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Personalised 360° video exposure therapy for the treatment of obsessive-compulsive disorder: a single case study

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Short running title: VR to treat OCD

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Abstract

Objective. Between 40 and 60 % of patients with obsessive-compulsive disorder (OCD) are resistant to first-line treatments, including exposure and response prevention techniques. Those are likely to benefit from the rise of virtual reality (VR). However, very few studies have been conducted on the use of VR in OCD with several limitations including a lack of ecological validity. This proof of concept study aims to assess the feasibility and therapeutic potential of a personalised exposure protocol using immersive video. Methods. This protocol was applied to a patient suffering from severe and resistant OCD and consisted of 15 weekly sessions of exposure via a VR headset to 360° immersive videos filmed from the subject's viewpoint in their own environment. Results. Besides the high acceptability of the immersive device, our patient exhibited a therapeutic response with a reduction in emotional responses measured by skin conductance recording, a reduction in obsessive-compulsive symptoms and an improvement in quality of life. Conclusions. This study provided promising results in a patient initially refractory to conventional treatments. Replication of these results would place personalised immersive 360° video exposure as a technique of choice in the therapeutic arsenal for OCD due to its cost-effectiveness and high acceptability.

Keywords: *OCD – 360° video – exposure and response prevention – personalised psychiatry*

1. Introduction

1.1. OCD and its treatment

With a lifetime prevalence of approximatively 2 to 3% world-wide [1], Obsessive Compulsive Disorder (OCD) is a disabling disorder characterised by either obsessions (recurrent, persistent, intrusive and unwanted thoughts), compulsions (repetitive behaviours or mental acts performed through rigid rituals) or both symptoms. Conventional patient care relies on the one hand on selective serotonin reuptake inhibitors (SSRI) and on the other on cognitive behavioural therapies (CBT); alone or in combination [2]. SSRIs have shown their efficiency in reducing obsessive compulsive symptoms but only for 40 to 60% of patients [3]. CBT, and particularly the exposure and response prevention (ERP) techniques have also been demonstrated as being efficient [4]. However, 30% of patients fail to display any significant improvement in their symptoms [5] which might be explained, in the case of imaginal exposure, by the fact that 33% of the patients show poor imagery ability [6] and that they attempt to set-up cognitive avoidance strategies during this kind of exposure [7]. Concerning *in vivo* exposure, this technique requires patients to put themselves in real, highly anxiety-provoking situations, resulting in a high attrition rate with 25 to 30% of patients dropping out of therapy early [8]. Thus, 20 to 40% of patients remain unresponsive to these first-line treatments, leading to chronic disabling functional disorders [9]. We therefore need to find novel therapeutic approaches. While drug research is struggling to find new treatments, psychotherapy is most likely to offer new approaches that could improve the treatment of OCD. Indeed, the development of new technologies has given increased impetus to CBT, particularly in ERP. More precisely, the development of virtual reality (VR), made possible by the latest technological advances opens the way to a potentially increased efficiency and a broader application of these exposure techniques, especially in the most severe patients who are often reluctant to be exposed to highly anxiogenic situations. Thus, VR could allow step-by-step exposure to anxiogenic stimuli in a

much more realistic and controlled manner than imaginal exposure, and in a realistic although safer situation than exposure *in vivo*.

1.2. VR contributions to OCD patient therapeutic care

In VR, patients are immersed interactively in real time in a two or three-dimensional computer-generated environment with the possibility to generate multimodal sensory stimuli like sounds, odours, etc... Three main categories of VR exist ranked by the degree of presence they provide: non-immersive systems where the virtual environment (VE) is viewed through a high-resolution monitor; semi-immersive projection systems where the VE is generated by a graphics computer system coupled with large unidirectional projector; and fully-immersive systems consisting in either head-mounted display or three-dimensional projector (CAVE) system. VR can address some inherent limitations of the classical ERP techniques notably by its flexibility (adjustment of the environment to the patient's requirements), reproducibility (each scenario can be accurately repeated), controlled nature (adjustment of the level of the anxiety-triggering stimuli), safety (exposure to a "false" situation that can be immediately terminated with no adverse consequences), more realistic nature than in imaginal exposure and confidentiality (occurs in the consulting room thereby avoiding public embarrassment) [10].

VR has been extensively used for more than twenty years for anxiety disorders with rather good results, but mainly in a research framework [11]. However, the literature on the use of VR for OCD patients remains scarce. The first VR-like study for OCD patients dates back from 1998 [12]. It provided promising results using a vicarious learning training based on interactive pictures. OCD patients had to learn to self-expose without performing their rituals, by looking at an avatar that suffered from the same symptomatology. At the end of the sessions, these patients displayed a modest but significant reduction in symptom severity on the Yale-Brown Obsessive-Compulsive scale (Y-BOCS). Ten years later, Kim and collaborators examined VR's ability to induce anxiety for OCD participants using a head-mounted display [13]. Not

only did VR trigger checking symptoms and anxiety, but this anxiety was positively correlated with the severity of the disorder and the subject's propensity to immerse in the VE. These results were reproduced in 2012 with patients suffering from symmetry/order OCD [14]. Two years later, Belloch [15] used a high-resolution monitor coupled with a movement tracker and demonstrated that VR is able to generate anxiety and disgust proportionally to the degree of dirtiness of the scenario administered to patients suffering from washing/contamination OCD. Laforest described the same results using a CAVE system, for the same category of symptoms [16]. More recently, van Bennekom, using first-person videos shot in a real environment and reproducing scenarios relevant to the subjects (dirty toilet, gas stove left on, etc...) displayed on a screen, demonstrated the ability of this kind of VR to induce OCD symptoms [17].

Therefore, VR seems able to trigger OCD symptoms, which is a crucial step for exposure treatments, but few studies attempt to assess its efficiency to **treat** OCD symptoms. A decrease in OCD symptoms in three patients was reported after a VR immersive exposure (CAVE system); even though this improvement was not maintained over the long term [7]. Interesting results have been shown with a VR and vicarious learning procedure [18]. The patients had to learn to expose without performing their rituals while exploring the VE with the help of an avatar displayed on the screen. At the end of the study, the patients displayed a modest but significant reduction of the severity of OCD symptoms (a reduction of 2.4 points in the total YBOCS score on average) at one-month post-treatment.

1.3. Limitations of VR studies

These preliminary results on the use of VR as an exposure technique are limited by the small number of studies and their sample size, requiring their reproduction with larger samples and with control groups that underwent the current gold standard therapy, namely, *in vivo* ERP. One of the factors affecting the effectiveness of VR as an exposure technique is its ability to immerse the subject in the anxiety-provoking situation. Thus, most studies report a high degree of

presence (perception of the virtual environment as real and inducing a disconnection from the real world), but we don't yet know how the behaviour in the VE can predict that in the real world. Moreover, it is not clear if the anxiety triggered during VE exposure is associated with the patient's disorder or induced by cybersickness (due to the discordance between the visual and vestibular perceptions as a result of the temporal offset between the head and the environment movements). This raises the need to evaluate anxiety by recording objective parameters such as heart rate or finger/palmar skin conductance which would be a more reliable measure of the patient's emotional state [16]; the latter not being affected by cybersickness [19]. Considering the technical aspects of VR, it is necessary to ensure a better ecological validity through more realistic scenarios that could be personalised and inspired by the patient's own life [20]. This can be achieved by improving the objective realism of the VE on the basis of the improved graphics quality now available. One could object that previous studies have shown that these types of VE were still able to trigger OCD symptoms, but no researcher has verified that the triggered symptoms are equivalent to the ones the patients have to cope with in their daily life. Slater & Wilbur [21] and Youngblut [22] support the need of an improved objective realism of the VE in their respective review by stressing that graphics quality of the VE influences the feeling of presence of the subject. The more realistic the VE, the more immersed the subject is. Nevertheless, according to Bouchard [23], emotion also plays an important role in the subject's immersion with a positive correlation between anxiety and the subject's immersion levels [24] and vice-versa [25]. Besides, beyond the objective realism of the VE, the subjective realism (interpreting the VE as real) is directly involved in the immersion of the subject and is based on their expectations, beliefs and the propensity of the scenario to be meaningful to them [26]. Moreover, the use of a familiar environment could improve the immersion into the VE as opposed to standardised environments [27]. It is therefore crucial to

focus on ecological validity with a relevant and personalised scenario to ensure a better immersion.

1.4. Rationale and objectives of our study

In order to improve the ecological validity and the immersivity of existing VR techniques, we decided to base our therapy on first-person view 360° acquired videos. This technique allows the best ecological validity ever by completely acquiring the subject's environment in order to construct meaningful scenarios. This first-person view also allows the subject to slip into the VE as if it was reality. Some studies have shown that a subjective view is sufficient for the subject to accept the virtual body as their own despite the discrepancies in motion between the virtual moving body and the static real body; both at the subjective [28] and neurophysiological level [29]. The use of the first-person subjective view has also demonstrated its ability to induce cognitive changes depending on the type of the avatar and its actions [30]. Just as interesting , embodying an avatar that does not display the patient's symptoms induces an increased motivation to change [31]. Lastly, the work of Clark [12] and Matthews [18] suggests that embodying a subject that acts normally in anxiogenic situations sets up vicarious learning processes and increase the feelings of self-efficiency [32].

Thus, the main objective of this single case study is to evaluate the feasibility of implementing a personalised immersive 360° video exposure treatment for severe OCD refractory to conventional ERP techniques and first-line drug treatments. The secondary goal aims at evaluating the therapeutic potential of such a method by analysing the changes in a series of therapeutic response indicators (symptomatology severity, quality of life, etc...).

2. Methods

2.1. Participant case

174 Ms. V., a fifty-year old female patient, was under psychiatric care at the Albert Chenevier
175 hospital (Créteil, France) for a severe (YBOCS score of 33) and treatment resistant
176 contamination/washing OCD with poor insight and from which she had been suffering since
177 her teen years. Nearly 8 hours per day were devoted to the washing compulsions. She had issues
178 with getting dressed, had disproportionate washing protocols, could not stand being in contact
179 with people or any “outside” objects she considered as being contaminated. She did not fear
180 getting ill, but she was anxious about becoming “contaminated”. These symptoms drove a
181 serious disability as she was socially isolated (no one has even entered her home in eight years),
182 had not worked for four years, had very little leisure and had hoarding issues in her house
183 (objects fallen on the floor being considered contaminated). With regard to comorbidities, she
184 also has a moderate dysexecutive syndrome (highlighted by a neuropsychological assessment
185 performed before the start of the study) associated with a history of polysubstance addiction
186 (mainly cocaine and heroin with occasional use of cannabis and MDMA; being totally abstinent
187 for 2 years) and a moderate depressive symptomatology (BDI score of 12) without major
188 depressive disorder (MDD).

189 She failed to respond to several pharmacological treatment approaches including three SSRIs
190 at optimal dose and duration and one serotonin-norepinephrine reuptake inhibitor; each alone
191 or in combination with lithium, atypical antipsychotics (risperidone and aripiprazole, but
192 discontinued early by herself due to reported gonalgia) or buspirone. She failed to respond to
193 two group CBT protocols (the first in 2010 was aborted after 4 sessions and the second in 2015
194 after 9 sessions) due to the influence of other participants' symptoms on her own
195 symptomatology (generation of new obsessions) and a reluctance to perform home exercises.
196 She also was refractory to *in vivo* exposure initiated in 2016 with the patient's drop out after 3
197 sessions and the impossibility to perform the tasks at home due to a complete intolerance to the

high level of anxiety generated. At the beginning of the study, Ms. V. had been on clomipramine treatment (75 mg/d) for 6 weeks and her treatment continued throughout this study.

2.2 Scenario filming

Three forty-five-minute scenarios were created by the patient to fit in with her everyday-life struggles such as going shopping and trying on clothes in a shop. These were rated according to a fear-scale. All the scenarios started at the patient's home, were then filmed in her neighbourhood and ended with her returning home.

We used a 360° 4K camera to film the different scenarios (KeyMission 360, Nikon). This camera allows both high-resolution 360° image acquisition and 360° sound recording in order to ensure the best quality possible (avoiding pixelization/fuzzy images) for the films for optimal immersion. During the filming sessions, the camera was carried by a female subject in our team (MM) with the same physical characteristics, and wearing the same kind of clothes as Ms. V. Once the films were recorded, they were uploaded to a private Youtube account in order to allow the patient self-directed exposure to anxiogenic sequences at home.

2.3. Scenario administration

We used a high-end VR helmet (Homido V2) and a light and flexible audio helmet (Philips SHL3060BK). The VR helmet was combined with a smartphone (G3, LG) having the advantage of being cheap while displaying a large 5.5" screen with a ultra-high resolution (2560*1440) which is crucial for high immersivity and highly recommended in VR to avoid deleterious image pixelisation (Figure 1A). Besides, it allowed us to perform a screen mirroring on the computer to see live what the patient was looking at during the session in order to prevent avoidance (Figure 1B). During the video exposure, we recorded the palmar galvanic skin response (GSR) to monitor the patient's anxiety level (Figure 1B). When the patient was at home, she could login on a dedicated private Youtube account and use a Google Cardboard like VR helmet for self-directed exposure.

2.4. Protocol

The protocol was initiated in March 2017, at the Psychiatry Department of Albert Chenevier hospital (Créteil). This therapy was offered to the patient as part of the routine medical care provided by the unit and was approved by the ethics evaluation committee of INSERM (approval n°14-161). The patient gave her informed consent prior to the beginning of the therapy. It started with a baseline clinical assessment: obsessive/compulsive symptom level (Y-BOCS [33] and Obsessive–Compulsive Inventory Revised (OCI-R [34]); depressive symptom level (BDI [35]); quality of life (brief version of the WHO Quality of Life scale, WHOQOL-26 [36]). 15 weekly therapeutic sessions followed. The first consisted of the validation of the patient elaborated scenarios and the explanation of the protocol and its aims. The patient's ability to be immersed in a virtual environment (sense of presence) was also assessed using the Immersive Tendencies Questionnaire (ITQ [37]). A neutral scenario was then administered in order to get used to the system and to assess cyber-sickness with the Simulator Sickness Questionnaire (SSQ [38]). After this session, the scenarios were filmed. Then all the sessions were organised the same way. They started with the evaluation of OCD symptom evolution since the latest session and the patient's self-exposure homework. The anticipatory anxiety level was assessed just before the VR projection with the Spielberger's State Anxiety Inventory (STAI-A [39]). The patient then visualised the scenario while palmar GSR was recorded. Immediately following the scenario projection, the level of cybersickness was assessed (SSQ). Then, the exposure session was discussed with the patient using all the data recorded during the session in order to obtain her feedback about her feelings and changes since the latest session. Between sessions, the patient was encouraged to self-expose at least once a day and to try to reproduce in real life the actions experienced in the VE. The shift to the next most anxiogenic scenario depended on good tolerance of the previous one corresponding to: a decrease in electrodermal reactivity, the subjective evaluation of the anxiety

by the patient and the behavioural manifestations of anxiety (disgust reactions, closed fist, complaining...) during exposure.

The final evaluation took place after the 15th session and focussed on OCD and depressive symptoms and the quality of life.

3. Results

During the first session, Ms. V. was administered a ten-minute neutral video and showed little cyber-motion-sickness (9/48 at the SSQ). She also demonstrated ease to slip into the VE with a total ITQ score of 72/126. The following 14 sessions were dedicated to the administration of the OCD related videos (Figure 1C). The patient found the videos very immersive and also anxiogenic: she had the feeling her hands were dirty and wanted to wash them. She was living the scene as if she was really in it and had obvious reactions of disgust. Visual avoidance of the anxiogenic parts of the environment was often present at the beginning. She was thus verbally encouraged to visualize these parts when visual avoidance was detected (while minimizing these interventions to limit the impact on immersion) by the monitoring of her gaze through the screen mirroring. Progressively, visual avoidance disappeared and she displayed good habituation with a decrease in the electrodermal reactivity, the STAI-A score (46 to 37/80 for the first scenario and 67 to 37/80 for the second) and the behavioural markers of anxiety (more relaxed attitude).

Although she did not self-expose regularly to videos (due to the use of her own smartphone, less powerful than the one used in session, with a "Google like" cardboard that we provided her, resulting in cybersickness) as assessed by the low number of views on YouTube, Ms. V. showed a moderate clinical improvement (Figure 2) with a 5-point drop in the Y-BOCS score. At OCI-R, there was a decrease of one point on the washing dimension, 3 points in the accumulation dimension but also a decrease of 4 points in the order dimension. The decline in

the latter two dimensions reflects her clinical improvement, allowing Ms. V. to deal with hoarded objects and thus be less concerned with order. In addition, depressive symptomatology improved with the BDI score dropping 8 points to 4.

This clinical improvement was reflected in real life by an expansion of Ms. V's repertoire of actions, with the possibility, for example, of taking her phone in her bag, reproducing a shopping scene in a store, hugging a friend (with less disgust according to her). More generally, she reported more voluntary exposure to anxiogenic stimuli ("this is the first time I challenge myself a little bit every day"). Among the actions that Ms. V. manages to carry out again, some were not included in any of the scenarios presented, indicating a generalisation process. In addition, Ms. V. reported that she sometimes surprised herself by not paying attention to "dirt", indicating a possible reduction in attention bias. In addition, Ms. V. accepted a temporary job when she had not worked for 4 years. All these elements have contributed to an improvement in her quality of life, as evidenced by the increase in WHOQOL-26 perceived physical and mental health scores (Figure 2).

4. Discussion

This proof of concept study aimed at first highlighting the feasibility and the good tolerance of personalised immersive 360° video exposure to treat OCD. The acceptance and compliance of the patient towards this therapy despite the severity of her disorder is an encouraging evidence that personalised immersive 360° video exposure can be easily implemented to treat patients with severe symptoms and a major reluctance to accept more classical ERP techniques.

The technology underlying this type of virtual exposure is also a guarantee of its facilitated implementation due to the use of inexpensive equipment (approximately \$400 for a complete video recording and viewing system). Concerning in situ video recording of exposure scenarios, it is quite easy to imagine involving the paramedical staff in a hospital environment or

alternatively the patient's family in a logic of empowerment of the patient and his relatives. Considering self-exposures, the experience of our patient using her own smartphone which proved to be unsuitable for 360° 4K video streaming, demonstrates that it is necessary for future studies to provide patients with equipment that is compatible with the latency-free streaming of this video type.

Considering the therapeutic potential of immersive 360° video exposure, these preliminary results are promising with, in addition to clinical improvement (5-point drop at the Y-BOCS), a substantial improvement in her quality of life (resulting in a 25-point improvement in the physical health dimension and a 19-point improvement in the psychological health dimension of WHOQOL-26).

Nevertheless, the patient was on clomipramine treatment initiated 6 weeks before the start of the protocol. The clinical improvement could thus be related to this drug and not to video viewing, or at least, the drug could have potentiated the exposure therapy. Although the oral dose of clomipramine was well below the recommended dose in OCD (75 mg/d for an effective dose in OCD around 250 mg/d [3]), the high interindividual variability in the clomipramine pharmacokinetics and the lack of plasma measurements prevent this hypothesis from being ruled out. Another confounding factor is the presence of depressive symptoms at the start of the study which is an influencing factor of OCD severity, even without comorbid MDD [40]. Thus, our results could be explained by the depressive symptom improvement. However, it has been shown that depressive symptomatology does not influence treatment response but rather it is OCD symptom improvement that leads to changes in depressive symptoms [41], allowing us to rule out this hypothesis. It is also necessary to mention the particular clinical profile of this patient. Indeed, her multiple comorbidities, first and foremost her history of polysubstance addiction complicated by a dysexecutive syndrome, make her case not generalizable to the general clinical population, which makes it necessary to continue this work on a more

representative sample. Finally, it is necessary to stress that a decrease in the YBOCS score of only 15% does not allow the patient to be classified as responsive to the treatment according to commonly accepted criteria (reduction of the YBOCS score by at least 25% [3]). However, it is also important to consider other indicators of therapeutic response that are equally important in routine clinical practice, foremost among which is the subject's quality of life. It is thus clear that the quality of life has improved significantly in a patient who was initially confined to her home because of her disorder. However, due to the uncontrolled nature of this pilot study, it is not possible to reliably link this improvement to a specific effect of the therapy. Indeed, as in any psychotherapy, there is a common factor (the "dodo bird effect" [42,43] or more commonly the contextual or placebo effect) which alone can explain a more or less important proportion of the therapeutic response. This technique is in line with an increasingly promoted approach of patient empowerment, enabling patients to become partners and actors in their psychotherapeutic care. Moreover, due to its high level of personalisation, the technique is consistent with the development of personalised psychiatry by allowing the specificity of the patient's symptoms to be taken into account, as well as the patient's own environment [44].

5. Conclusion

In conclusion, this study has produced promising results but needing to be replicated on a larger and more representative sample before the recognition of personalised exposure therapy by immersive 360° video as the technique of choice in the therapeutic arsenal of OCD. Indeed, it would enable a low financial cost solution that can be easily replicated to bring the patient's environment within the therapist's consulting room for a more easily accepted exposure to anxiogenic stimuli that are relevant to the patient and therefore a lower drop-out rate.

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Figures

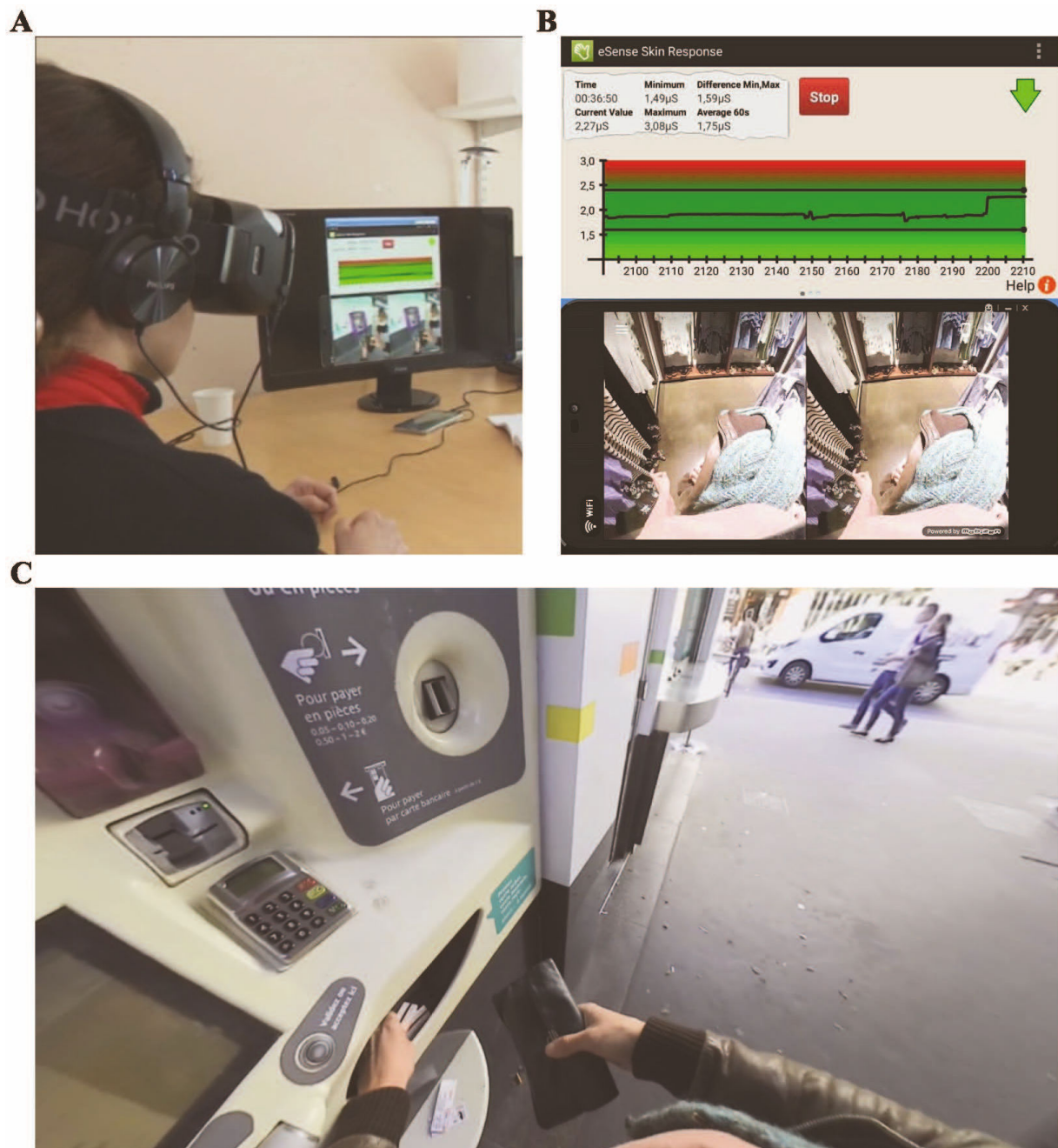


Figure 1. The personalised 360° video exposure therapy.

(A) Therapy session during which the patient experiences an anxiety-provoking situation of her daily life while her emotional response is measured by a sensor placed on her hand. **(B)** Recording during the session of the electrodermal activity and the region of the 360° video observed. **(C)** Subjective view of an anxiety-provoking scene shot at the ticket machine in a metro station chosen by the patient.

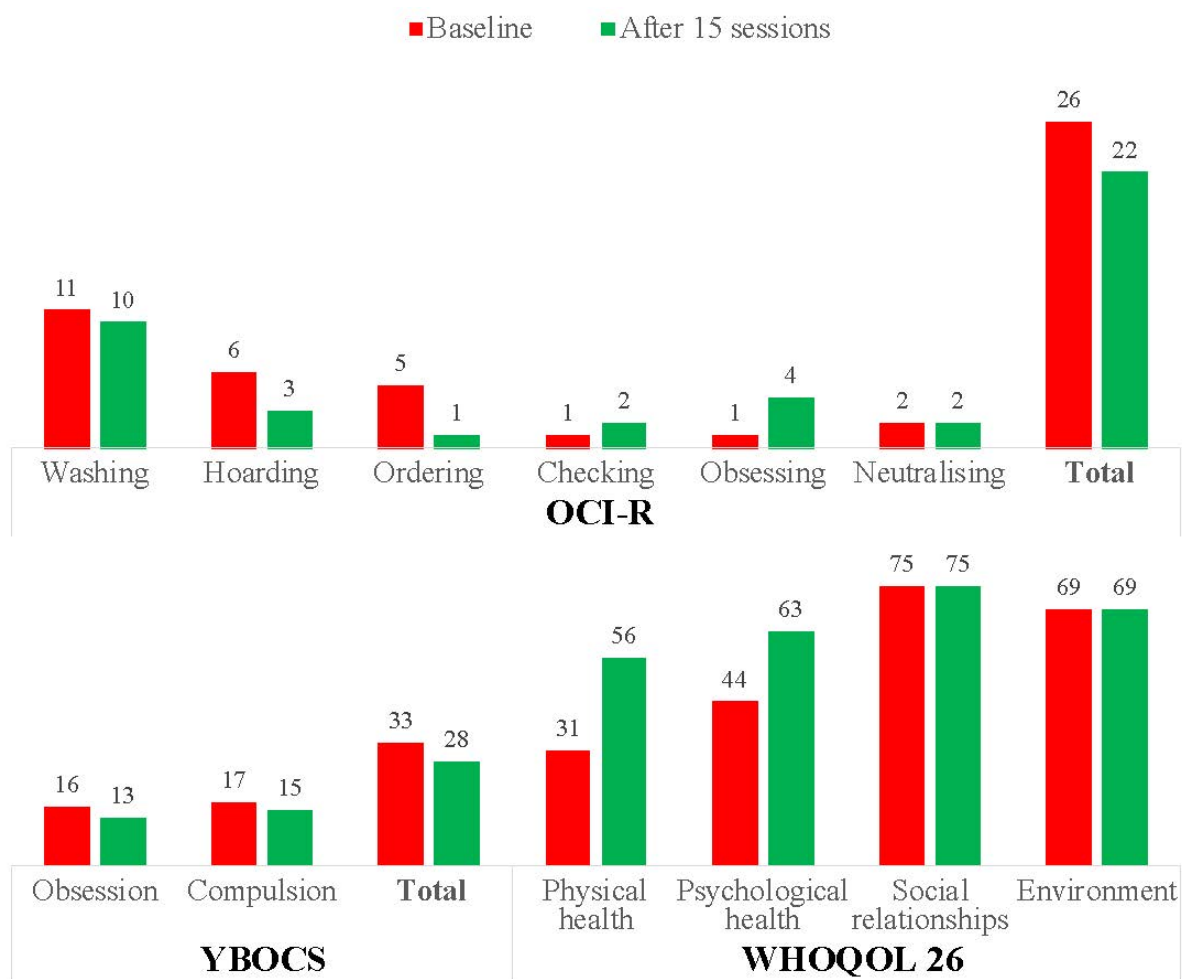


Figure 2. Clinical and life quality improvement.

Clinical improvement (lowering of scores) attested by self-assessment (OCI-R) and clinical assessment (YBOCS). Improved quality of life in terms of perceived physical and mental health attested by increased scores for these dimensions on the WHOQOL-26.