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► To cite this version:

Nabil Benzina, Margot Morgiève, Marine Euvrard, João Flores Alves dos Santos, Antoine Pelissolo, et al.. Personalised 360o video exposure therapy for the treatment of obsessive-compulsive disorder: A single case study. French Journal of Psychiatry, 2020, 1, pp.31-38. 10.1016/j.fjpsy.2020.02.004 . hal-03911455

HAL Id: hal-03911455

<https://hal.science/hal-03911455v1>

Submitted on 17 Jan 2023

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

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14 Short running title: VR to treat OCD

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25 Words: 3487

Figures: 2

26 **Abstract**

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

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

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51 **1. Introduction**

52 **1.1. OCD and its treatment**

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

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

78 **1.2. VR contributions to OCD patient therapeutic care**

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

92 VR has been extensively used for more than twenty years for anxiety disorders with rather good
93 results, but mainly in a research framework [11]. However, the literature on the use of VR for
94 OCD patients remains scarce. The first VR-like study for OCD patients dates back from 1998
95 [12]. It provided promising results using a vicarious learning training based on interactive
96 pictures. OCD patients had to learn to self-expose without performing their rituals, by looking
97 at an avatar that suffered from the same symptomatology. At the end of the sessions, these
98 patients displayed a modest but significant reduction in symptom severity on the Yale-Brown
99 Obsessive-Compulsive scale (Y-BOCS). Ten years later, Kim and collaborators examined
100 VR's ability to induce anxiety for OCD participants using a head-mounted display [13]. Not

101 only did VR trigger checking symptoms and anxiety, but this anxiety was positively correlated
102 with the severity of the disorder and the subject's propensity to immerse in the VE. These results
103 were reproduced in 2012 with patients suffering from symmetry/order OCD [14]. Two years
104 later, Belloch [15] used a high-resolution monitor coupled with a movement tracker and
105 demonstrated that VR is able to generate anxiety and disgust proportionally to the degree of
106 dirtiness of the scenario administered to patients suffering from washing/contamination OCD.
107 Laforest described the same results using a CAVE system, for the same category of symptoms
108 [16]. More recently, van Bennekom, using first-person videos shot in a real environment and
109 reproducing scenarios relevant to the subjects (dirty toilet, gas stove left on, etc...) displayed on
110 a screen, demonstrated the ability of this kind of VR to induce OCD symptoms [17].
111 Therefore, VR seems able to trigger OCD symptoms, which is a crucial step for exposure
112 treatments, but few studies attempt to assess its efficiency to **treat** OCD symptoms. A decrease
113 in OCD symptoms in three patients was reported after a VR immersive exposure (CAVE
114 system); even though this improvement was not maintained over the long term [7]. Interesting
115 results have been shown with a VR and vicarious learning procedure [18]. The patients had to
116 learn to expose without performing their rituals while exploring the VE with the help of an
117 avatar displayed on the screen. At the end of the study, the patients displayed a modest but
118 significant reduction of the severity of OCD symptoms (a reduction of 2.4 points in the total
119 YBOCS score on average) at one-month post-treatment.

120 **1.3. Limitations of VR studies**

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

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

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

152 **1.4. Rationale and objectives of our study**

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

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

171

172 **2. Methods**

173 **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

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

200 **2.2 Scenario filming**

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

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

212 **2.3. Scenario administration**

213 We used a high-end VR helmet (Homido V2) and a light and flexible audio helmet (Philips
214 SHL3060BK). The VR helmet was combined with a smartphone (G3, LG) having the
215 advantage of being cheap while displaying a large 5.5" screen with a ultra-high resolution
216 (2560*1440) which is crucial for high immersivity and highly recommended in VR to avoid
217 deleterious image pixelisation (Figure 1A). Besides, it allowed us to perform a screen mirroring
218 on the computer to see live what the patient was looking at during the session in order to prevent
219 avoidance (Figure 1B). During the video exposure, we recorded the palmar galvanic skin
220 response (GSR) to monitor the patient's anxiety level (Figure 1B). When the patient was at
221 home, she could login on a dedicated private Youtube account and use a Google Cardboard like
222 VR helmet for self-directed exposure.

223 **2.4. Protocol**

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

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

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

252

253 **3. Results**

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

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

273 the latter two dimensions reflects her clinical improvement, allowing Ms. V. to deal with
274 hoarded objects and thus be less concerned with order. In addition, depressive symptomatology
275 improved with the BDI score dropping 8 points to 4.
276 This clinical improvement was reflected in real life by an expansion of Ms. V's repertoire of
277 actions, with the possibility, for example, of taking her phone in her bag, reproducing a
278 shopping scene in a store, hugging a friend (with less disgust according to her). More generally,
279 she reported more voluntary exposure to anxiogenic stimuli ("this is the first time I challenge
280 myself a little bit every day"). Among the actions that Ms. V. manages to carry out again, some
281 were not included in any of the scenarios presented, indicating a generalisation process. In
282 addition, Ms. V. reported that she sometimes surprised herself by not paying attention to "dirt",
283 indicating a possible reduction in attention bias. In addition, Ms. V. accepted a temporary job
284 when she had not worked for 4 years. All these elements have contributed to an improvement
285 in her quality of life, as evidenced by the increase in WHOQOL-26 perceived physical and
286 mental health scores (Figure 2).

287

288 **4. Discussion**

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

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

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

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

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

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

338

339 **5. Conclusion**

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

346

347

348 **Acknowledgements**

349 We thank Ms. V. for her helpful and dedicated involvement in this study.

350

351 **Disclosure Statement**

352 The authors declare no conflicts of interest.

353

354 **Funding**

355 This research did not receive any specific grant from funding agencies in the public,
356 commercial, or not-for-profit sectors.

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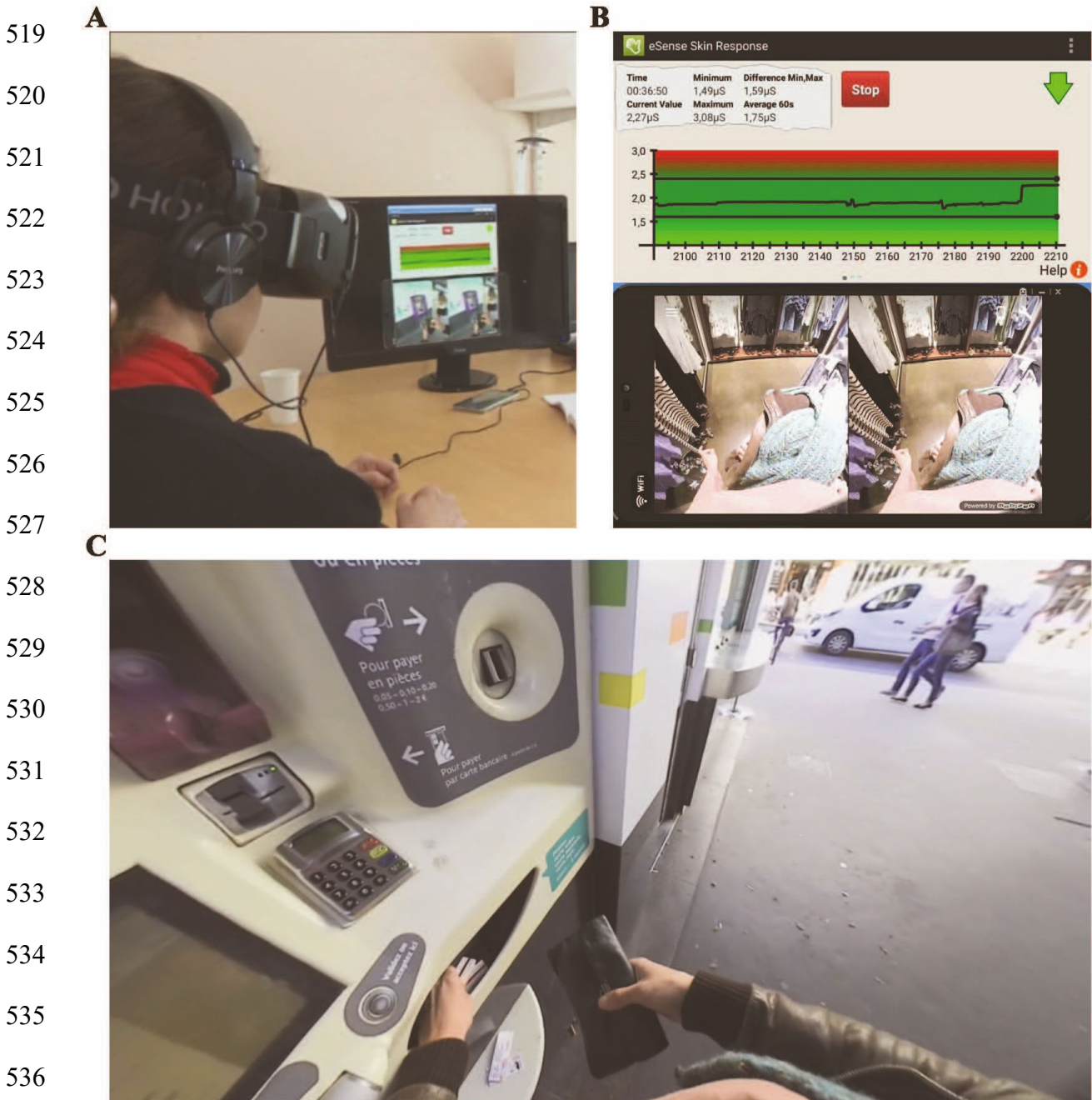
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518 **Figures**



537 **Figure 1. The personalised 360° video exposure therapy.**

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

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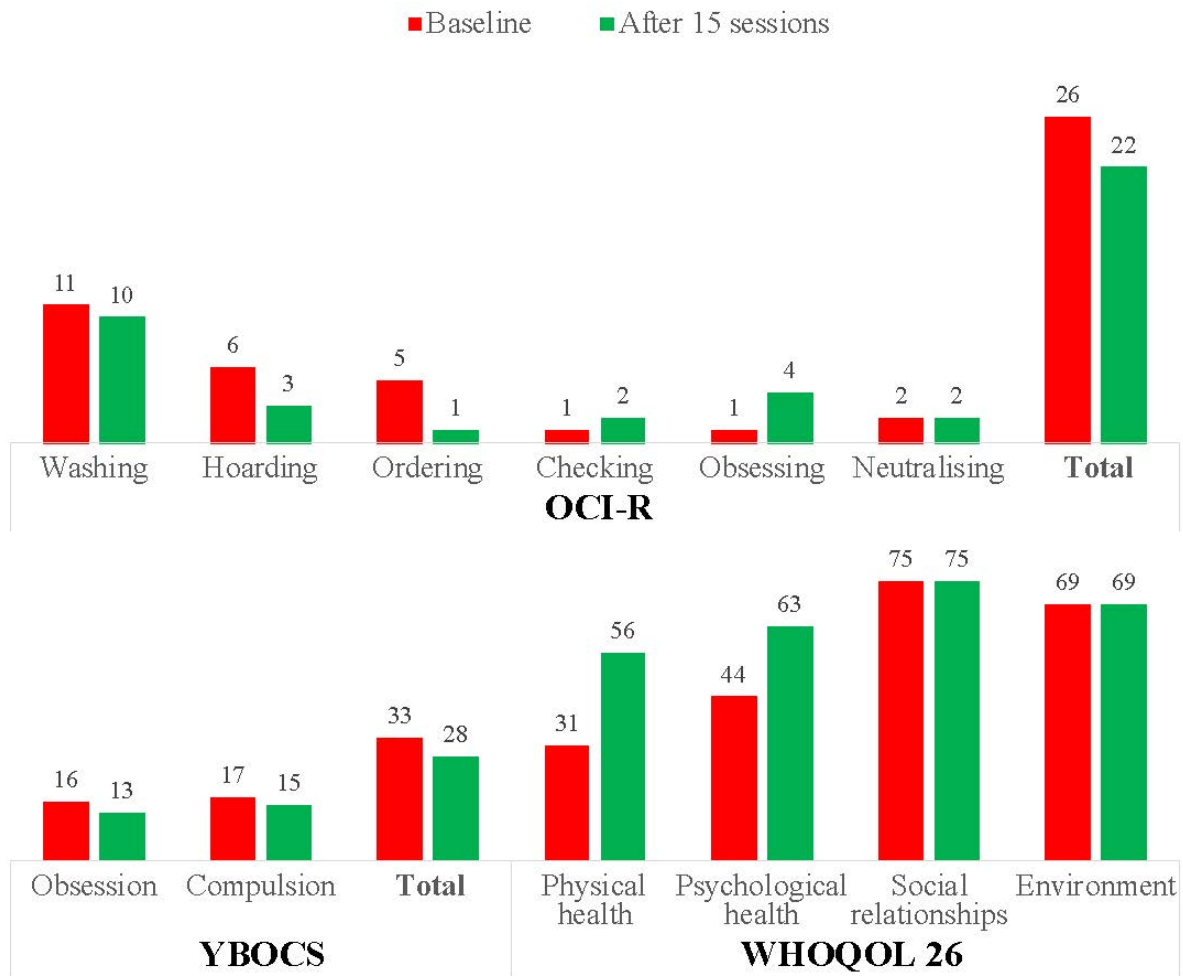


Figure 2. Clinical and life quality improvement.

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.