

1 Virtual reality in the assessment, understanding, and 2 treatment of mental health disorders

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9 Mental health problems are inseparable from the environment. With virtual reality (VR), computer-generated interactive
10 environments, individuals can repeatedly experience their problematic situations and be taught, via evidence-based psy-
11 chological treatments, how to overcome difficulties. VR is moving out of specialist laboratories. Our central aim was to
12 describe the potential of VR in mental health, including a consideration of the first 20 years of applications. A systematic
13 review of empirical studies was conducted. In all, 285 studies were identified, with 86 concerning assessment, 45 theory
14 development, and 154 treatment. The main disorders researched were anxiety ($n = 192$), schizophrenia ($n = 44$), substance-
15 related disorders ($n = 22$) and eating disorders ($n = 18$). There are pioneering early studies, but the methodological quality
16 of studies was generally low. The gaps in meaningful applications to mental health are extensive. The most established
17 finding is that VR exposure-based treatments can reduce anxiety disorders, but there are numerous research and treat-
18 ment avenues of promise. VR was found to be a much-misused term, often applied to non-interactive and non-immersive
19 technologies. We conclude that VR has the potential to transform the assessment, understanding and treatment of mental
20 health problems. The treatment possibilities will only be realized if – with the user experience at the heart of design – the
21 best immersive VR technology is combined with targeted translational interventions. The capability of VR to simulate
22 reality could greatly increase access to psychological therapies, while treatment outcomes could be enhanced by the tech-
23 nology's ability to create new realities. VR may merit the level of attention given to neuroimaging.

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25 **Key words:** Assessment, mental health, theory, treatment, virtual reality (VR).

26 Introduction

27 A technological revolution in mental health care is
28 approaching. At the forefront may be virtual reality
29 (VR), a powerful tool for individuals to make new
30 learning for the benefit of their psychological well-
31 being. Immersive VR creates interactive computer-
32 generated worlds, which substitute real-world sensory
33 perceptions with digitally generated ones, producing
34 the sensation of actually being in life-sized new envir-
35 onments. VR allows such tight control over the stimuli
36 presented that therapeutic strategies can be precisely
37 implemented; VR can produce situations that can be
38 therapeutically helpful if used in the right way but
39 near impossible to recreate in real life; VR allows
40 repeated, immediately available and greater treatment
41 input; and VR can reduce inconsistency of treatment
42 delivery. With high-quality VR devices reaching the

consumer market for the first time, the future is sud- 43
denly imminent. The affordability makes it feasible 44
for the technology to break out of the laboratory and 45
enter the home – and forward-thinking mental health 46
clinics too. 47

VR 48

The basic elements of VR – a computer generating an 49
image, a display system presenting the sensory infor- 50
mation, and a tracker feeding back the user's position 51
and orientation in order to update the image – have 52
existed for 50 years. The hardware recognizable 53
today emerged in the 1980s but has been largely 54
confined to specialist laboratories (Slater & 55
Sanchez-Vives, 2016). Systems vary greatly. For 56
example, the Cave Automatic Virtual Environment 57
(CAVE) projects computer images onto the walls of a 58
room and the participant wears tracked shutter glasses 59
to view the scene three-dimensionally (Cruz-Neira 60
et al. 1993). Sometimes described as VR are much 61
lower-specification systems that use displays on com- 62
puter monitors or large projector screens, but the 63

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64 limited levels of immersion and interaction make it
 65 questionable whether these are truly VR. The current
 66 excitement relates to the new generation of head-
 67 mounted display (HMD) and associated equipment
 68 that have emerged as affordable consumer products
 69 due to the investment of global companies.
 70 Smartphones, laptops or desktop computers can run
 71 the software. VR is moving out of specialist laborator-
 72 ies. The transformation in what the hardware and soft-
 73 ware can now realize compared with even a few years
 74 ago is great.

75 An HMD displays images, one for each eye, forming
 76 an overall stereo scene. Each image is computed and
 77 rendered separately with correct perspective from the
 78 position of each eye with respect to a mathematical
 79 description of a three-dimensional (3D) virtual scene.
 80 The HMD is typically tracked, with continuous captur-
 81 ing of the position and orientation of the participant's
 82 head and therefore head-based gaze direction. As par-
 83 ticipants turn or move their head to look around, the
 84 computer updates at a very high frame rate – typically
 85 60 frames per second – the images displayed. Therefore
 86 participants see a surrounding 3D stereo scene that can
 87 change dynamically. Although much VR program-
 88 ming has omitted it, one particular object in the
 89 scene can have special status – the virtual body of
 90 the participant. At its simplest, this visual substitution
 91 of the person's real body can be aligned to the head
 92 tracking. But if the participant wears a motion-tracking
 93 capture suit with an HMD, then the data from this,
 94 continuously streamed to the computer, will effectively
 95 substitute the body of the participant by a life-sized
 96 virtual body that fully moves in correspondence with
 97 their own movements, leading to the illusion of body
 98 ownership (Slater *et al.* 2010; Spanlang *et al.* 2014).

99 Perception through natural movement is the key
 100 element of an immersive VR system. Immersion
 101 reflects the system's technical capabilities; the subject-
 102 ive experience delivered is termed 'presence', which
 103 is the illusion of being in the place rendered by VR.
 104 Presence comprises two concepts: place illusion (PI)
 105 and plausibility illusion (Psi) (Slater, 2009). PI is the
 106 sense of being in the virtual place. A necessary condi-
 107 tion for PI is that the VR is perceived through natural
 108 sensorimotor contingencies, based on the active vision
 109 paradigm (Noë, 2004). The idea of this paradigm is that
 110 we perceive through using our whole body, via a set of
 111 implicit rules involving head turning, leaning, reach-
 112 ing, looking around and so on. The illusion of 'being
 113 there' is generated to the extent that the VR system
 114 affords perception through such contingencies. If
 115 what we see matches our movements then the brain's
 116 conclusion is that these are our surroundings. The Psi
 117 is the sense that the events experienced in VR are hap-
 118 pening (e.g. that there are people walking about, that a

ball is flying through the air), even though, of course, 119
 individuals consciously know that these are not real. 120
 Psi requires that the virtual environment responds to 121
 actions of the participants, generates spontaneous 122
 actions towards them, and is ecologically valid when 123
 real-life events are depicted. For example, when the 124
 environment includes virtual human characters, these 125
 avatars should respond to the presence and actions 126
 of the participants (e.g. by gaze and maintaining 127
 appropriate interpersonal distances). When both PI 128
 and Psi operate, participants will be likely to behave 129
 realistically in VR. 130

VR and mental health

131
 132 VR has extraordinary potential to help people over-
 133 come mental health problems if high levels of presence
 134 are achieved for situations that trouble them. 135
 Difficulties interacting in the world are at the heart of 136
 mental health issues [e.g. becoming highly anxious 137
 near spiders in arachnophobia, having intense flash- 138
 backs with reminders of past trauma in post-traumatic 139
 stress disorder (PTSD), fearing attack from people in 140
 persecutory delusions, resisting the urge to take 141
 another drink in alcohol abuse disorders]. Therefore 142
 recovery concerns thinking, reacting and behaving dif- 143
 ferently in these situations. The most successful inter- 144
 ventions are those that enable people to make such 145
 changes in real-world situations. With VR, individuals 146
 can enter simulations of the difficult situations and be 147
 coached in the appropriate responses, based upon the 148
 best theoretical understanding of the specific disorder. 149
 The simulations can be graded in difficulty and repeat- 150
 edly experienced until the right learning is made. 151
 Problematic situations difficult to find in real life can 152
 be realized at the flick of a switch. And the great 153
 advantage of VR is that individuals know that a com- 154
 puter environment is not real but their minds and bod- 155
 ies behave as if it is real; hence, people will much more 156
 easily face difficult situations in VR than in real life and 157
 be able to try out new therapeutic strategies. The learn- 158
 ing can then transfer to the real world. For some disor- 159
 ders it may be possible to eradicate the need for any 160
 therapist input, while for other disorders the time 161
 required of skilled therapists could be greatly reduced. 162
 Thus VR could help improve access to the most effect- 163
 ive psychological treatments. It may become the 164
 method of choice for psychological treatment: out 165
 with the couch, on with the headset.

166 There are also many other potential uses of VR in
 167 mental health. We originally set out seven purposes
 168 (Freeman, 2008): symptom assessment, identification
 169 of symptom markers or correlates, establishment of
 170 factors predictive of disorders, tests of putative causal
 171 factors, investigation of the differential prediction of

172 symptoms, determination of toxic elements in the
 173 environment, and the development of treatment. For
 174 instance, standard mental health diagnosis chiefly
 175 comprises retrospective recall using clinician interview
 176 and validated questionnaires. Inevitably, human
 177 beings tend to be very subjective in their views.
 178 Memory, moreover, is notoriously fallible. In the clinic
 179 of the future, it is possible that problems could also be
 180 assessed live in VR. The technology could also help
 181 make substantial inroads into understanding the
 182 causes of mental health disorders, for example, pin-
 183 pointing the environmental characteristics that raise
 184 the risk of adverse psychological reactions in the con-
 185 text of individual differences.

186 The aim of this paper is to highlight for clinicians
 187 and researchers in mental health the potential of VR
 188 technology. This includes a review of what has been
 189 learned empirically from the first generation of studies
 190 about the use of VR in assessing, understanding and
 191 treating the main adult mental health disorders. We
 192 wished to identify established findings, obvious areas
 193 of neglect and new directions of interest. These are
 194 the studies that have been conducted in specialist
 195 laboratories over the past 20 years, before the current
 196 transformation in availability and capabilities of the
 197 technology. It is the ambition of these pioneering stud-
 198 ies that we aim to capture, as new hardware and soft-
 199 ware are dramatically altering what can be created in
 200 VR and the ease of use.

201 Method

202 The literature on VR in mental health was searched up
 203 to the end of 2016. The inclusion criteria were: a
 204 specific focus on the assessment, theory, or treatment
 205 of adult mental health disorders; published in a peer-
 206 reviewed journal; was an empirical study (including
 207 case studies with data); used a form of immersive VR
 208 (HMD, CAVE, large projection screen, screen with 3D
 209 glasses); and in the English language. The exclusion
 210 criteria were: non-immersive VR method [e.g. personal
 211 computer (PC) screen only, websites such as Second
 212 Life]; qualitative data or review; unable to obtain the
 213 paper; use of VR but no specific focus on a mental
 214 health symptom or condition. We did not look at
 215 health psychology, cognitive disorders, personality
 216 disorders, childhood-onset disorders, or at the effects
 217 of VR games that were not designed as interventions.

218 PubMed was used for the searches, which were con-
 219 ducted separately by major disorder types. The general
 220 search terms were: [(Virtual reality OR Immersive vir-
 221 tual reality] AND [Assessment OR treatment OR
 222 research OR study OR experiment OR understanding])
 223 AND (disorder-specific terms inserted here)] AND
 224 English (language). For anxiety disorders, the search

terms added were: (Anx* OR obsessive-compulsive 225
 OR post-traumatic OR panic OR social phobia OR 226
 social anxiety OR phob*OR GAD OR OCD OR PTSD 227
 OR SAD). For depression, the search terms added 228
 were: (depression OR depress*). For psychosis the 229
 search terms added were: (Delus*OR Hallucinat* OR 230
 Psychosis OR Psychotic OR Schizophren* OR 231
 Schizotyp* OR Bipolar OR Mania OR Manic). For sub- 232
 stance disorders, the search terms added were: (sub- 233
 stance disorder OR substance abuse OR substance 234
 OR abuse OR cannabis OR tobacco OR alcohol OR 235
 amphetamine OR hallucinogens OR heroin). For eating 236
 disorders, the search terms added were: AND (anor- 237
 exia nervosa OR bulimia nervosa OR eating disorders 238
 OR binge eating). For sleep disorders, the added 239
 terms were: (insomnia OR sleep OR nightmares OR cir- 240
 cadian). For sexual disorders, the added search terms 241
 were: (sexual OR orgasm OR desire OR erectile OR 242
 ejaculation OR dyspareunia). Titles and abstracts 243
 were read, and, if appropriate, the whole paper, in 244
 order to determine whether the inclusion and exclu- 245
 sion criteria were met. 246

247 Results

248 A total of 1096 studies were identified from the litera- 248
 249 ture searches, of which 285 met the review inclusion 249
 250 criteria. Summaries of the searches by each of the dis- 250
 251 order types are displayed in the online Supplementary 251
 252 Figs S1–S7. Descriptions of the individual VR studies 252
 253 are available in the online Supplementary Tables S1– 253
 254 S7. The most common reason for an empirical study 254
 255 to be excluded from review was the use of non- 255
 256 immersive technology (e.g. participants simply viewed 256
 257 a standard computer screen for presentation) or empir- 257
 258 ical data were not reported. 258

259 Anxiety disorders

260 Overwhelmingly, VR studies have concerned the treat- 260
 261 ment of anxiety disorders ($n=127$ intervention 261
 262 reports). Even the assessment studies ($n=46$) have 262
 263 mainly been conducted for the purpose of validating 263
 264 VR environments for treatment. The use of VR to 264
 265 investigate the causes of anxiety has been more rarely 265
 266 conducted ($n=19$). The focus of the treatment studies 266
 267 has typically been on specific phobias (e.g. Rothbaum 267
 268 *et al.* 2000; Emmelkamp *et al.* 2002; Garcia-Palacios 268
 269 *et al.* 2002; Botella *et al.* 2004) or social anxiety (e.g. 269
 270 Anderson *et al.* 2013; Bouchard *et al.* 2016) or post- 270
 271 traumatic stress disorder (e.g. Difede *et al.* 2007; 271
 272 Rizzo *et al.* 2009), with many fewer investigations for 272
 273 obsessive– compulsive disorder (OCD), which is sur- 273
 274 prising given that treatment often requires change in 274
 275 fears about external stimuli, and generalized anxiety 275

276 disorder, which is less surprising given the internal
 277 focus of the disorder. The principal intervention tech-
 278 nique has been exposure, with a therapist present to
 279 guide the person in most of the intervention studies.
 280 The treatment studies have undoubtedly been pioneer-
 281 ing in recognizing the potential for the technology in
 282 this treatment area especially (e.g. Hodges *et al.* 1995;
 283 Rothbaum *et al.* 1996; Botella *et al.* 1998). Case study
 284 reports or small randomized controlled trials have
 285 dominated the field. The quality of studies has too
 286 often been low (Meyerbröker & Emmelkamp, 2010;
 287 McCann *et al.* 2014). There are too few convincing ran-
 288 domized controlled trials, although this is beginning to
 289 change (e.g. Anderson *et al.* 2013; Bouchard *et al.* 2016;
 290 Reger *et al.* 2016), too few experimental studies of
 291 potential treatment mediators (e.g. Shiban *et al.* 2016),
 292 and comparisons between different techniques have
 293 typically been underpowered. Overall, however, VR
 294 treatments seem to perform comparably in efficacy to
 295 face-to-face equivalent interventions. With the caveat
 296 concerning the quality of the studies, the treatment
 297 efficacy has been shown in meta-analyses to be large
 298 (e.g. Oprış *et al.* 2012), with evidence that the beneficial
 299 effects transfer to the real world (Morina *et al.* 2015).
 300 When long-term follow-ups have been included, treat-
 301 ment effects for these short-term therapies have
 302 strikingly been shown to persist over a number of
 303 years (e.g. Rothbaum *et al.* 2002; Wiederhold &
 304 Wiederhold, 2003). There are indications that drop-out
 305 rates may be lower with VR treatments but that may
 306 simply reflect a problem of quality control with
 307 face-to-face therapy delivery. The range of VR-type
 308 methods used has been wide, varying from large pro-
 309 jection screens to the computer-assisted research envi-
 310 ronment (CAREN) system, in which the person has a
 311 walking platform surrounded by a 360° display, to
 312 CAVEs, flight simulators, and to HMDs. Not all
 313 reports make clear which type of technology was
 314 used. The greater the sense of presence in VR achieved
 315 then the more likely anxiety will occur (Ling *et al.*
 316 2014). The importance of sound in achieving presence
 317 in VR should not be overlooked (e.g. Taffou *et al.*
 318 2013). Detailed studies of how best to present stimuli
 319 in VR are warranted but in our opinion have been
 320 far too rare (e.g. Shiban *et al.* 2015).

321 *Depression*

322 Surprisingly, we identified only two studies that
 323 clearly used immersive VR in relation to depression.
 324 These feasibility studies tested out single treatment
 325 techniques in small case series with no control condi-
 326 tions (Shah *et al.* 2015; Falconer *et al.* 2016), with levels
 327 of depression found to decrease with time. There have
 328 also been two studies of (non-immersive) VR-type

tasks assessing spatial navigation memory in patients 329
 with depression (e.g. Gould *et al.* 2007). 330

Psychosis

331
 332 There have been 44 VR studies about schizophrenia 332
 and related problems, with 23 concerning theory 333
 development, 15 concerning assessment, and six test- 334
 ing treatment. The types of VR studies here were prob- 335
 ably the most heterogeneous compared with the other 336
 mental health conditions, reflecting the complexity of 337
 the clinical problem and the different perspectives 338
 taken towards diagnosing and understanding psych- 339
 osis. The studies have predominately used VR to assess 340
 psychotic experiences in order to understand the 341
 causes. VR has been of particular use in assessing para- 342
 noia because the presentation of neutral social situa- 343
 tions enables unfounded, rather than genuine, 344
 hostility to be detected. It is clear that VR can safely 345
 assess psychotic experiences in patients with schizo- 346
 phrenia and related diagnoses. Our group pioneered 347
 the work on VR in relation to paranoia. We have 348
 used VR to: assess paranoia (e.g. Freeman *et al.* 2003); 349
 understand the individual characteristics predictive of 350
 paranoia (e.g. Freeman *et al.* 2008); manipulate psycho- 351
 logical factors in order to determine the causes of para- 352
 noia (e.g. Freeman *et al.* 2014); and, most recently, treat 353
 persecutory delusions in the context of schizophrenia 354
 (Freeman *et al.* 2016). A rare use of VR to create a situ- 355
 ation that cannot be achieved in real life is provided by 356
 our manipulation of a person's height in order to affect 357
 self-esteem and hence paranoia (Freeman *et al.* 2014). 358
 The small treatment study with 30 patients with perse- 359
 cutory delusions showed that VR cognitive therapy is 360
 potentially much more efficacious than VR exposure 361
 therapy both in terms of reducing delusions and les- 362
 sening distress in real-world situations. The controlled 363
 effect size ($d=1.3$) for VR cognitive therapy was large, 364
 which is notable given that it was compared with 365
 another credible treatment approach. VR has also 366
 been used to study environmental factors that make 367
 an impact on paranoia, by altering variables such as 368
 population density and ethnicity (e.g. Valmaggia 369
et al. 2015; Veling *et al.* 2016). There is also a strand 370
 of VR work assessing cognitive and social functioning 371
 in schizophrenia (e.g. Sorkin *et al.* 2006) and conse- 372
 quent intervention (e.g. Rus-Calafell *et al.* 2014). 373
 Treatment studies are generally very few in number 374
 and small in size but the results are very encouraging. 375
 No studies related to mania were identified. 376

Substance disorders

377
 378 VR has the potential to present individuals with simu- 378
 lations of the cues that lead to the cravings that drive 379
 subsequent problematic behaviours such as drug 380

381 misuse, alcohol abuse or excessive gambling. There
 382 have been 22 VR studies on substance disorders,
 383 with 15 concerning assessment, five treatment, and
 384 two theory development. The overwhelming majority
 385 of the studies have simply shown that appropriate
 386 VR environments can trigger cravings. Misuse of a
 387 range of substances has been studied, including alco-
 388 hol (e.g. Lee *et al.* 2008) and cocaine (e.g. Saladin
 389 *et al.* 2006). However, the majority of the work has con-
 390 cerned smoking (e.g. Bordnick *et al.* 2005) and it is evi-
 391 dent that VR environments can produce strong
 392 cravings for cigarettes (Pericot-Valverde *et al.* 2016).
 393 The elicitation of cravings means that VR has the
 394 potential to be successfully used in treatment, though
 395 this has not yet been rigorously demonstrated.
 396 Uncontrolled studies do indicate that VR might be
 397 able to help reduce cravings for cigarette smoking (e.
 398 g. Pericot-Valverde *et al.* 2014). Even crushing virtual
 399 cigarettes has been found to be helpful when added
 400 to standard treatment (Girard *et al.* 2009). For smoking
 401 cessation, a randomized controlled trial testing cogni-
 402 tive-behavioural therapy (CBT) with VR cue exposure
 403 is underway (Giovancarli *et al.* 2016).

404 *Eating disorders*

405 There are a number of obvious mechanistic targets for
 406 VR in the treatment of eating disorders: reducing food
 407 cravings, improving body image, and enhancing emo-
 408 tion regulation skills. A total of 18 empirical studies
 409 were identified, 10 concerning treatment, seven assess-
 410 ment, and one theory development. Despite an early
 411 use of VR for eating disorders (e.g. Riva, 1998), it has
 412 been recognized that the field has very few methodo-
 413 logically strong studies (Riva, 2011; Ferrer-García &
 414 Gutiérrez-Maldonado, 2012). Suitable VR environ-
 415 ments can bring on food cravings (e.g. Ferrer-García
 416 *et al.* 2015), with responses to VR food comparable
 417 with real food (Gorini *et al.* 2010), and there has even
 418 been an initial test of high-calorie food presented using
 419 augmented reality (Pallavicini *et al.* 2016). The prelimin-
 420 ary trial evidence is that VR techniques added to standard
 421 CBT help to improve body image (Riva *et al.* 2003; Cesa
 422 *et al.* 2013; Marco *et al.* 2013). In an intriguing VR experi-
 423 mental study, Keizer *et al.* (2016) helped patients with
 424 anorexia nervosa to experience ownership of a healthy-
 425 body mass index (BMI) body, which led afterwards, for
 426 at least 2 h, to a reduction in body size overestimation.
 427 New research on understanding the body ownership illu-
 428 sion in VR is likely to enhance eating disorder treatments
 429 (Normand *et al.* 2011; Maselli & Slater, 2013).

430 *Additional disorders*

431 VR could have potential uses in the understanding and
 432 treatment of sexual disorders concerning desire,

arousal and orgasm. This work has not been carried
 out. The literature search revealed four reports describ-
 ing a series of uncontrolled studies in which a form of
 psychodynamic therapy for erectile dysfunction or pre-
 mature ejaculation included a VR element (e.g. Optale
et al. 2003). Another notable area is sleep disorder,
 which is very common in the general population, but
 VR has not been used to study causes or treatments.
 Three studies have used a VR paradigm (road cross-
 ing) to assess the adverse effects of sleep disorders
 for the daytime safety of children (e.g. Avis *et al.* 2014).

444 **Discussion**

445 We conclude from the early studies that VR environ-
 446 ments can elicit psychiatric symptoms, manipulation
 of VR can inform the understanding of disorders,
 and simpler psychological treatments can be success-
 fully administered in VR. This is highly encouraging
 for the future application of VR to mental health.
 However, our inspection of the older literature warns
 that the technology of VR is not an answer in and of
 itself: the content delivered will matter for outcomes
 (e.g. Freeman *et al.* 2016; Reger *et al.* 2016). Across a
 breadth of disorders there are instances of real innova-
 tions in the interaction between the technology and
 insights into mental health problems. This has largely
 been unheralded, perhaps because the methodological
 quality has been limited and the potential for wider
 dissemination hitherto constrained. The studies have
 typically been small, negative results are less likely to
 have been reported, and, in most places, the literature
 has been distinctly piecemeal. Progress has been
 understandably slow because hardware and software
 have been expensive and expertise limited. This is
 about to change (Wiederhold, 2016).

466 The gaps in the literature are astonishingly large.
 467 This technology has simply not been applied enough
 468 to mental health. Psychiatric symptoms can be
 469 assessed in VR, but robust tests of reliability and valid-
 470 ity have been very few; compared with retrospective
 471 self-report, VR has the potential to prove a 'gold stand-
 472 ard' assessment method for many mental health prob-
 473 lems but this has not remotely been tested. VR has
 474 been used to develop the understanding of too few dis-
 475 orders, although even when used as an investigative
 476 tool it has principally been used to assess symptoms
 477 rather than provide firmer causal conclusions via
 478 manipulation tests (Cook & Campbell, 1979).
 479 Treatment trials have been small in size, rarely pre-
 480 registered, and seldom conducted to the standards
 481 now expected in clinical research. Of the range of treat-
 482 ment techniques available it is the simpler ones, such
 483 as exposure, that have been used. A therapist has
 484 nearly always still been engaged in the VR
 485

486 interventions. Numerous other important treatment
 487 techniques remain to be implemented in VR, especially
 488 for more complex disorders. There is an intriguing pro-
 489 gramme of research to be conducted concerning the
 490 degree to which therapies can be delivered without a
 491 therapist present for each type of presenting problem,
 492 and whether avatars can compensate for the important
 493 human presence fundamental to traditional psycho-
 494 logical interventions. Many common disorders, for
 495 example, depression, have barely received any VR
 496 research attention. VR also has obvious, but untested,
 497 use in psychiatric settings such as hospital wards or
 498 forensic units where contact with the outside world
 499 is highly restricted.

500 We believe that there are three overarching treat-
 501 ment questions that need to be addressed: (1) What
 502 is the best way to immerse individuals in VR so that
 503 learning most readily transfers to the real world, balan-
 504 cing the need to use affordable equipment? (2) Can key
 505 theory-driven psychological treatment techniques
 506 (beyond simple exposure) be successfully delivered in
 507 VR? (3) Do engaging, personalized, theory-driven
 508 treatments implemented in affordable VR, with limited
 509 use of clinicians, produce large real-world benefits for
 510 patients? This work will need to be carried out with the
 511 user experience put at the centre of design. Given its
 512 use in gaming, VR could be made a highly appealing
 513 treatment approach for patients. There is also the
 514 issue of how related technologies, notably augmented
 515 reality and wearable devices, could dovetail with the
 516 new approaches.

517 Our review offers, perhaps, a glimpse of the future
 518 of mental health care. It is, however, still relatively
 519 early days with VR for mental health: scenarios are
 520 limited, as is the degree of social interaction, for
 521 example conversation, that is possible. Specialist pro-
 522 gramming expertise is still required to create suitable
 523 environments that lead to presence. Simulator sickness
 524 may occur in poorly realized scenarios and systems.
 525 Multi-sensory presentation of stimuli is most likely to
 526 induce presence, but generalized touch feedback, that
 527 is tactile stimulation on any part of the body contin-
 528 gent on collision with a virtual object, is not feasible
 529 at present. The potential therapeutic power of body own-
 530 ership manipulation remains confined to specialist
 531 laboratories. But the technology is developing fast: these
 532 are likely to be short-term concerns. Psychological
 533 research and clinical practice have made huge strides in
 534 recent years too (Layard & Clark, 2015). We now have a
 535 much clearer picture of which therapeutic techniques
 536 are most effective, but suitably trained therapists are in
 537 short supply, and quality control remains a concern. VR
 538 and related technologies could help in solving this prob-
 539 lem, making the best therapy available to many more peo-
 540 ple. Yet the power of VR is such that it promises much

more than an improved delivery method for psycho- 541
 logical therapies. VR allows us to try things that are not 542
 easily practical in the real world. That means it could 543
 potentially generate the kind of results that even a course 544
 of standard treatment could not produce. ‘Revolutionary’ 545
 is an overused word; for VR and mental health care, it may 546
 actually be justified over the coming years. 547

Supplementary material 548

The supplementary material for this article can be 549
 found at <https://doi.org/10.1017/S003329171700040X> 550

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Declaration of Interest 558

Oxford VR is a University of Oxford spin-out company 559
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 Co-founders include D.F., M.S. and B.S. 561

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