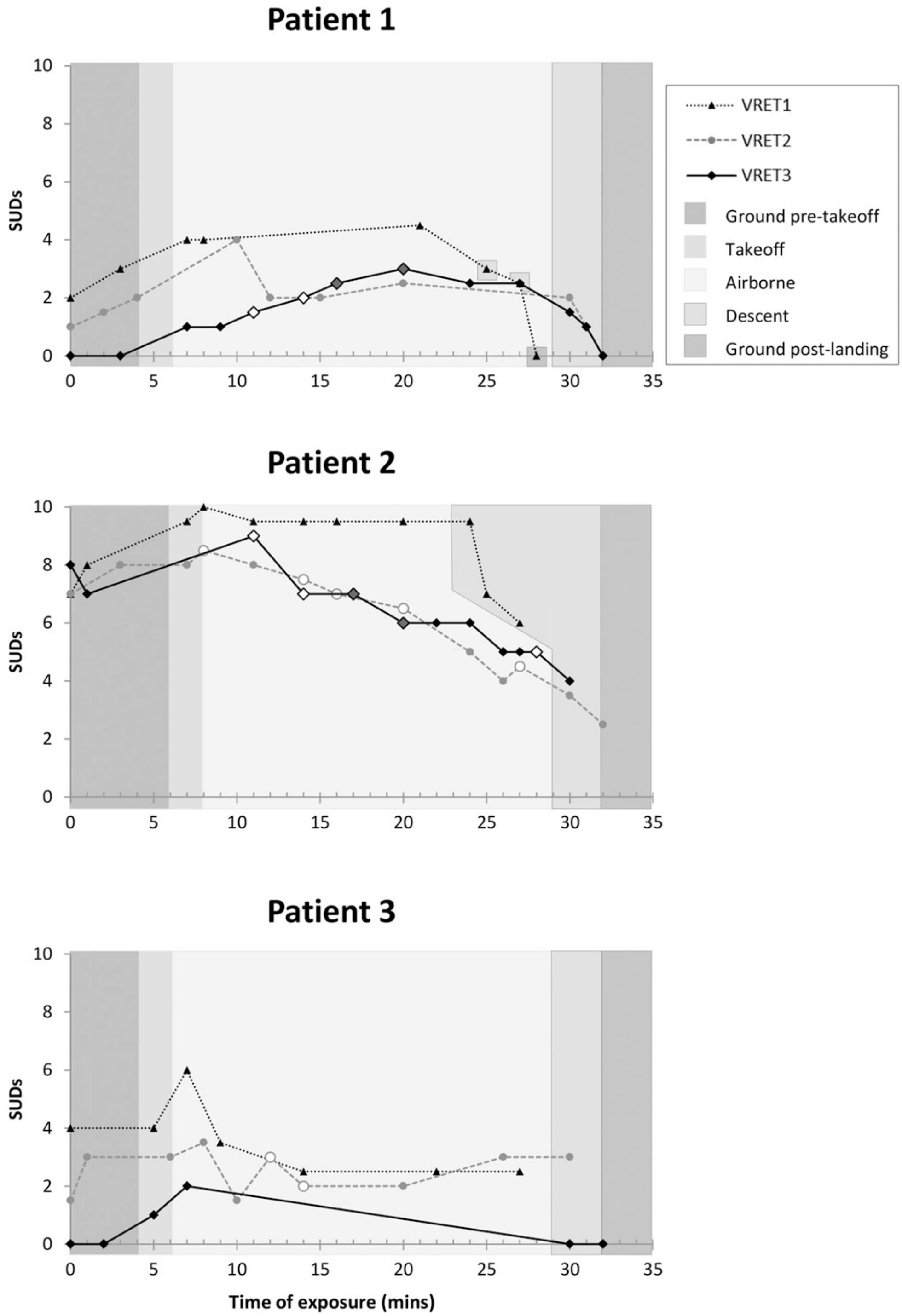

Fig. 3. The change in Subjective Units of Distress (SUD; 0-10 scale) values of anxiety levels across the first, second, and third virtual reality exposure therapies (VRET 1-3) in Patients 1-3. Scores were obtained throughout key phases of flight experience, e.g., takeoff and descent (distinct backgrounds, see key; for color, please see the online figure). The larger white markers indicate the anxiety levels during simulated turbulence and the larger gray markers indicate anxiety during simulated fire and smoke. For Patients 1 and 2, VRET 1 sessions were shorter; thus the isolated rectangles and the shifted backgrounds, respectively, designate the flight phase.

anxiety level compared to that in the previous exposure and also reached a lower peak level, although he was exposed to a mediocre level of turbulence. This spontaneous decrease was attributed to acclimatization and the use of coping methods.

During the third and last VRET this patient was exposed to a high level of turbulence, fire and smoke coming from the engine, and a siren. Nevertheless, the patient showed a 0 level of initial anxiety, a low peak level, and quick acclimatization. Overall and as displayed in SUDs, this patient's maximum anxiety decreased across VRETs (VRET 1 = 4.5; VRET 2 = 4; VRET 3 = 3). This patient had relatively stable FAS scores: 129 at baseline and 130 at the end of treatment; FAM scores slightly decreased following the intervention from 63 to 58. He also reported to have adjusted to the flight simulation, e.g., showing almost no excitement preceding the last exposure.

We contacted this patient 1 mo after he completed the treatment and he said that he 'felt prepared to board a plane'. However, he did not feel completely secure about flying alone. He also reported having gotten helpful tools for managing panic attacks in general and regarding flight safety. This subject was further contacted 21 mo after he completed the treatment and he informed us he had flown once (7 mo from the end of treatment; recall, he had not flown for 12 yr prior to the treatment). This patient flew accompanied by his friends and, with their support, he listened to music and avoided taking anxiolytics.

Patient 2 reported that the first VRET session provided him with coping skills, gave him confidence, and educated him regarding his anxiety. He showed a relatively high initial anxiety level and maintained high levels during most of the simulation. The anxiety increased to the maximal level (SUD = 10) and then decreased with landing (Fig. 3 middle panel). There were a few moments when the patient wanted to get up, but managed to hold himself. In this patient, anxiety was expressed also by somatic symptoms, e.g., high heart rate, chest pressure.

In the second VRET the patient's anxiety decreased spontaneously after 8 min and slightly increased at 27 min. It was finally attenuated using the given coping methods. Generally, the patient showed lower anxiety and better control over the situation. The last exposure included high a turbulence level, fire, cabin smoke, and a siren. During this exposure the patient showed the same initial anxiety level, but reached a lower maximum anxiety level, which attenuated quite rapidly. During this simulation, the patient sat back, loosened his legs, and wished the flight would not end.

As depicted in Fig. 3, the maximum anxiety levels decreased throughout the treatment (VRET 1 = 10; VRET 2 = 8.5; VRET 3 = 9). This patient reported relatively stable FAS scores: 109 at baseline to 116, but FAM scores substantially decreased from 67 at baseline to 46 immediately after the last VRET. In addition, this patient fully adjusted to the flight simulator, claiming he would book a flight a couple of weeks from the end of the treatment.

We contacted this subject 1 mo and 21 mo from the end of treatment and he informed us that he has flown four times, twice within the first month after treatment, 9 mo and 18 mo after treatment (recall he had not flown for 16 yr prior to the treatment). This patient reported greatly benefiting from the exposure and the anxiety-managing skills.

Patient 3 started treatment with major doubts regarding the effect the virtual environment would have on him in reference to the goal of real flight situations, insinuating that 'real flight safety issues exist only in real flights.' Unlike his two peers, he was invited to two meetings with the therapist prior to the VRETs. Fig. 3 (bottom panel) depicts the ongoing level of anxiety Patient 3 experienced based on the SUD records. During the first VRET takeoff, the patient displayed a high initial anxiety level as well as somatic symptoms, which decreased instantly once airborne. In the following VRETs initial anxiety levels were fundamentally lower even during takeoff or in the presence of increasing levels of turbulence. This patient benefited less from the tools he received during the treatment due to rather low receptiveness to the virtual environment; it was only toward the third VRET that he became more open to the experience.

However, as can be seen in Fig. 3, his maximum anxiety levels remarkably decreased across VRETs. (VRET 1 = 6; VRET 2 = 3.5; VRET 3 = 2). Measured immediately after the last VRET, Patient 3 scored higher on both FAS and FAM questionnaires at the end of treatment compared to baseline: 96 vs. 108 in the end, and 67 vs. 78 in the end, respectively. He reported being almost desensitized to the virtual environment due to an instant and inevitable distinction between the virtual flight and a real one. This patient admitted to not being fully submerged into the virtual scene; he experienced the stimuli as weaker than Patients 1 and 2 did, and therefore showed lower anxiety and smaller improvement. We contacted this subject 1 mo and 18 mo after the treatment and he informed us that he had not flown since the completion of the treatment, citing that an appropriate opportunity to do so did not come up.

DISCUSSION

This report's aim is to describe our initial experience with VR for the treatment of the widely spread phenomenon FoF. We performed three VRET sessions on three participants who have avoided flying during 4-16 yr prior to treatment due to FoF. Exposure therapies, especially VRET, are the treatment of choice in FoF as well as in other specific phobias. Although VR-based treatments for FoF have been described before,[6,12] we describe here a unique setup which is based on a large VR system enhancing the sense of presence in the simulated flight (Fig. 1 and Fig. 2). This is achieved also by adding the physical sensation component to the VR environment. Using our VRET, the patients generated moderate to high levels of anxiety (measured in SUDs) when confronting challenging simulated situations throughout the sessions.

Generally, throughout VRET 1 patients showed the highest anxiety levels compared to those during VRETs 2 and 3, reaching maximum anxiety at takeoff. Anxiety levels attenuated meaningfully once reaching cruising altitude in Patient 3 and with descent for landing and touchdown in Patients 1 and 2. In VRETs 2 and/or 3, once airborne, patients were introduced to simulated challenging situations such as turbulence and technical malfunctions. Nevertheless, their maximum anxiety levels did not exceed those in VRET 1 (Fig. 3). Overall, VRET sessions effectively and consistently reduced anxiety levels throughout the session and across sessions. For these cases we did not observe consistent and solid improvements in FAS and FAM scores; this might be attributed to the fact that they were answered by the subjects immediately after the completion of the third VRET, which might have had a great impact on their degree of fear and agitation (see more in 'limitations' below).

Patients 1 and 2, who showed great satisfaction from the virtual environment starting from VRET 1, went on actual flights in the months following treatment. Patient 2 even flew twice within the first month and then again after 9 mo and 18 mo, bringing 16 yr of avoidance to an end. During their flights Patients 1 and 2 claimed to have effectively managed their anxiety, beliefs in catastrophic thoughts, and the distress accompanying FoF along the years. Although Patient 3 was the one to show the biggest decrease in anxiety levels, he experienced immersion difficulties with the virtual environment. This subject did not participate in an actual flight eventually. It appears that the main factor preventing positive results for this subject was the desensitization to the VR environment. This variation was expressed by a noticeable decrease in anxiety levels, reflecting acclimatization to the virtual environment. Thus, in future studies subjects for whom the VR environment does not provoke anxiety should be treated alternatively.

The present results are in line with those of recent VR studies in the treatment of FoF successfully eliciting anxiety using VRET[6,12] and then considerably reducing it. To date, this report and the subsequent studies of Muhlberger and colleagues[6,7] are the only ones to present motion stimulus in addition to visual and auditory stimuli in VRET for FoF. An advantage of our simulation is the motion aspect, allowing the integration of critical elements such as takeoff/ landing/touchdown as well as turbulence and technical malfunctions.

Muhlberger and colleagues used a motion platform with 6 degrees of freedom of movement simulating speed acceleration and deceleration, as well as air turbulence, based on the performance of a real pilot in a flight simulator. We also used a 6 degrees of freedom moving platform; however, speed accelerations and decelerations were produced using subtle rotations and translations of the platform. Next, Muhlberger and colleagues[7] tested the contribution of motion (vibrations) stimulus in addition to visual and auditory stimuli in one VRET session, showing VRET to be similarly effective with or without motion.

While similar effectiveness comparison was not done in the present study, we did find support for the added value of the physical movements factor in our exposures. As displayed in Fig. 3, ongoing anxiety levels were elevated during the "takeoff" and the "turbulence" elements, both relying on motion stimulus, further enhancing the exposure experience. Moreover, these and other 'physical' elements (e.g., turns) were presented with full time synchrony between the motion, visual, and auditory stimuli.

An additional indispensable advantage of a large VR system compared to a head-mounted display is the absence of cyber-sickness, i.e., discomfort arising from the conflict between different sensory modalities.[5] We strongly suggest the inducement of motion stimulus in the treatment of phobias from experiences that are strongly related to physical movement (i.e., flight).

This is a case report, by definition restricting the generalization of our findings. Further, there were inconsistent trends in FAS and FAM scores; as discussed earlier, it might be that passing these questionnaires too closely to too-recent vivid experience compromised the reliably of these records. It is noteworthy that many times FAS and FAM are administered during real flights.

We propose considering the following aspects to address these limitations and to further explore the efficacy of FoF treatment based on VR: 1) randomized controlled trials with several therapeutic arms, e.g., CBT vs. VR; 2) a longer follow-up period to learn whether treatment gains were maintained; 3) an additional scene addressing anticipatory anxiety (e.g., packing a suitcase, at the terminal); and 4) heart rate and skin conductance real time monitoring to provide additional input to the therapist.

The potential in developing new treatments through the use of VR is huge due to the almost infinite degrees of freedom available for the designer. It is important, however, to identify the specific target of the treatment and isolate the core elements that need to be addressed. Here we used this approach for the treatment of FoF. These case reports provide us with support for the validity of this mindset.

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