LITERATURE REVIEW

Virtual reality in assessment and treatment of schizophrenia: a systematic review

Realidade virtual na avaliação e no tratamento da esquizofrenia: uma revisão sistemática

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ABSTRACT

Objective: To conduct a systematic review about the use of virtual reality (VR) for evaluation, treatment and/or rehabilitation of patients with schizophrenia, focused on: areas, fields and objectives; methodological issues; features of the VR used; viability and efficiency of this resource. **Methods:** Searches were performed about schizophrenia and virtual reality in PsycINFO, Academic Search Complete, MEDLINE Complete, CINAHL with Full Text, Web of Science and Business Source Premier databases, using the following keywords: ["schizophrenia"] AND ["virtual reality" OR "serious game"] AND ["treatment" OR "therapy" OR "rehabilitation"]. The search was carried out between November 2013 and June 2014 without using any search limiters. **Results:** A total of 101 papers were identified, and after the application of exclusion criteria, 33 papers remained. The studies analysed focused on the use of VR for the evaluation of cognitive, social, perceptual and sensory skills, and the vast majority were experimental studies, with virtual reality specifically created for them. All the reviewed papers point towards a reliable and safe use of VR for evaluating and treating cognitive and social deficits in patients with schizophrenia, with different results in terms of generalisation, motivation, assertiveness and task participation rate. Some problems were highlighted, such as its high cost and a constant need for software maintenance. **Conclusion:** The studies show that using the virtual reality may streamline traditional evaluation/rehabilitation programmes, allowing to enhance the results achieved, both in the cognitive and in the social field, helping for the legitimisation of this population's psycho-social inclusion.

Keywords
Schizophrenia, virtual reality, evaluation, rehabilitation, review.

RESUMO

Objetivo: Realizar uma revisão sistemática sobre a utilização da realidade virtual (RV) na avaliação, tratamento e/ou reabilitação de pessoas com esquizofrenia, enfocando: as áreas, domínios e objetivos; as questões metodológicas; as características da RV utilizada; a viabilidade e eficácia desse recurso. **Métodos:** Foram realizadas buscas por artigos sobre esquizofrenia e realidade virtual nas bases de dados PsycINFO, Academic Search Complete, MEDLINE Complete, CINAHL with Full Text, Web of Science e Business Source Premier, utilizando as palavras-chave: ["schizophrenia"] AND ["virtual reality" OR "serious game"] AND ["treatment" OR "therapy" OR "rehabilitation"]. A busca foi realizada entre novembro de 2013 e junho de

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2014, sem a utilização de limitadores de pesquisa. **Resultados:** Foram identificadas 101 publicações e, depois de aplicados critérios de exclusão, permaneceram 33 artigos. Os estudos analisados concentram-se no uso da RV para a avaliação de habilidades cognitivas, sociais e perceptossensoriais, sendo na ampla maioria estudos experimentais, com ambientes virtuais criados especificamente para os estudos. Todos os artigos revisados apontam para o uso fiável e seguro da RV na avaliação e tratamento de pessoas com esquizofrenia, com resultados diferenciados relativamente a generalização, motivação, assertividade e taxa de participação na realização de tarefas. Foram assinaladas dificuldades como alto custo e necessidade constante de manutenção de *software*. **Conclusão:** Ficou evidenciado que o recurso do ambiente virtual pode potencializar os programas de avaliação/reabilitação tradicionais, permitindo ampliar as dimensões dos resultados obtidos, tanto no âmbito cognitivo quanto no social, iluminando o caminho da legitimação da reinserção psicossocial dessa população.

Palavras-chave
Esquizofrenia, realidade virtual, avaliação, reabilitação, revisão.

INTRODUCTION

Sixty years ago, the only treatment alternative for patients with schizophrenia was confinement in mental hospitals, where most of them would remain for the rest of their lives. In 1952, the experimental use of chlorpromazine in psychiatric patients had excellent results in the remission of the psychotic symptoms of those patients, leading to the introduction of pharmacology applied to schizophrenia. Currently, second-generation or atypical anti-psychotic drugs are available which, apart from acting on the positive effects of schizophrenia, also have positive results in decreasing the negative symptoms of this pathology. This result had a direct impact on the optimisation of other interventions (*e.g.* psycho-social, cognitive), as well as on the reduction of the number of hospitalisations. However, for the inclusion and maintenance of this population in society, there was a need to improve the treatment techniques in order to solve some of the remaining negative symptoms (avolia, apathy, social isolation, disorganisation) which hinder the integration of patients with schizophrenia into the different occupational performance contexts (*e.g.* family, study, work)[1-4]. Therefore, in addition to symptom control, the treatment of schizophrenia started focusing on the improvement of this population's social participation through competent performance in daily activities.

Studies point out that the low occupational and social performance of these people is related to deficits in their cognitive (*e.g.* executive functions) and social skills (*e.g.* emotional recognition)[5,6]. Currently, cognitive impairment has been pointed out as a core characteristic of schizophrenia, which may be related to poor social relationships and to the inability to manage an independent life. Treatment and rehabilitation programmes for these skills have been developed, preferably through tasks in a lab environment, focusing on attaining some improvement in terms of psycho-social functioning and mood, and, to a larger extend, on the optimisation of psychiatric treatment[7,8]. Meanwhile, the therapeutic approach to schizophrenia has evolved in terms of the shape and contents of evaluation, treatment and rehabilitation programmes, as new techniques and technologies emerge. With the advent of information technology, software programs have been created and adapted to the evaluation and treatment of these people's symptoms and skills. Recently, studies reported the inclusion of virtual reality (VR) in programmes using for evaluating and training cognitive and social skills with promising results[9-13].

VR is a computer technology which enables immersion in complex environments that refer to reality through devices that transmit different types of stimuli, which are perceived by one or more senses of the user[14]. VR has three basic features: sense of presence, immersion and interaction. The sense of presence is the feeling of being present, as be a part of the virtual environment. Integrating the sense of presence, the immersion is the existence of sensory context, meaning that reality is experienced also by the sensory system (*e.g.* vision and hearing), creating the illusion of being in another place. VR can be classified as immersive or non-immersive due the sense of presence that provides. Multisensory devices like head-mounted display (HMD), trackers or electronic gloves are needed to capture the movements and behaviours to transport the user to the application domain, in an immersive experience. When shipping to the virtual world is in part provided through a window (*e.g.* a monitor), set up a non-immersive experience. This set generates the third central aspect of the RV, the interaction. It is related to the computer's ability to detect user actions and react in real time, responding to commands given by the user and altering the landscape. The creative possibilities are limitless, similar to the real world or merely synthetics, the virtual environments provide situations that are handled and safe for achieving results often impossible in a real context[14,15].

Since the first description of the use of VR applied to psychiatric disorders (acrophobia)[16], the results of the use of this resource have proven favourable and efficient for the treatment of the symptoms of some pathologies, such as anxiety disorders[17,18], eating disorders[19,20] and attention deficit disorder[21]. Regarding schizophrenia, published studies hi-

ghlight the efficacy of this resource, showing positive results in the evaluation and training of cognitive and social skills[22-29].

Recently, two literature review studies were published[30,31] regarding research performed using VR for evaluating and treating patients with schizophrenia, and the results point towards the use of VR in schizophrenia in three areas of intervention: cognitive, social, and perception/sensory deficits. They also reported the use of VR for creating symptom models (*e.g.* paranoia) with the aim of understanding the mechanisms of such manifestations in schizophrenia and also of contributing to creating safer and more efficient virtual realities specifically for this population. As a limitation of this resource, La Barbera *et al.*[31] point out the high cost of the technology and suggest that this barrier will be overcome as the price of materials and products for the use of VR tends to decrease with the growth of the information technology (IT) market.

When faced with a promising tool for the treatment of schizophrenia deficits, there is a need to summarise the knowledge obtained on the viability and reliability of the use of VR for the treatment of this population. This paper presents a systematic review on the use of VR for evaluating, treating and/or rehabilitating patients with schizophrenia, analysing: (1) areas, fields and objectives; (2) methodological issues; (3) characteristics of the VR used; (4) viability and efficiency of this tool.

METHODS

This study follows the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)[32].

Inclusion criteria

The inclusion criteria were the following: (1) the use of virtual reality for evaluating or treating schizophrenia symptoms, (2) with adult participants, (3) diagnosed with schizophrenia or schizoaffective disorder, (4) published in English.

Search method

The search was conducted on the papers indexed in the PsycINFO, Academic Search Complete, MEDLINE Complete, CINAHL with Full Text, Web of Science and Business Source Premier databases, using the following key words: ["schizophrenia"] AND ["virtual reality" OR "serious game"] AND ["treatment" OR "therapy" OR "rehabilitation"]. The search was carried out between November 2013 and June 2014, without using any search limiters. The references to each selected paper were checked for additional studies that could have been overlooked during the database search.

The eligibility of the studies was analysed independently by two reviewers and, whenever there was lack of consensus, a third author was consulted.

Data extraction

A table was created in order to extract the data, and a pilot test was conducted with 10 randomly selected studies, for stablish common criteria among reviewers. One author extracted the data included in the form: nature of the study; area, fields, objectives and focus; country of origin; demographic data, sample size, control group and evaluation tools; VR characteristics; evidence of VR viability and efficiency. The second author verified the extracted data. Potential discrepancies were discussed among the authors, who reviewed the papers together, and whenever consensus could not be reached, a third reviewer was consulted to analyse and clarify the issue.

RESULTS

Database search

A total of 101 papers were identified and, after excluding duplicate studies, 70 potentially relevant papers remained. Upon analysing the abstracts, 28 did not meet the inclusion criteria. After reading the 42 selected papers in full, nine studies were excluded, as shown in figure 1. One study[33], which used a sample of patients with early psychosis (50% diagnosed with schizophrenia and 50% with non-specific psychosis) was included by the reviewers since it covered important aspects related to the acceptability and safety of the use of VR. In total, 33 papers were analysed in this systematic review.

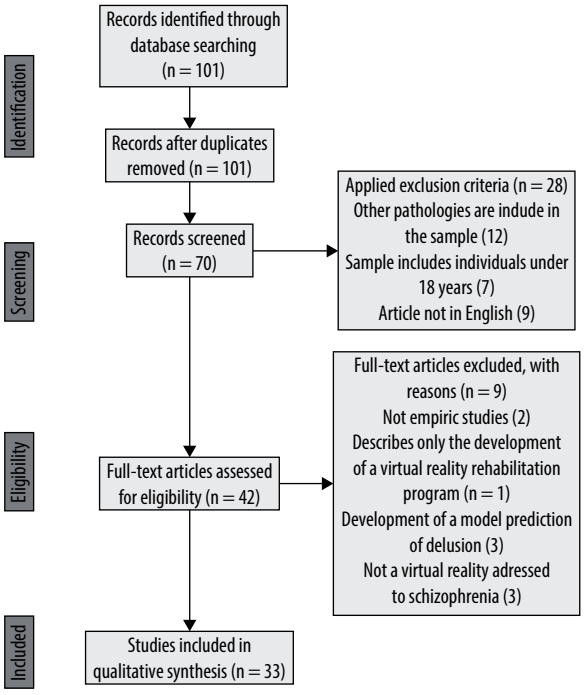

Figure 1. Flow diagram of the include process (template from PRISMA[32]).

Country of origin and number of papers per year

Regarding the country of origin, from the 33 studies analysed, 19 came from Asia, eight from Europe, five from North America and one from South America (Figure 2). The temporal distribution of papers is summarised in figure 3, where it can be seen that the first reported study dates back to 2003.

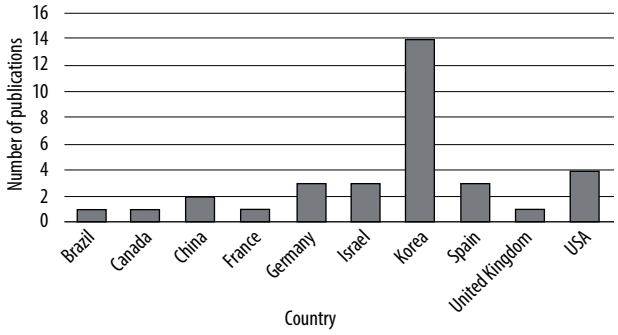

Figure 2. Publications by country.

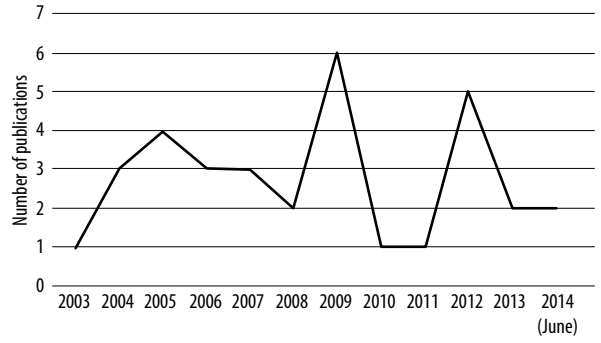

Figure 3. Number of publications by year.

Areas, fields and objectives

The studies reveal three areas (Table 1): cognitive, social, and perceptual/sensory areas, classified into two main fields, namely evaluation of skills and symptoms (n = 27) and skill training (n = 6).

Table 1. Summary of areas, domains and objectives of selected studies

Area	n	Domain	n	Objective	n
Cognitive	15	Evaluation	13	Executive functions	10
				Atention	5
				Spacial memory	4
				Visual memory	3
		Trainning	2	Cognitive skills	2
Social	14	Evaluation	10	Social interaction	5
				Social perception	3
				Emotional recognition	2
		Trainning	4	Social skills	3
				Comunication skills	1
Senso-perceptual	4	Evaluation	4	Reality perception	2
				Sense of perception	1
				Auditory hallucination	1
				Delusion	1

Characteristics of the sample and procedures

Participants were recruited at psychiatric units (outpatient and inpatient units), and the average number of participants in the experiments is 22 (SD = 10). A total of 24 studies included a control group, usually using a paired group with corresponding genders and ages. Considering all the studies, the age of the participants ranged from 28 to 66 years, which resulted in an average age of 31.5 years.

Regarding procedures, 26 were experimental studies and two were randomised controlled trials (RCT).

Evaluations and measurements

Positive and negative symptoms of schizophrenia were evaluated in 29 studies, and in 23 studies, these were evaluated with The Positive and Negative Syndrome Scale (PANSS), as listed in table 2. The feeling of presence was verified in five papers, using the Presence Questionnaire, and side effects related to the use of VR were evaluated in three studies using the Simulator Sickness Questionnaire (SSQ).

Characteristics of the virtual reality used

Most studies (62%) used virtual realities specifically designed for the experiments. The remaining studies resorted to commercially available programs or programs developed originally for other studies. Regarding the feeling of presence, 55% of the studies used a non-immersive interface.

VR viability and efficiency

The conclusions of all (100%) studies indicate that VR is a useful tool to evaluate and treat patients with schizophrenia, as shown in table 2. The results from the evaluations of cognitive, social, and perceptual and sensory skills supported by VR show significant correlations with the results obtained from evaluations with classic tools (*e.g.* WCST, SBS). In the six studies that used VR for training cognitive and social skills, there was an improvement in results and performance, when compared to training with classic programs (*e.g.* CRTT, RBANS, SSKT). Out of these six studies, four measured, from a subjective perspective, the usability of VR in the training program (Table 3).

The results of the two randomised trials are consistent, demonstrating an increase in the level of motivation, assertiveness and participation rate of individuals during the performance of the tasks proposed. In the vast majority of the studies (97%), subjects did not have side effects caused by the use of the technology. Three studies reported a possible interference of positive symptoms in task performance and two main limitations were reported regarding the technology: the high cost of software development and the need for constant technical support for the set up and maintenance of the process (n = 1).

Table 2. Results by area: I. Cognition; II. Social; III. Senso-perceptual abilities

Reference (year)	Country	Field	Objective	Type of study	Assessments and measurements	Total sample/CG [M age (SD)]	VR Programs	Presence	VR Usability, Feasibility and Safety in schizophrenia patients
I. Cognition Abilities									
Ku *et al.* (2003)[34]	Korea	A	EF	ES	EF: (WCST) Intelligence: (SPM)	13 patients [30(2.5)] 13 healthy controls [27.8(3.4)]	Virtual Environment based on WCST – designed for research	I	Parameters in VR correlate to WCST and SPM. This allows verifying how distracters influence cognitive skills. It also allows identifying perseverance behaviours that are specific to the pathology
Ku *et al.* (2004)[35]	Korea	A	EF	ES	EF: (WCST) Intelligence: (SPM)	15 patients [n.i.] 18 healthy controls [n.i]	Virtual Environment based on WCST – designed for research	I	Parameters in VR correlate to WCST and SPM. This allows verifying how distracters influence cognitive skills. It also allows identifying perseverance behaviours that are specific to the pathology
Costa and Carvalho (2004)[14]	Brazil	A	Cognitive Training Program	PS	Direct observation Questionnaire	4 patients [45.2(8.6)] No CG	Ambiente Virtual Integrado para Reabilitação Cognitiva (AVIRC)	I	The technology is safe and efficient for cognitive training. The immersive mode promotes greater attention and motivation by users
St. Germain and Kurtz (2004)[36]	USA	A	Attention Work Memory Visual Perception	ES	Number of erros	11 individuals [34.9(11.2)] 15 healthy controls [24,1(5,4)]	Virtual Driving Simulator	NI	The technology allows analysing the task of driving safely, in order to identify the driver's difficulties
Sorkin *et al.* (2005)[27]	Israel	A	Work Memory	ES	Symptoms: (PANSS) 26 parameters for subjects performance divided in 3 groups: work-memory and integration, navigation, strategy	39 patients [n.i.] 21 healthy controls matched by age	Virtual Maze – designed for research	I	VR allows collecting multiple metrics on complex behaviours, including multi-modal interactions (working memory), widening the spectrum of the cognitive evaluation. It improves the participant's motivation and attention
Sorkin *et al.* (2006)[37]	Israel	A	EF	ES	Symptoms: (PANSS) 26 parameters for subjects performance divided in 3 groups: work-memory & integration, navigation & strategy	39 patients [32.3(7.9)] 21 healthy controls matched by age	Virtual Environment based on WCST – designed for research	I	VR allows collecting multiple metrics on complex behaviours, including multi-modal interactions (working memory), widening the spectrum of the cognitive evaluation. It improves the participant's motivation and attention
Baker *et al.* (2006)[22]	USA	A	Medication Compliance Behavior	ES	Attention: (CPT) Cognition: (SCT) Memory (HVLT-R) Symptoms: (PANSS) Number of errors Time discrepancy Number of clock/reminder checks	25 participants [n.i.] No CG	Virtual Apartment – designed for research	NI	It enables ecological assessment. It demonstrates predictive power over adherence to medication. It has major potential in the field of evaluation of cognitive skills
Kurtz *et al.* (2007)[38]	USA	A	Medication Management Skills	PS	Attention: (CPT) Cognition: (SCT) Memory: Test (HVLT) Medication Management Ability Assessment (MMAA) Symptoms: (PANSS) Number of errors (quantitative and qualitative) Time discrepancy Total distance travelled	25 patients [42.1(10.5)] 18 healthy controls [39.1(11)]	Virtual Reality Apartment Medication Management Ability Assessment (VRAMMA)	NI	The technology is well tolerated and efficient for the evaluation of cognitive skills. It allows simulating a multi-modal environment, in order to recruit a range of neurocognitive a sensory-motor skills
Weniger and Irle (2008)[39]	Germany	A	Spatial Memory	ES	Intelligence: (WAIS-R) Memory: (WMS-R) Outcomes: (CGI), (GAF) Symptoms: (SANS), (SAPS) Number of errors Questionnaire about navigation strategies	25 inpatients [30(10)] 25 healthy controls [32(10)]	Park and Virtual Maze – design for research	NI	It is an adequate, practical and cost-efficient technology for evaluating spatial capacity. It does not cause side effects

Reference (year)	Country	Field	Objective	Type of study	Assessments and measurements	Total sample/CG [M age (SD)]	VR Programs	Presence	VR Usability, Feasibility and Safety in schizophrenia patients
Josman *et al*. (2009)[40]	Israel	A	EF	ES	EF: (BADS) Symptoms: (PANSS)	30 individuals [46.7(10.5)] 30 healthy controls [47.7(12.4)]	Virtual Action Plan-Supermarket (VAP-S)	NI	It is an ecologically valid technology for EF evaluation tools. It enables the inclusion of independence and participation measurements, according to WHO recommendations
Chan *et al*. (2009)[23]	China	T	Attention Memory Orientation	ES	Cognition: (Cognistat) Side effects: (SSQ) Volition: (VQ)	12 individuals [66.4(6.2)] 15 individuals schizophrenia disorder [65.8(5.5)]	VR Program adapted from IREX® - Interactive Rehabilitation Exercise System	NI	It is efficient in cognitive functioning and volition training. It does not cause side effects
Han *et al*. (2012)[41]	Korea	A	EF – Cognitive flexibility	ES	Intelligence: (K-WAIS) Sense of Presence: (ITQ), (PQ), (VRQ) Social Problem Solving: (SPSI) Symptoms: (PANSS)	30 patients [30(4.9)] 30 healthy controls [29.5(4.9)]	Virtual Environment designed for research	NI	It allows for safe evaluation, through stimuli, in environments similar to reality, with the advantage of not being limited time or space
Spieker *et al*. (2012)[10]	USA	A	Spatial Learning Spatial Memory	ES	Cognition: (RBANS) Symptoms: (BPRS), (SANS)	33 outpatients [40 (11.9)] 39 healthy controls [40.5(11.4)]	Radial Arm Maze (RAM) adapted for a virtual environment	NI	The VR paradigm can provide information on the effects of cognitive training on the improvement of the pre-frontal cortex and hippocampus functions
Tsang and Man (2013)[26]	China	T	Attention Memory EF	RCT	Attention: (DVT) Cognition: (BNCE), (VCRS) EF: (WCST) Memory: (RBMT) Self-designed checklist - sales performance Self-efficacy performance scale	25 inpatients [39.6(7.9)] 50 inpatients TAG (n=25) [40.7(9.1)]; CG (n=25) [41.56(9.9)]	Virtual Reality-Based Vocational Training System (VRVTS)	NI	It enables the restoration of cognitive skills and enhances vocational training. The technology requires constant technical support and side effect monitoring
Zawadzki *et al*. (2013)[42]	Canada	A	Spatial Learning Spatial Memory	ES	Cognition: (RBANS) Intelligence: (K-WAIS) Quality of life: (QLS) Symptoms: (SAPS)	33 outpatients [40 (10.9)] 39 healthy controls [43 (11.3)]	Virtual Environment designed for research	NI	The results obtained at VR environment are correlated with classical assessments (*e.g.* Repeatable Battery for the Assessment of Neuropsychological Status). The using of naturalistic virtual environment is supported as a measure of cognitive functioning
II. Social Abilities									
Kim *et al*. (2005)[43]	Korea	A	Social Perception	ES	Intelligence: (K-WAIS) Sense of Presence: (ITQ), (PQ), (VRQ) Symptoms: (PANSS) Verbal/non-verbal social cue Happy/sad/angry situation Emotional recognition Interpretation of relevant cue	17 inpatients [30.4(5.3)] 17 healthy controls [30.05(6)]	Virtual Reality Behavior & Facial Data Base (VRBFDB)	NI	The application of the evaluation in virtual mode is faster and easier, and it also allows to quickly change facial parameters, thereby creating variability in the interactions proposed
Jang (2005)[44]	Korea	A	Social Interaction Social Anxiety	ES	Anxiety: (SAQ)	15 inpatients [28.6(7)] 15 healthy controls [25.1(1.5)]	Virtual environment designed for research	I	VR technology (ecological model) is a safe option for experimenting emotions in induced social situations and can be used for coping training in a safe environment
Ku *et al*. (2005)[45]	Korea	A	Social Interaction	ES	Symptoms: (PANSS) Interpersonal distance Verbal response time	11 inpatients [29.5(8.9)] No CG	Virtual environment designed for research	NI	The technology allows social interaction responses that are similar to those of a real context
Ku *et al*. (2006)[46]	Korea	A	Social Interaction	PS	Symptoms: (PANSS) Interpersonal distance Verbal response time	11 inpatients [29.5(8.9)] No CG	Virtual environment designed for research	NI	The technology allows social interaction responses that are similar to those of a real context

Continuation

Reference (year)	Country	Field	Objective	Type of study	Assessments and measurements	Total sample/CG [M age (SD)]	VR Programs	Presence	VR Usability, Feasibility and Safety in schizophrenia patients
Kim *et al*. (2007)[47]	Korea	A	Social Perception	ES	Intelligence: (K-WAIS) Sense of Presence: (ITQ), (PQ), (VRQ) Symptoms: (PANSS) Verbal/non-verbal social cue Happy/sad/angry situation Emotional recognition Interpretation of relevant cue	30 inpatients [29.6(4.9)] 30 healthy controls [29.5(5.3)]	Virtual environment designed for research	NI	It is a potential tool for evaluating social perception, problem solving ability and assertiveness skills, as well as for training social skills
Ku *et al*. (2007)[28]	Korea	T	Conversational Skills	ES	Symptoms: (PANSS) Verbal response time Questionnaire about general options, usability and presence	10 patients [28.8(9)] No CG	Virtual environment designed for research	I	It is an efficient technique for conversation training. It provides objective clinical metrics. Its application can be limited by pathology-specific conditions (negative symptoms)
Park *et al*. (2009)[11]	Korea	A	Emotional Perception Emotional Response	ES	Anxiety: (STAI-Y) Intelligence: (RPM) Symptoms: (PANAS), (PANSS), (PSAS), (SAS)	27 individuals [28.5(5.7)] 27 healthy controls [26.5(4.4)]	Virtual environment designed for research	I	It is an efficient technique for evaluating social cognition. The experience causes joy, interest and emotional confrontation
Park *et al*. (2009)[48]	Korea	A	Social Interaction – Spatial Behavior	ES	Symptoms: (PANSS) Distance from a virtual person Orientation head angle	30 individuals [28.7(5.5)] 30 healthy controls [26.3(4.3)]	Virtual environment designed for research	I	It is a safe alternative for verifying interpersonal space
Park *et al*. (2009)[49]	Korea	A	Social Interaction	PS	Clinical: (BARS), (SARS) Social Functioning: (SBS), (RCS) Symptoms: (PANAS) (PANSS)	18 female Aripiprazole group (n = 10) [30.2(7.7)]; Risperidone group (n = 8) [29.3(6.8)] 15 healthy female [28.1(8)]	Virtual Reality Functional Skills Assessment (VRFSA)	I	It is a valid tool to measure functional skills
Dyck *et al*. (2010)[6]	Germany	A	Emotional Recognition	ES	Intelligence: (MWT-B) Symptoms: (PANAS), (PANSS) Questionnaire of computer game experience	20 patients [36.7(1.9)] 20 healthy controls [36.9(2.2)]	Virtual faces	I	It allows controlling animation and changing parameters in real time, which increases the number of observation/research options
Park *et al*. (2011)[24]	Korea	T	Social Skills	RCT	Symptoms: (PANSS) Social Functioning: (AI),(SBS), (RAS), (RCS), (SPSI-R), (SST) Questionnaire of VR experience	33 inpatients [28.1(7.7)] 31 inpatients with schizophrenia disorder [31.2(7.7)]	VR role-playing (SST-VR)	I	It can be applied to conversation and assertiveness skill training; however, it is less effective for non-verbal skills. It allows enhancing motivation. Its usage is limited, due to the fact that it is expensive
Gutiérrez-Maldonado *et al*. (2012)[29]	Spain	A	Facial Recognition	ES	Attention: (CPT), Symptom: (PANSS), (SCIP), (TAS-20)	30 outpatients [n.i.] No CG	Virtual faces	NI	It is a useful tool for evaluating emotion recognition. Its dynamic nature improves accuracy in recognising facial expressions
Rus-Calafell *et al*. (2012)[25]	Spain	T	Social Skills	CS	Anxiety: (SADS) Social Functioning: (AI), (SFS) Symptom: (PANSS)	1 woman [30 year old] No CG	SOSKITRAIN - VR	NI	It allows strengthening other treatment approaches in an individualised manner and it presents a larger degree of generalisation of the gains obtained
Rus-Calafell *et al*. (2014)[8]	Spain	T	Social Skills	PS	Anxiety: (SADS) Social Functioning: (AI), (SFS), (SSIT) Symptom: (PANSS)	12 participants [36.5(6)] No CG	SOSKITRAIN - VR	NI	It enables treating patients who refuse to participate in group therapy; it is an ecological tool; it allows practising skills in specific social interactions; it allows for direct, real-time observation of social behaviours

Continuation

Reference (year)	Country	Field	Objective	Type of study	Assessments and measurements	Total sample/CG [M age (SD)]	VR Programs	Presence	VR Usability, Feasibility and Safety in schizophrenia patients
III. Senso-Perceptual Abilities									
Fornells-Ambrojo *et al.* (2008)[33]	UK	A	Safety and Feasibility of Using VR Sense of Presence Delusion in VR	ES	Anxiety: (STAI) Intelligence: (WTAR) Sense of presence: (SPQ) Side Effects: (SSQ) Symptom: (PANSS), (G-PTS), (SSPS) VR semi structured interview	22 participants with early psychosis [23.5(3.1)] 20 non clinical group [25.5(4.4)]	VE designed for research	I	VE can be used safely in people with persecutory delusions
Lallart *et al.* (2009)[50]	France	A	Sense of Presence	ES	Sense of Presence: (PQ) Symptom: (PANSS)	19 individuals [33.3(8.2)] 19 healthy controls [32.6(8)]	VE designed for research	I	VR tests can safely contribute to evaluating agency deficit
Han *et al.* (2012)[51]	Korea	A	Auditory Hallucination	ES	Cognitive Ability: (RPM) Sense of presence: (PQ), (VREQ) Side Effects: (SSQ) Symptom: (PANSS), (BAS), (SARS)	36 patients [28.9(6)] 20 healthy controls matched by age	VE designed for research	I	VR is particularly valuable in supplying objective parameters for evaluating behavioural characteristics
Moritz *et al.* (2014)[52]	Germany	A	Delusion	ES	Symptom: (PANSS), (POD)	33 in-out patients [40.5 (9.9)] No CG	VE designed for research	NI	VE was safe and efficient in the evaluation of paranoid symptoms. It does not have side effects

Note 1: ID: Identification; A: Assessment; T: Training; CS: Case Study; ES: Experimental Study; PS: Pilot Study; RCT: Randomized Control Trial; I: Immersive; NI: No Immersive; CG: Control Group.
EF: Executive Functions; (AI): Assertion Inventory; (BARS): Barnes Akathisia Rating Scale; (BAS): Barnes Akathisia Scale; (BADS): Behavioral Assessment of Dysexecutive Syndrome; (BNCE): Brief Neuropsychological Cognitive Examination; (BPRS): Brief Psychiatric Rating Scale; (CGI): Clinical Global Impression Scale; (CPT): Continuous Performance Test; (DVT): Digit Vigilance Test; (GAF): Global Assessment of Functioning Scale; (G-PTS): Green *et al.* Paranoid Thoughts Scales; (HVLT-R): Hopkins verbal learning test; (ITQ): Immersive Tendency questionnaire; (K-WAIS): Coreia do Suln-Wechsler Adult Intelligence Scale; (MMAA): Medication Management Ability Assessment; (MWT-B): Mehrfachwahl Wortschatz Intelligenztest; (PSAS): Physical and Social Anhedonia Scale; (PANAS): Positive and Negative Affective Schedule; (PANSS): Positive and Negative Syndrome Scale; (PO): Paranoia, Obsessive-compulsive and Depression Questionnaire; (PQ): Presence Questionnaire; (QLS): Quality of Life Scale; (RAS): Rathus Assertiveness Schedule; (RCS): Relationship Change Scale; (RPM): Raven's Progressive matrices; (RCS): Relationship Change Scale; (RBANS): Repeat Battery for the Assessment of Neuropsychological Status; (RBMT): Rivermead Behavioral Memory Test; (SANS): Scale for the Assessment of Negative Symptoms; (SAPS): Scale for the Assessment of Positive Symptoms; (SAS): Schizotypal Ambivalence Scale; (SCIP): Screen for Cognitive Impairment in Psychiatry; (SPQ): Sense of Presence Questionnaire; (SCT): Short Category Test; (SARS): Simpson Angus Rating Scale; (SSQ): Simulator Sickness Questionnaire; (SADS): Social Anxiety and Distress Scale; (SAQ): Social Anxiety Quest; (SBS): Social Behavior Scale; (SFS): Social Functioning Scale; (SPSI): Social Problem Solving Inventory; (SSIT): Simulated Social Interaction Test; (SST): Social Skill Training; (STAI): Spielberg State-Trait Inventory; (SPM): Standard Progressive Matrices; (SSPS): State Social Paranoia Scale; (STAI-Y): State-Trait Anxiety Inventory-Form Y; (TAS-20): Toronto Alexithymia Scale; (VAP-S): Virtual Action Plan-Supermarket; VE: Virtual Environment; (VREQ): Virtual Reality Experience Questionnaire; (VRFSA): Virtual Reality Functional Skills Assessment; (VRQ): Virtual Reality Questionnaire; (VCRS): Vocational Cognitive Rating Scale; (WAIS-R): Wechsler Adult Intelligence Scale-Revised; (WMS-R): Wechsler Memory Scale-Revised; (WCST): Wisconsin Card Sorting Test.

Table 3. VR Usability in training abilities (subjective perspective)

Study	VR issue	Assessment/Measuremnt	Results Mean (Standard Deviation) [Range]
Ku *et al.* (2007)[28]	Usefulness	Questionnaire	6.3 (±1.6) [0-10]
Ku *et al.* (2007)[28]	Interest	Questionnaire	7.3 (±2) [0-10]
Park *et al.* (2011)[24]	Interest	Interest-in-Participation Questionnaire	81.5 (±10) [0-100]
Ku *et al.* (2007)[28]	Volition	Questionnaire	7.5 (±2.7) [0-10]
Chan *et al.* (2009)[23]	Volition	Volition Questionnaire	26.8 (±4.8) [15-56]
Russ-Callafel *et al.* (2014)[8]	Satisfaction	Satisfaction Questionnaire	8.7 (±0.3) [0-10]
Russ-Callafel *et al.* (2014)[8]	Acceptance	Satisfaction Questionnaire	9.2 (±0.7) [0-10]

DISCUSSION

A variety of programs was found for evaluating and treating schizophrenia symptoms (*e.g.* paranoia, cognitive and social deficits) which used VR with different features and specificities. There seems to be a consensus regarding the viability of applying this technology in patients with schizophrenia, and that confirms Freeman's[53] prognosis, which highlighted this resource as a new paradigm for the study and treatment of schizophrenia. VR tends to overcome some of the limitations in terms of evaluation and treatment of cognitive and social skills, providing a natural environment which is very close to the real context. This seems to be the major difference of VR – the feeling of presence (immersion) – that allows subjects to perceive the environment as if it were real. However, it appears to allow a safer experience than in a real setting, namely regarding emotional issues, such as frustration when faced with failures and mistakes[24,26,41-46]. This tool also allows

using and monitoring the performance of complex tasks in a dynamic manner, enabling real-time changing of parameters by therapist. Assessments or programs based on virtual environments overcome the limitations of data obtained in laboratory settings, allowing real-time interventions in a simulated context, with strong ecological validity inasmuch as they greatly resemble everyday functioning[54,55]. Those virtual environments features allow to reproduce the real-world challenges in VR. In agreement with this, Emmelkamp *et al.*[18] developed a study with 33 acrophobic participants (16 exposures *in vivo* and 17 with VR), aiming to evaluate the effectiveness of virtual reality (VR) exposure versus exposure *in vivo*, using virtual environments exactly copied from the real settings used in the exposure *in vivo* platform. The authors concluded that the VR treatment was as effective as exposure *in vivo* in combating anxiety and avoidance. Additionally, Tsang and Man[26] reported similar results in a randomized study aiming to investigate the efficacy and effectiveness of VR as a cognitive intervention for enhancing vocational outcomes. Seventy five schizophrenia patients [25 VR group (VRG), 25 therapist administered group (TAG) and 25 conventional group] participated in vocational training, where contents of VRG and TAG were the same, just differing in training mode. Participants of VRG and TAG showed a significant improvement in cognition, although VRG showed better performance in Wisconsin Card Sorting Test (WCST) than TAG. This comfortable and motivating scenario, in which patients may face challenges as if they were actually in the real context, thus feeling safe, can also explain the promising result generalisation rates, revealing the potentialities of this promising ecological tool for the evaluating and rehabilitating of patients with schizophrenia[11].

Twelve years have passed since the first experiment with the use of VR in schizophrenia. Despite all the positive facts concerning the use of this technology in the evaluation and treatment of schizophrenia, there are a few number of publications per year. It can be explained by the high cost and complexity of the tool[24,26], however, as mentioned by La Barbera *et al.*[31], this is a market in highly development, which tends to substantiate the facilitation in the access to inputs and technology, and, consequently, enable further researches in this area.

The first researchers group that published studies about VR environments addressed to people with schizophrenia is from Korea[34]. They have published the largest number of studies to date, particularly related to social skills. Nonetheless, is possible to notice an increasing interest from Spanish, Chinese and Canadian groups, to develop pilot studies and randomized trials using VR on training social and cognitive skills programs, contributing to the importance of this tool in the treatment of schizophrenia.

Regarding methodology, the analysis of the selected studies revealed that most of them are experimental studies, with small samples, basically focused on the usability of VR for the evaluation of symptoms and skills (cognitive, social, and perceptual and sensory) of patients with schizophrenia. Studies[35,42] that proposed adapting classic evaluation tasks such as WCST and RBANS to the virtual platform obtained results which correlated positively with those obtained using the classic method. Meanwhile, the technology allowed going beyond the fields established in conventional evaluations, and the immersive environment seems to provide a multidimensional response to the tasks proposed, allowing to observe behaviours that are intrinsic to the pathology. The small number of controlled trials covering the efficiency of the VR programme in the training of cognitive and social skills made impossible to statistically compare the results obtained. It is expected that, in the near future, a larger number of randomised trials with more robust samples is conducted, because the results of the experimental studies so far advocate and encourage this new approach to treatment.

Regarding the virtual environments used in the studies under analysis, a wide diversity of scenarios, specifically designed for each study, was observed, which justifies an experimental stage in the introduction of the VR tool in the treatment of schizophrenia. This situation may interfere in the reproducibility of the studies, due to the complexity of the technology, and this may precisely be the explanation for the difficulties found in the development, replication and validation of VR-based programs. However, studies were found regarding the design, development and application of seven virtual reality programmes applied to schizophrenia: five programs designed for skill training (AVIRC[14], VRAMMA[38], VAP-S[40], VRVTS[26], SOSKITRAIN-VR[8]) and two for skill evaluation (VEBFDB[43], VEFSA[49]). All authors reported an improvement in the trained skills, as well as greater efficiency and user interest and motivation in the use VR, although these studies reveal obstacles to the technology, such as its high cost and a frequent need for maintenance. Results also show that VR computer programmes can outperform classic computer programs[7] and increase the gains obtained from cognitive and social remediation, by allowing to train skills in environments that can be customised to each user[56]. Therefore, it can be assumed that VR-based skill rehabilitation can also entail gains in the psycho-social performance of this population.

Despite the highlighted potential, experiments with this technology in schizophrenia are recent, when compared to those conducted for other psychiatric disorders. Perhaps the uniqueness of the positive symptoms of this disorder may have been a cause for doubts on the safe use of this tool, leading to the postponement of experimental studies with this population. However, studies[33,50-52] show that VR does not interfere in the worsening of paranoid delusions and that, quite the contrary, it may be a useful tool for understanding and treating those symptoms. Therefore, results from experiments point towards the possibility of setting parameters

related to behaviours that are specific to patients with schizophrenia[37], which may be important for a better understanding of the behavioural responses of these patients and, consequently, for the development of specific programmes for the treatment of schizophrenia.

Even though problems such as its high cost and the constant need for maintenance were highlighted in this review, other pathologies (*e.g.* phobias) have been widely treated with this technology[57-59], showing that its benefits may overcome such potential obstacles. This paper stresses the need for strengthening partnerships between psychological and technological research teams, in order to solve problems, such as technical support, software cost and maintenance, which could speed up the development of new programmes, possibly more efficient, due to the potential they present for treatment teams, allowing to streamline the attainment of intervention goals in schizophrenia. These programmes may contribute to the inclusion of this population into its social and labour contexts in a competent and significant manner.

CONCLUSION

This study highlights the benefits of VR for the evaluation, treatment and skill training of patients with schizophrenia, showing that this tool has the potential to become a new effective way of treating the symptoms and deficits experienced by this population. However, it is important to highlight that VR is a complementary tool, which can integrate programs consisting of other therapeutic approaches. This device gives the therapist not only a new instrument, but ascribes an active role in prescription and customization of approaches tailored to the user's needs and context of daily living, as well as in terms of stimulus presentation, monitoring and adjusting the process according to need and developments in. The results suggested to conduct randomised and follow-up multicentre trials, comprising larger samples that will allow to obtain more consistent data regarding the improvement of the skills trained, as well as to validate and perform the meta-analysis of the results, confirming the evidence on the use of VR to assess and treat schizophrenia. This technology also appears to allow a more efficient generalisation of the gains achieved, which may enable a better perception of their improvement by the patients themselves, a factor which is intrinsically related to quality of life[60]. It is important that efforts are made so that research continues in this area, namely through consortia between psychology labs and information technology labs, as VR seems to allow patients with schizophrenia to be exposed to challenges in a safe and efficient way, so that they can overcome their difficulties and thus have an efficient social participation.

INDIVIDUAL CONTRIBUTIONS

Mônica Macedo – Contributed in the conception and design of the study, in the analysis and interpretation of the data, in the drafting of the article, and completed and approved the written version for publication.

António Marques – Contributed in the conception and design of the study, in the analysis and interpretation of the data, in the revision of the article, and approved the final version for publication.

Cristina Queirós – Contributed in the analysis and interpretation of the data, in the revision of the article, and approved the final version for publication.

AUTHOR DISCLOSURE STATEMENT

No competing financial interests exist.

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