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Emotion recognition training with virtual reality in schizophrenia: A case series study

David Alejandro Pérez-Ferrara[1], Jesús Luna-Padilla[2], Daniela Ramos-Mastache[2], Kevin Miranda-Romo[2], Jocelyn Peña-Fernández[2], Alejandra Mondragón-Maya[2*]

[1]Facultad de Psicología, Universidad Nacional Autónoma de México, Ciudad de México, 04510, México.
[2]Facultad de Estudios Superiores Iztacala, Universidad Nacional Autónoma de México, Estado de México, 54090, México.

Corresponding author: Alejandra Mondragón-Maya (*Email: ale.mondragon@comunidad.unam.mx*)

Abstract

The purpose of the study was to assess the tolerability and acceptability, and to explore the preliminary efficacy of an 8-session emotion-recognition training using virtual reality (VR-ER) through the software VR-Tóol in three patients within the schizophrenia spectrum. Methodology: A single case AB design was employed. Prior to the intervention, three emotion recognition (ER) baseline measurements were collected, and three additional measurements were obtained during the intervention. Pre- and post-intervention measures of ER, symptomatology, neurocognition, apathy, depression, and functionality were obtained by independent researchers. For quantitative analysis of the baseline measures, the Conservative Dual-Criterion method, two-standard deviation band, and Non-overlap of all Pairs were employed. For the pre- and post-intervention measures, the reliable change index was used. Findings: None to minimal cybersickness symptoms were observed during the intervention. Patients reported motivation toward the intervention and good levels of perceived effectiveness. Regarding the intervention efficacy, we found clinical changes in ER, neurocognition, and functionality. Conclusions: The present study offers preliminary evidence of the acceptability and efficacy of a targeted VR-ER intervention in patients within the schizophrenia spectrum. Practical implications: These findings underscore the practical efficacy of virtual reality in social cognition interventions. VR-Tóol is a promising technological tool that has the potential to serve as a rehabilitation aid for sociocognitive processes in psychiatric conditions, such as schizophrenia.

Keywords: Case series study, Cognitive remediation, Emotion recognition, Schizophrenia, Virtual reality.

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1. Introduction

The capacity to recognize emotions in others is a foundational process that enables the development of social interactions. Emotion recognition (ER) has been defined as the ability to perceive and comprehend the emotional state of another individual based on a series of social cues, including facial expressions, body language, and prosody [1, 2]. It has been demonstrated that ER is impaired in numerous disorders. Among the most extensively studied are autism spectrum disorder and schizophrenia spectrum disorders. Schizophrenia is a major psychiatric disorder characterized by positive (i.e., hallucinations, delusions and disorganized speech and motor behavior), negative (i.e., emotional flattening, apathy, alogia), and cognitive symptoms [3, 4]. Deficits in neurocognition and social cognition have been demonstrated to be positively correlated with difficulties in functionality and quality of life [5]. The most consistently observed alterations in social cognition processes in patients with schizophrenia are those related to ER and theory of mind [6]. Social cognition deficits may contribute to difficulties in social interactions and an increased likelihood of social stress and isolation/loneliness. Therefore, interventions aimed at improving these skills are essential in the treatment of psychotic disorders, like schizophrenia.

1.1. ER in Schizophrenia Spectrum Disorders

The recognition of facial emotions requires the involvement of various processes and networks. These encompass not only the early perceptual processes but also the affective processes (i.e., valence and arousal) and the semantic categorization of facial expressions [7]. Face ER is associated with increased activation in limbic regions (i.e., amygdala, parahippocampal gyrus, and posterior cingulate cortex), inferior frontal gyrus, medial prefrontal gyrus and putamen [6].

A substantial body of research has demonstrated that individuals diagnosed with schizophrenia tend to exhibit poorer performance on tasks designed to assess their ability to recognize emotions, when compared to individuals without schizophrenia [6]. In particular, it has been reported that patients with schizophrenia have greater difficulty in identifying emotions with negative valence and faces with neutral expressions, compared to emotions with positive valence [8]. Neuroimaging studies have revealed a consistent decreased activation of the fusiform gyrus, left amygdala, anterior cingulate cortex, medial prefrontal cortex, and thalamus in patients with schizophrenia during affective face perception. In contrast, the insula, cuneus, parietal lobule, and superior temporal gyrus exhibit increased activation [6, 9]. Furthermore, consistent alterations have been identified in studies employing event-related potentials during the perception of emotional facial expressions, particularly in the N170 and N250 components [10].

Evidence suggests ER deficits are present in individuals at ultra-high risk for psychosis Tsui, et al. [11] relatives of patients with schizophrenia [12] and individuals with schizotypy [2]. A meta-analysis conducted by Murrihy, et al. [13] revealed a significant yet small effect between ER and social functioning, highlighting that deficits in ER have meaningful implications for real-world social interactions. Additionally, the analysis identified that the intensity of positive, negative, and disorganized symptoms partially mediated such relationship. Thus, it is imperative that early ER interventions be considered as a standard practice in the clinical management of individuals with schizophrenia spectrum disorders.

1.2. ER Interventions in Schizophrenia

A broad range of ER interventions have been employed in the treatment of patients diagnosed with schizophrenia. Some of these programs employ bottom-up techniques, such as training participants to direct their attention (attentional shaping) to relevant regions of the face to recognize emotions, mimicry, or role-playing. Other ER training programs, such as Training Affect Recognition [14] or Reading a Smile [15] have focused on integrating tasks to enhance ER in a dynamic context (e.g., short videos, speeches, situations), as well as integrating bottom-up strategies (e.g., attentional shaping, errorless learning, repetition) with top-down strategies (e.g., metacognitive strategies, self-monitoring, self-instructions) to facilitate learning and generalization [16].

Regarding efficacy, studies have demonstrated that ER interventions yield moderate to large effect sizes on measures of ER. However, this effect is less consistent on general measures of functioning and social functioning [17-19]. It has been suggested that the generalizability of the benefits obtained from ER interventions may be limited. This may be attributed to the fact that a significant number of studies have concentrated exclusively on the six basic emotions, despite a substantial body of literature indicating the existence of a broader array of emotions that serve adaptive functions and are accompanied by specific facial expressions [7, 18, 20]. Furthermore, the facial expressions utilized are isolated from social contexts. Context has been demonstrated to play an inherent role in the processing of facial expressions [7, 20, 21]. Additionally, most studies fail to consider dynamic contexts and the numerous cues that could potentially modulate ER. Indeed, there is evidence that neural responses are significantly enhanced when individuals are presented with dynamic, intricate, and naturalistic stimuli as opposed to artificial and simplistic stimuli [7].

1.3. ER Interventions with Virtual Reality (VR)

VR has been defined as a form of advanced human-computer interaction that enables naturalistic interaction with virtual environments and characters. It entails the real-time stimulation and interaction of an embedded subject through multiple sensory channels [22, 23]. VR allows the immersion of participants in virtual environments that would facilitate obtaining valid results in real-lifelike scenarios [24].

The utilization of VR in the context of ER interventions for patients diagnosed with schizophrenia has yet to be extensively investigated. In a scoping review conducted by our research group [25] five social cognition training programs with VR were identified, four of which included ER. The studies were heterogeneous regarding the type of intervention (i.e., targeted, integrative, and broad-based) and the methodological approach employed. Given the heterogeneity and the limited number of studies, no definitive conclusions could be drawn about their efficacy. Three studies reported an improvement in tasks assessing ER after the intervention [26-28]. However, a randomized clinical trial did not demonstrate a significant improvement in ER skills [18]. Notwithstanding these developments, virtual reality emotional recognition (VR-ER) interventions continue to exhibit some of the constraints observed in conventional methodologies. Most of the interventions analyzed exclusively on the six basic emotions, with no consideration given to postural movements. In light of the aforementioned considerations, the objectives of this pilot study were: 1) to assess the tolerability and acceptability and 2) to assess the preliminary efficacy of a VR-ER intervention program denominated *VR-Tóol* in three patients within the schizophrenia spectrum. These objectives will provide valuable information in identifying some technical and practical aspects that can be improved for further research using *VR-Tó*ol in the clinical context.

2. Materials and Methods

The study employed a single-case experimental design (A-B). Inclusion criteria were as follows: participants were required to be diagnosed within the schizophrenia spectrum, regardless of gender, who had completed at least six years of formal education, were undergoing pharmacological treatment, and expressed willingness to participate. Individuals with neurological disorders (e.g., epilepsy, traumatic brain injury) or significant non-corrected sensory disabilities were excluded from participation. Moreover, the elimination criteria encompassed any participants exhibiting discomfort associated with the utilization of VR, including, but not limited to, dizziness, vertigo, and cybersickness. No significant cybersickness symptoms were observed, therefore no participants were eliminated from the study. Three participants were selected for the study using a non-probability convenience sampling method.

Participants were informed of the study's objective and characteristics and provided with informed consent. Following the signature of the consent form, appointments were scheduled for the pre-intervention evaluation. The pre- and post-intervention assessments were conducted by JLP, DRM, and JPF in an independent manner. The assessment period comprised two sessions, each lasting between 1.5 and 2 hours. Subsequently, three baseline assessments were conducted over the course of a week. Once the requisite assessments and baseline measurements had been completed, the training program was initiated. The therapists responsible for the treatment were DPF and KMR. During the course of the intervention sessions, cybersickness measures and baselines were obtained (sessions 4, 6 and 8). Upon completion of the intervention, the post- intervention assessment was conducted over the course of two sessions, each lasting approximately two hours.

2.1. Description of the Intervention

This cognitive training program employs immersive VR to facilitate the recognition of both basic and complex emotions. The program integrates cognitive-behavioral (psychoeducation and the link with one's own experiences) and neuropsychological approaches, including bottom-up (e.g., repetition, error-free learning), top-down (e.g., self-monitoring, self-instructions), and compensatory strategies. The objective is to enhance the precision of the capacity to perceive and recognize emotional cues from facial expressions and body postures. The intervention was conducted in an individual setting and comprised eight sessions, each lasting approximately 60 minutes. The training intensity was two sessions per week, resulting in a total duration of four weeks. Table 1 provides a detailed overview of the session structure.

Table 1.
Description of the intervention sessions.

# of sessions	Structure	Activities
	Introduction (20 minutes)	The introduction to the intervention program included a detailed explanation of the program's structure and objectives.
Session 1	Psychoeducation (25 minutes)	1) A brief overview of alterations in emotional recognition linked to schizophrenia; 2) An analysis of how this process affects daily life; 3) An explanation of facial and bodily cues that convey emotional information.
		Examples and reinforcement exercises were included to enhance understanding.
	VR habituation (10 minutes)	Participants used VR head-mounted displays (HMDs) for a five-minute acclimation period. They explored the virtual environment and received instructions on the tasks and interactions required for the intervention.
	Closure (5 minutes)	A summary of the activities undertaken during the session was provided, along with an analysis of the potential benefits of the intervention and its capacity to enhance certain cognitive abilities.
	Introduction (10 minutes)	A brief report is presented, outlining its structure, activities, and objectives. An overview of the previous session's proceedings is then provided, followed by addressing any remaining questions or comments.
Session 2	Presentation (15 minutes)	The session explores facial and body traits linked to joy, sadness, and anger, along with their emotional valence. The clinician provides examples and encourages participants to share personal scenarios related to these emotions.
	VR training (25 minutes)	The training involved dynamic stimuli for target emotions, followed by multiple-choice responses with feedback. Alongside software feedback, the clinician offered personalized guidance. Tasks were divided into three blocks, each with more stimuli and increased difficulty.
	Closure (10 minutes)	Summary of the session's activities and topics, followed by addressing and clarifying any participant questions or observations.
Session 3		This session is similar to Session 2, but with different target emotions: surprise, disgust and fear
Session 4		This session is similar to Session 2, but with different target emotions: admiration, shame and arrogance.
Session 5		This session is similar to Session 2, but with different target emotions: compassion, pain and contempt.
	Introduction (10 minutes)	A brief report is presented, outlining its structure, activities, and objectives. An overview of the previous session's proceedings is then provided, followed by addressing any remaining questions or comments
Session 6	VR training (40 minutes)	Tasks were divided in two blocks, each with more stimuli and increased difficulty. For this task the target emotions were joy, sadness, anger, surprise, disgust, and fear.
	Closure (10 minutes)	Summary of the session's activities and topics, followed by addressing and clarifying any participant questions or observations.
Session 7		This session is similar to Session 6, but with different target emotions: admiration, shame, arrogance, compassion, pain, and contempt.
	Introduction (10 minutes)	The session begins with a brief report outlining its structure, activities, and objectives, followed by a review of the previous session, and addressing any remaining questions.
Session 8	VR training (40 minutes)	The tasks, divided into two blocks with increasing difficulty, showcased all emotions. In the final task, participants evaluated whether an avatar's emotion matched a social scenario. Their arguments were then analyzed and discussed.
	Closure (10 minutes)	The concluding session comprised a synthesis of the strategies deployed during the intervention, with an invitation to integrate these into the subject's social interactions in daily life.

2.2. Intervention Materials

Computer. An Asus® TUF F15 with a Core i7 12 Gen processor was used. It comprised 16GB DDR4 for RAM memory and 1 TB SSD of storage capacity. The equipment included An NVIDIA RTX 4070 8GB GDDR6 Graphics video card. The monitor was of 15.6”, and Windows 11 was employed.

Slides presentations. A series of presentations were developed for the purposes of psychoeducation and the delineation of the characteristics of each of the target emotions.

VR-Tóol. The software, developed by our research group, is an immersive VR application that enables the generation of both basic (i.e., anger, disgust, fear, happiness, sadness, and surprise) and complex (i.e., admiration, compassion, contempt, pain, pride, and shame) emotional facial expressions in a virtual avatar. In the virtual environment, participants are situated in a VR living room in which a female avatar is seated. Participants are placed in front of the avatar and when a beep is presented, they must focus on her facial expressions and body postures. After the avatar's facial and body gestures are presented, participants must identify the emotion expression. Once the participant has responded, a new stimulus will be presented following the same sequence (i.e., beep – emotion expression - response). The software is designed to record various types of responses, different expression intensities (e.g., mild, moderate, or high), and allows for the creation of automated protocols and real-time stimuli presentation. For the purpose of the present study, a forced multiple choice with feedback response was utilized (Supplemental material 2). The software has been proven to have favorable usability and sense of presence indicators, and negligible symptoms of cybersickness. A comprehensive examination of software development, as well as its usability properties, sense of presence, and acceptability, is available for review in Pérez-Ferrara, et al. [29].

2.3. Assessment Materials

Cognitive assessment. MATRICS Consensus Cognitive Battery (MCCB) [30]. It is a battery that attempts to provide a brief assessment of some of the cognitive domains most relevant to schizophrenia and related disorders: attention, processing speed, visual and verbal memory, working memory, planning, and social cognition.

Facial and Body Emotion Recognition (REFyC) [31]: It consists of five tests (four emotional and one non-emotional control task) composed of video stimuli with an approximate duration of five seconds each. In the videos, people are observed expressing emotions with the face or the whole body or performing movements without emotional content. The two tests of basic emotions (posture and face) are composed of 28 videos each, those of complex emotions (posture and face) of 24 videos each, and the test of body movements without emotion of 18 videos. This test has an acceptable reliability, authors report a Cronbach alpha of 0.863. For the purpose of the present study, we only used the facial basic and complex emotions blocks.

Baseline assessment. The creation of the baselines involved the collection of photographs depicting basic emotions (i.e., anger, surprise, joy, sadness, disgust, fear) and a selection of complex emotions (i.e., arrogance, compassion, pain, shame, admiration, and contempt). Each of the twelve emotions was represented by two images. The images were obtained from REFyC [31], FACS [20], and PERE [32]. The images were then randomized into three lists, with each list containing 12 images.

Clinical measures. Positive and Negative Syndrome Scale in Schizophrenia PANSS [33]. This instrument was used to evaluate the intensity and frequency of positive, negative, and general symptoms present in the patients.

Apathy Evaluation Scale AES [34]. This scale was developed as a method to measure apathy as a result of some pathology. It is a Likert-type scale and consists of 18 items related to apathy, the total range of scores is 18-72, a higher score corresponds to more apathy. The clinical version (AES-C) was used.

Brief Assessment of Functioning Test FAST [35]. It was developed for the clinical assessment of the functioning limitations of psychiatric patients. It consists of 24 items and 6 subscales: autonomy, work functioning, cognitive functioning, finances, interpersonal relationships, and leisure. This scale is easy and quick to apply (3-6 minutes).

Calgary Depression Scale for Schizophrenia CDSS; [36]. The CDSS is a nine-item scale, each item is graded on a four-point Likert type scale (absent to severe), which estimates the severity of depression in patients with schizophrenia. The sum score is derived by adding the point scores of all nine items.

Tolerability and acceptability measures. Simulator Sickness Questionnaire (SSQ) [37]: This questionnaire assesses 16 symptoms related to cyber motion sickness on a 4-point Likert scale. Symptoms are grouped into three dimensions (i.e., oculomotor, disorientation, and nausea). Higher scores indicate more severe symptoms. Sevinc and Berkman [38] reported good reliability of the total scale (Cronbach's alpha = 0.94) and the subscales of nausea (Cronbach's alpha = 0.84), oculomotor (Cronbach's alpha = 0.91), and disorientation (Cronbach's alpha = 0.88). Brown, et al. [39] proposed the following cut-off points: 0 = No symptoms; ≤ 5 = Negligible symptoms; 5 – 10 = Minimal symptoms; 10 – 15 = Significant symptoms; 15 – 20 = Symptoms are of concern; ≥ 20 = A poor intervention. Such ranges were used in the present study.

Acceptability of the intervention questionnaire. This instrument was designed by our research group to delve into participants' opinions about their experience with *VR-Tóol*. It was developed considering some of the dimensions of the concept of acceptability proposed by Sekhon, et al. [40]. The questionnaire comprises 22 Likert-type questions, ranging from 0 to 6, and 4 open-ended questions. Four subscales were considered: Affective attitude and motivation toward the intervention subscale (eleven items) which includes items assessing participant preferences regarding tasks and the virtual environment, their motivation to engage with tasks, and their intention to participate again and to refer the intervention to others. Scores within this subscale range from 0 to 6, with higher scores indicating stronger motivation and positive attitude toward the intervention. Secondly, the Burden subscale (three items) appraises the effort demanded to complete the intervention. Higher scores indicate greater perceived effort. Thirdly, the Coherence of the Intervention subscale (three items) encompasses items that appraise the level of understanding and clarity of the objectives. Higher scores indicate greater clarity and coherence. Finally, the Perceived Effectiveness subscale (five items) inquires about perceived change and the effect the intervention had on the subject's daily life. Higher scores indicate greater perceived effectiveness.

2.4. Data Analysis

Baseline analysis. For visual analysis and quantitative visual aids, the Conservative Dual-Criterion method (CDC) Fisher, et al. [41] was employed to delineate a line based on the baseline data from the treatment phase, thereby facilitating visual inspection.

In order to analyze the variability between phases, the two-standard deviation band (SD-Band) Perdices and Tate [42] technique was employed. This technique was implemented by first calculating the mean of a phase and then adding and subtracting two standard deviations (i.e., the standard deviation of the studied phase only) from it. This methodology enables the analysis of the number of treatment phase measurements that fall above or below the delineated lines. The app https://manolov.shinyapps.io/Overlap/ was utilized for graphing and analysis (Figures 1, 2, and 3), enabling the execution of various analyses of the Single Case Experimental Designs (SCEDs).

The Non-overlap of all pairs (NAP) technique was employed. This nonparametric technique quantifies nonoverlap or "dominance" between two phases. It calculates the proportion of non-overlapping data relative to all possible comparisons. The calculation of the index was performed using a complimentary calculator developed by Vannest, et al. [43]: https://singlecaseresearch.org/calculators/nap/.

Finally, for the measures that exhibited a significant change, as determined by the NAP and visual analysis, generalized least squares (GLS) was employed to ascertain the estimate of the effect size. The R programming language and a GLS script developed by Manolov, et al. [44] were utilized in this analysis.

Pre-post analysis. The calculation of the Reliable Change Index (RCI) of the variables of interest was performed using a RCI calculator based on the assumptions proposed by Bauer, et al. [45]. This calculator enables the estimation of the RCI, which serves to ascertain the reliability of the observed alteration. The calculation considers the pre-test and post-test scores, the standard deviation and the alpha coefficient of the normative sample. The calculation was performed using the formula proposed by Bauer, et al. [45]:

$$RCI = \frac{x_{post} - x_{pre}}{\sqrt{2}S_E^2}$$

The minimum change on a scale indicating reliable change (RC) can also be calculated. In this calculation, the standard deviation of the normative sample and the coefficient alpha are taken into consideration. The formula employed was expressed as follows:

$$RC = 1.96\sqrt{2}S_E^2$$

Finally, the cut-off points were determined by calculating the means and standard deviations of a normative sample and a clinical sample of the scale. The following formula was employed:

$$Cuttoff = \frac{(SD_{nonfunctional} * M_{functional}) + (SD_{functional} * M_{nonfunctional})}{(SD_{nonfunctional} + SD_{functional})}$$

The RCI of the pre- and post-measures of the MCCB was calculated using the intraclass correlation coefficients of the test-retest reliability results published by Keefe, et al. [46] for each index. For the means and standard deviations of the normative sample, we employed the data published by Rodriguez-Jimenez, et al. [47]. For the clinical group, we used the data published by Keefe, et al. [46]. The RCI of the REFyC measures was calculated using the reliability and normative data from the paper published by Leiva [31]. Given the absence of a clinical sample in this test, it was not feasible to calculate the cut-off point for this measure. For FAST, the reliability and normative group data from Gisbert-Gustemps, et al. [48] and the clinical sample from Ventura, et al. [49] were utilized. Finally, for the PANSS normative and clinical group data, the study from Ivanova, et al. [50] was used, and reliability data were obtained from the work of Fresán, et al. [33].

3. Results

3.1. Case EC

Description of the patient. EC is a 26-year-old patient who was diagnosed with undifferentiated schizophrenia in 2014 by the Department of Psychiatry at the Dr. Juan N. Navarro Children's Psychiatric Hospital. At the age of 15, the patient began to demonstrate difficulties in organization and time management when attempting academic activities. Furthermore, educators expressed concerns regarding the patient's academic performance and social integration. The initial pharmacological intervention by the psychiatrist was with antidepressants, yet no improvement was observed. At the children's psychiatric hospital, a pharmacological treatment plan was initiated, comprising the following medications: sertraline (2 tablets, 50 mg each, administered every 24 hours), quetiapine (1 tablet, 300 mg, administered every 8 hours), lorazepam, and aripiprazole (1 tablet, 15 mg each, administered every 24 hours), along with piracetam. In 2019, the pharmacological treatment was discontinued at the family's discretion due to the patient's persistent lack of motivation, emotional flattening, and deterioration in daily functioning. In October 2023, the family sought the advice of a neurologist, who recommended that the patient undergo electroencephalogram (EEG) studies and a structural magnetic resonance imaging (MRI) scan. The EEG studies yielded no pathological findings. Furthermore, the MRI scan revealed a left temporal arachnoid cyst of the Glasse type, which did not exert mass effects. At the time of writing, it was reported that EC was able to perform basic self-care activities, although he required motivation to do so. No evidence of delusional, hallucinatory, manic, or psychotic symptoms was observed. Moreover, there is no evidence of difficulties in any area prior to this situation. EC displays difficulties in performing activities of daily living without prompting and exhibits a lack of interest in social activities. Furthermore, he displays deficiencies in attention, processing speed, verbal learning, problem-solving, and social cognition. At present, the pharmacologic treatment regimen consists of a 20 mg tablet of fluoxetine in the morning and a 10 mg tablet of olanzapine in the evening.

Acceptability / tolerability of intervention. EC exhibited no symptoms of cybersickness, as evidenced by a mean total score of zero, which indicates an absence of symptoms. Conversely, he exhibited a mean of 4.2 on the subscale of affective attitude and motivation toward the intervention, 4 on the subscale of burden, 3.3 on the subscale of coherence of the intervention, and 4 on the subscale of perceived effectiveness. In response to the open-ended questions, EC indicated that the aspect of the intervention he found most appealing was “being able to see the virtual reality”, while the aspect he found least appealing was “the duration”. He further proposed a modification to the intervention by suggesting that it should be shorter. No additional comments were provided.

Efficacy of the intervention: Baseline. Concerning the assessment of the precision of ER, the CDC clearly demonstrates that the scores attained in the intervention phase are considerably higher than those obtained in the pre-intervention phase (Figure 1a). This finding aligns with the observations depicted in the SD-Band analysis graph, where the three scores consistently exceed the bands of two standard deviations. The NAP demonstrated a non-overlap index of 1 ($z = 1.964$; $p = 0.049$) (Figure 1b). Finally, GLS analysis demonstrated an increase of 14.3 standard deviations from the pre-intervention phase to the intervention phase. In terms of the mean response times, a reduction in response time was anticipated; nevertheless, none of the intervention phase measurements fell below the response times observed in the pre-intervention phase. Notably, an increase in response time was observed in the intervention phase evaluations (Figure 1c, 1d). The obtained NAP index was 0.33 ($z = 0.654$; $p = 0.51$).

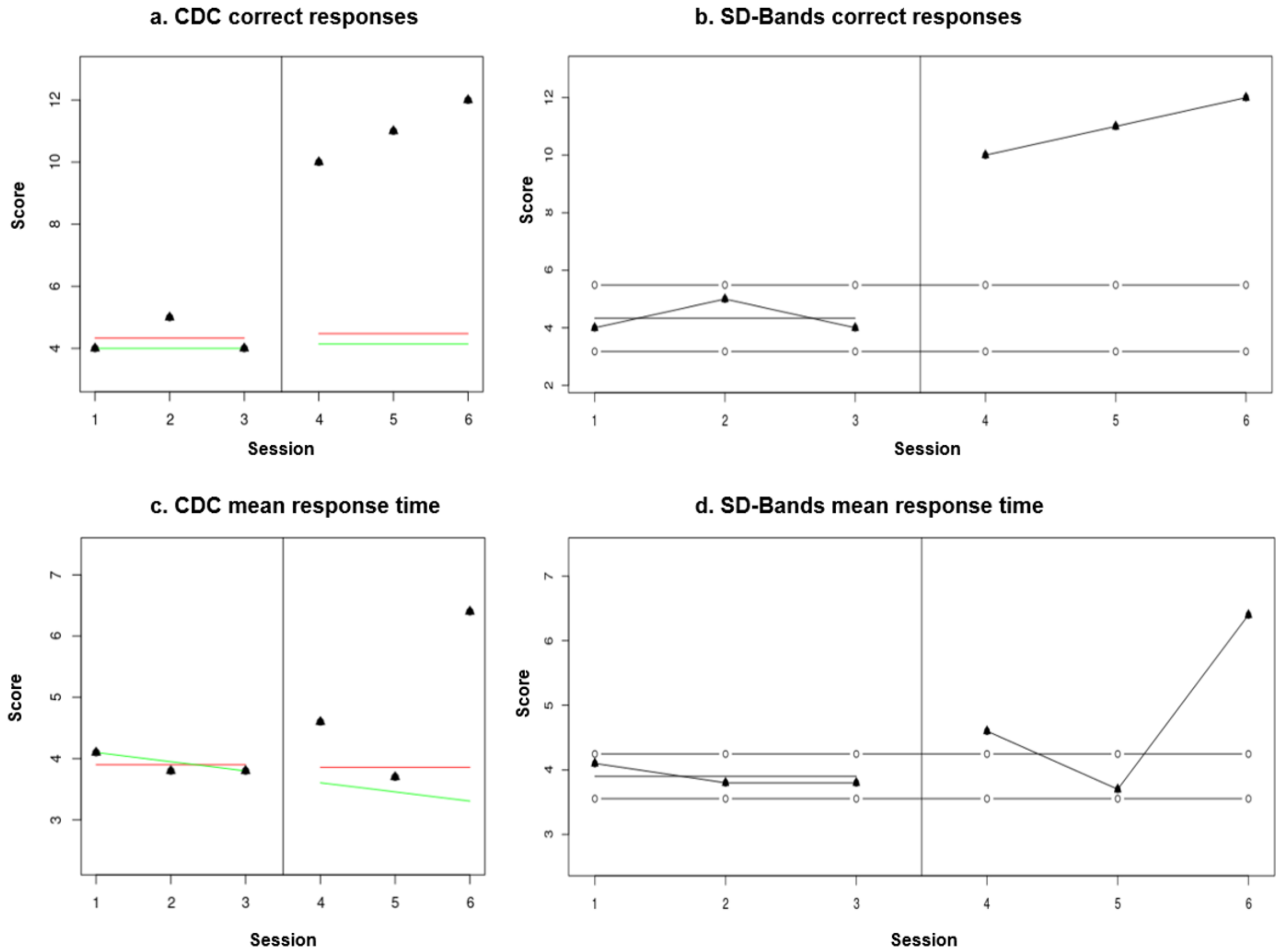

Figure 1.
CDC and SD-Bands graphics of the correct responses and the mean response time of EC.
Note: * Red lines = mean of the baseline phase; Green lines = trend of the baseline phase.

Figure 1a. AB graph showing EC’s correct responses in the ER baseline assessments. The central vertical line in the figure delineates the onset of the intervention phase. This figure presents the CDC method for visual analysis, where the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 1b. AB graph of EC’s correct responses and the projection of the standard deviation bands on both phases. Figure 1c. AB graph of the CDC method for the mean response time of EC, the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 1d. AB graph of EC’s mean response time and the projection of the standard deviation bands for both phases.

Pre-post assessment. The RCI was utilized to analyze the pre- and post-measures. A reliable change was observed in the measures of attention (RCI = -3.46), social cognition (RCI = -5.12), and total score (RCI = -2.63) of the MCCB. Notably, at the post-assessment, EC obtained a T-score of 66 in social cognition, indicating clinical recovery. A significant change was also observed in the measures of recognition of basic (RCI = -4.17) and complex (RCI = -5.62) emotions of the REFyC, although the clinical data is not available to determine the cut-off point. The score obtained by EC in the recognition of basic emotions (24 hits) is within the mean of the normative group (mean = 22.76; SD = 2.12) of this task [31]. In the case of complex emotions (23 hits), the score exceeded the mean of the aforementioned normative group (mean = 19.33; SD = 2.33). Finally, a clinically significant change was observed in the autonomy (RCI = 7.1), cognition (RCI = 17.61), finance (RCI = 7.81), interpersonal relationships (RCI = 5.48), and total score (RCI = 17.63) subscales of the FAST Table 2.

Table 2.
RCI of the pre-post change observed in EC.

Test	Subtest	Pre	Post	Change	RCI	Interpretation	RC (SD)	Cutoff score	Interpretation
MCCB	Processing speed	20	15	-5	0.78	Not reliable	12.58	41.71	Not recovered
	Attention	18	40	22	-3.46	Reliable	12.45	43.71	Not recovered
	Working memory	33	36	3	-0.48	Not reliable	12.19	43.2	Not recovered
	Verbal learning	29	28	-1	0.1	Not reliable	19.22	40.4	Not recovered
	Visual learning	31	35	4	-0.49	Not reliable	16.07	41.6	Not recovered
	Problem solving	24	21	-3	0.47	Not reliable	12.5	45.01	Not recovered
	Social cognition	28	66	38	-5.12	Reliable	14.55	42.64	Recovered
	Total score	11	24	13	-2.63	Reliable	9.7	38.76	Not recovered
REFyC	Basic emotions	16	24	8	-4.17	Reliable	3.76	-	-
	Complex emotions	12	23	11	-5.62	Reliable	3.84	-	-
FAST	Autonomy	12	10	2	7.1	Reliable	0.55	0.74	Not recovered
	Laboral	15	14	1	0.92	Not reliable	2.13	5.64	Not recovered
	Cognition	15	5	10	17.61	Reliable	1.11	1.79	Not recovered
	Finance	6	4	2	7.81	Reliable	0.5	0.84	Not recovered
	Int. Relationships	14	11	3	5.48	Reliable	1.07	2.25	Not recovered
	Leisure	6	4	2	1.94	Not reliable	2.02	1.2	Not recovered
	Total score	68	48	20	17.63	Reliable	2.22	9.83	Not recovered
PANSS	Positive	27	22	5	3.59	Reliable	2.73	14.21	Not recovered
	Negative	36	35	1	0.63	Not reliable	3.13	14.2	Not recovered
	General psychopathology	35	36	-1	-0.25	Not reliable	7.93	31.29	Not recovered
	Total score	98	93	5	1.03	Not reliable	9.49	59.22	Not recovered

Note: RCI = Reliable Change Index; RC = Reliable Change; SD = Standard deviation; MCCB = MATRICS Consensus Cognitive Battery; REFyC = Facial and Body Emotion Recognition; FAST = Brief Assessment of Functioning Test; CDSS = Calgary Depression Scale for Schizophrenia; PANSS = Positive and Negative Syndrome Scale in Schizophrenia.

3.2. Case EA

Description of the patient. EA is a 26-year-old male who was diagnosed with schizophrenia in February 2016. It was indicated that during his childhood, there was a suspicion of attention deficit hyperactivity disorder. Consequently, psychological treatment was initiated, yet the diagnosis was not confirmed. During his time in elementary school, he demonstrated an average level of academic and social performance. At the outset of junior high school, he began engaging in altercations with his father, which were precipitated by the loss of his father's employment and his parents' divorce. Therefore, he was required to live with his father exclusively. Upon enrolling in an open high school system, he began to exhibit challenges in organization and academic performance, which ultimately resulted in his withdrawal from the institution. However, he subsequently enrolled in the same academic year and completed his studies. In February 2016, EA was admitted to the emergency room on eight occasions due to complaints of dyspnea. However, no underlying medical conditions were identified, and the father subsequently transported EA to Fray Bernardino Hospital, where a diagnosis of schizophrenia was rendered. During this period, EA also exhibited symptoms of depression and suicidal ideation and was treated with pharmacological agents. He was able to resume his normal school and daily activities in an appropriate manner. In October 2023, a physician elected to withdraw the antipsychotic medication from the patient who had been diagnosed with obsessive-compulsive disorder (OCD) only. Subsequently, the patient began displaying aggressive behavior towards his father, including physical assaults and property destruction. The girlfriend of EC played an instrumental role in facilitating his admission to the Fray Bernardino facility, which lasted for a period of three weeks. The diagnosis was schizophrenia with comorbid OCD. The current pharmacological treatment regimen comprises the following medications, which are administered in the morning and at night: fluoxetine 20 mg (four tablets), paroxetine 20 mg (one tablet), and biperiden 2 mg (two tablets). In addition to the aforementioned morning and nighttime medications, the evening regimen includes pregabalin 75 mg (one tablet), risperidone 2 mg (one tablet), and haloperidol 5 mg (one and a half tablets). EA currently demonstrates the capacity for self-care and independent living, with occasional employment and remuneration by commission. However, additional difficulties have been observed in processing speed, verbal learning, and social cognition.

Acceptability / tolerability of intervention. EA exhibited only minimal symptoms of cybersickness and achieved a mean total score of 9.3 on the SSQ. He exhibited a mean of 3.8 on the subscale of affective attitude and motivation toward the intervention, 4.3 on the subscale of burden, 3.3 on the subscale of coherence of the intervention, and 4.2 on the subscale of perceived effectiveness. In response to the open-ended questions, the participant indicated that his favorite aspect of the intervention was "the use of visors and the psychologists' attention." Conversely, he reported that his least favorite aspect was "that the clinic was a bit far away" He further proposed a modification to the intervention by suggesting "a bit faster the way to explain". Finally, as an additional comment, he stated that "I feel that the intervention helped me a bit with things like attention and recognition of emotions to socialize"

Efficacy of the intervention: Baseline. The findings of the study suggest that the scores obtained from the intervention phase are marginally above the mean of the pre-intervention phase. When the standard deviation bands are plotted, it is observed that only one measurement exceeds the bands (Figure 2a, 2b). The NAP index was determined to be 0.88 ($z = 1.52$; $p = 0.12$). A significant decrease in execution times was observed in the intervention phase compared to the pre-intervention phase, with all three measurements falling below the SD-Bands (Figure 2c, 2d). The NAP index exhibited a non-overlap value of 1 ($z = 1.964$; $p = 0.049$). Finally, GLS analysis demonstrated an increase of 0.86 standard deviations from the pre-intervention phase to the intervention phase.

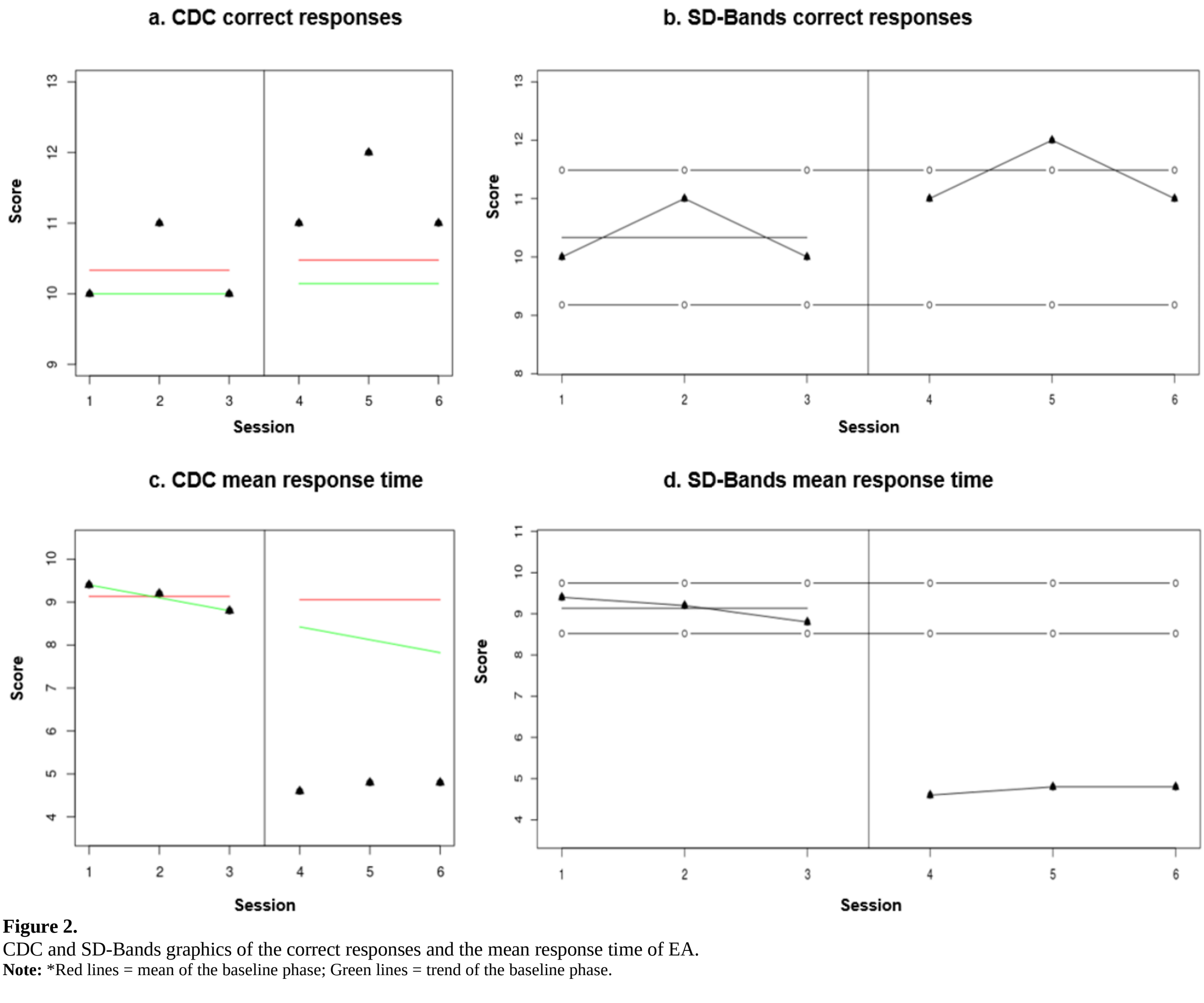

Figure 2.
CDC and SD-Bands graphics of the correct responses and the mean response time of EA.
Note: *Red lines = mean of the baseline phase; Green lines = trend of the baseline phase.

Figure 2a. AB graph showing EA's correct responses in the ER baseline assessments. The central vertical line in the figure delineates the onset of the intervention phase. This figure presents the CDC method for visual analysis, where the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 2b. AB graph of EA's correct responses and the projection of the standard deviation bands on both phases. *Figure 2c.* AB graph of the CDC method for the mean response time of EA, the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 2d. AB graph of EA's mean response time and the projection of the standard deviation bands on both phases.

Pre-post assessment. A reliable change was observed in the measures of verbal learning (RCI = -3.26) and the total score (RCI = -2.63) of the MCCB. Notably, at the post-assessment, EC obtained a T-score of 59 in verbal learning, indicating clinical recovery. A significant change was observed in the measures of recognition of complex (RCI = -3.58) emotions, but not for the basic emotions (RCI = 0). A subsequent comparison of his post-intervention score with the mean of the normative group reveals that he exhibits below-average performance in basic emotions (18 hits; mean = 22.76, SD = 2.12) and average performance in complex emotions (21 hits; mean = 19.33, SD = 2.33). Finally, a clinically significant change was observed in all subscales of the FAST, with the exception of the Leisure subscale (Table 3).

Table 3.
RCI of the pre-post change observed in EA.

Test	Subtest	Pre	Post	Change	RCI	Interpretation	RC (SD)	Cutoff score	Interpretation
MCCB	Processing speed	29	26	-3	0.47	Not reliable	12.58	41.71	Not recovered
	Attention	35	28	-7	1.1	Not reliable	12.45	43.71	Not recovered
	Working memory	33	39	6	-0.96	Not reliable	12.19	43.2	Not recovered
	Verbal learning	27	59	32	-3.26	Reliable	19.22	40.4	Recovered
	Visual learning	31	45	14	-1.71	Not reliable	16.07	41.6	Recovered
	Problem solving	48	45	-3	0.47	Not reliable	12.5	45.01	Worsen
	Social cognition	15	26	11	-1.48	Not reliable	14.55	42.64	Not recovered
	Total score	20	33	13	-2.63	Reliable	9.7	38.76	Not recovered
REFyC	Basic emotions	18	18	0	0	Not reliable	3.76	-	-
	Complex emotions	14	21	7	-3.58	Reliable	3.84	-	-
FAST	Autonomy	8	6	2	7.1	Reliable	0.55	0.74	Not recovered
	Laboral	14	8	6	5.52	Reliable	2.13	5.64	Not recovered
	Cognition	12	8	4	7.04	Reliable	1.11	1.79	Not recovered
	Finance	3	5	-2	-7.81	Reliable	0.5	0.84	Not recovered
	Int. Relationships	14	10	4	7.31	Reliable	1.07	2.25	Not recovered
	Leisure	6	6	0	0	Not reliable	2.02	1.2	Not recovered
	Total score	57	43	14	12.34	Reliable	2.22	9.83	Not recovered
PANSS	Positive	11	9	2	1.43	Not Reliable	2.73	14.21	Not recovered
	Negative	21	19	2	1.25	Not reliable	3.13	14.2	Not recovered
	General psychopathology	32	34	-2	-0.49	Not reliable	7.93	31.29	Not recovered
	Total score	64	62	2	0.21	Not reliable	9.49	59.22	Not recovered

Note: RCI = Reliable Change Index; RC = Reliable Change; SD = Standard deviation; MCCB = MATRICS Consensus Cognitive Battery; REFyC = Facial and Body Emotion Recognition; FAST = Brief Assessment of Functioning Test; CDSS = Calgary Depression Scale for Schizophrenia; PANSS = Positive and Negative Syndrome Scale in Schizophrenia.

3.3. Case JA

Description of the patient. JA is a 23-year-old male who received a diagnosis of paranoid schizophrenia in 2022. No complications were reported during the periods of pregnancy, childbirth, or developmental milestones. It has been documented that JA encountered no significant impediments in achieving his academic goals during his years in elementary, middle and high school. However, it was observed that he did experience certain difficulties during the transition from preschool to elementary school, as well as during the period of change of residence that coincided with this stage. In 2018, it was reported that he began to isolate himself, becoming withdrawn even during vacations and less active than usual. In 2021, the family's residence was burglarized while they were absent. Following this incident, JA expressed a desire to relocate from his family home. Consequently, he resided with his aunt for a period of time before deciding to seek professional assistance. During this period, JA reported feelings of being followed and ruminations that "they would be better off without him." In February 2022, he had his first suicide attempt by ingesting detergents, stating that he did so because he could not bear the voices. In that same year, he initiated a consultation with a psychiatrist, who prescribed risperidone and citalopram. This treatment resulted in a reduction of auditory hallucinations, enabling him to successfully complete a semester at university. However, JA ceased to receive pharmacological treatment in December of that same year and demonstrated stability for a period of several months. In February 2023, JA began to experience hallucinations again and during an altercation, he tried to jump a fence, and accidentally touched the street's electrical cables. Consequently, he was admitted in the Fray Bernardino Hospital, where he was diagnosed with paranoid schizophrenia and antipsychotic medication was recommenced. However, he subsequently ceased medication in May 2023, and was able to re-engage with school and exercise. In December 2023, the intensity of the symptoms increased, accompanied by an escalation in suicidal ideation, auditory hallucinations, and sleep-related problems. He was readmitted to a psychiatric facility and commenced a pharmacological treatment regime, which currently consists of 200 mg of magnesium valproate administered every eight hours, 1.5 mg of brexpiprazole administered once daily, 20 mg of fluoxetine administered twice a day in the morning, 50 mg of quetiapine administered once a day at night, and 8,000 units of vitamin administered once a day. It has been documented that he currently exhibits a diminished response speed; however, he is not experiencing any difficulties with self-care and independent living.

Acceptability / tolerability of intervention. JA exhibited no symptoms of cybersickness, as evidenced by a mean total score of 2, which indicates an absence of symptoms. He exhibited a mean of 3.8 on the subscale of affective attitude and motivation toward the intervention, 1.3 on the subscale of burden, 3.3 on the subscale of coherence of the intervention, and 4.4 on the subscale of perceived effectiveness. In response to the open-ended questions, the participant indicated that his favorite aspect of the intervention was "slides with information about each emotion." Conversely, he reported that his least favorite aspect was "the transfer I had to make to the intervention" He further proposed a modification of the intervention by suggesting “add more emotions”. No additional comments were provided.

Efficacy of the intervention: Baseline. The CDC demonstrates that the scores attained in the intervention phase are considerably higher than those obtained in the pre-intervention phase (Figure 3a). This finding aligns with the observations depicted in the SD-Band analysis graph, where two of the three scores consistently exceed the bands of two standard deviations. The NAP demonstrated a non-overlap index of 0.88 (z = 1.52; p = 0.12). GLS analysis demonstrated an increase of 6.07 standard deviations from the pre-intervention phase to the intervention phase. In terms of the mean response times, a reduction in response time was anticipated; nevertheless, none of the intervention phase measurements fell below the response times observed in the pre-intervention phase (Figure 3c, 3d). The obtained NAP index was 0.22 (z = -1.09; p = 0.27).

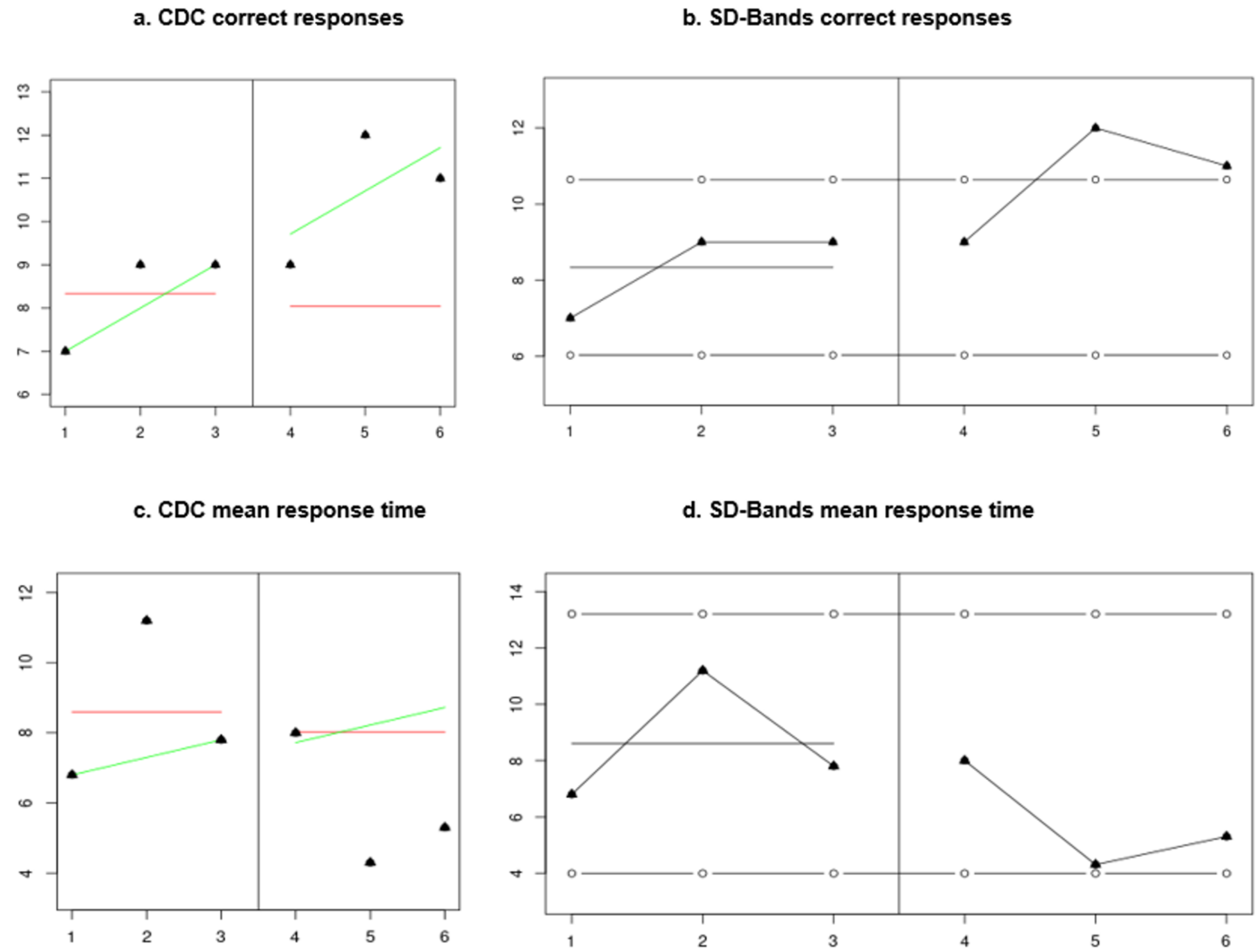

Figure 3.
CDC and SC-Bands graphics of the correct responses and the mean response time of JA.
Note: *Red lines = mean of the baseline phase; Green lines = trend of the baseline phase.

Figure 3a. AB graph showing JA’s correct responses in the ER baseline assessments. The central vertical line in the figure delineates the onset of the intervention phase. This figure presents the CDC method for visual analysis, where the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 3b. AB graph of JA’s correct responses and the projection of the standard deviation bands on both phases. Figure 3c. AB graph of the CDC method for the mean response time of JA, the mean (red line) and trend (green line) of the baseline phase are presented in the baseline phase and the intervention phase. Figure 3d. AB graph of JA’s mean response time and the projection of the standard deviation bands on both phases.

Pre -post assessment. A reliable change was observed in the verbal learning domain of the MCCB (ICC = -3.50) from pre- to post-intervention, with the post-intervention score reaching T = 61, indicative of clinical recovery. Additionally, significant changes were observed in REFyC measures for both basic (ICC= -3.65) and complex ER (ICC= -2.53) emotions, with scores comparable to normative means. Finally, clinical significant changes were also detected in the FAST subscales of autonomy (ICC= 23.81), cognition (ICC= 8.80), finance (ICC= 7.81), and interpersonal relationships (ICC= 7.31) (Table 4).

Table 4.
RCI of the pre-post change observed in JA.

Test	Subtest	Pre	Post	Change	RCI	Interpretation	RC (SD)	Cutoff score	Interpretation
MCCB	Processing speed	29	36	7	-1.23	Not reliable	11.18	44.40	Not recovered
	Attention	41	45	4	-0.69	Not reliable	11.31	45.66	Not recovered
	Working memory	44	44	0	0	Not reliable	10.03	45.24	Not recovered
	Verbal learning	37	61	24	-3.50	Reliable	15.09	43.74	Recovered
	Visual learning	34	34	0	0	Not reliable	13.45	46.21	Not recovered
	Problem solving	40	36	-4	0.61	Not reliable	12.89	45.77	Not recovered
	Social cognition	26	26	0	0	Not reliable	14.00	41.00	Not recovered
	Total score	27	34	7	-1.88	Not reliable	7.30	45.14	Not recovered
REFyC	Basic emotions	18	25	7	-3.65	Reliable	3.76	-	-
	Complex emotions	15	20	5	-2.53	Reliable	3.88	-	-
FAST	Autonomy	11	5	-6	23.81	Reliable	0.49	0.74	Not recovered
	Laboral	15	15	0	0	Not reliable	2.13	5.64	Not recovered
	Cognition	11	6	-5	8.80	Reliable	1.11	1.79	Not recovered
	Finance	6	4	-2	7.81	Reliable	0.5	0.84	Not recovered
	Int. Relationships	16	12	-4	7.31	Reliable	1.07	2.25	Not recovered
	Leisure	6	4	-2	1.94	Not reliable	2.02	1.2	Not recovered
	Total score	65	46	-19	16.75	Reliable	2.22	9.83	Not recovered
PANSS	Positive	16	17	1	-0.72	Not Reliable	2.73	14.07	Not recovered
	Negative	34	34	0	0	Not reliable	3.13	13.46	Not recovered
	General psychopathology	32	29	-3	0.74	Not reliable	7.93	30.00	Not recovered
	Total score	82	80	-2	0.21	Not reliable	9.49	57.03	Not recovered

Note: RCI = Reliable Change Index; RC = Reliable Change; SD = Standard deviation; MCCB = MATRICS Consensus Cognitive Battery; REFyC = Facial and Body Emotion Recognition; FAST = Brief Assessment of Functioning Test; PANSS = Positive and Negative Syndrome Scale in Schizophrenia.

4. Discussion

The objectives of this pilot study were: 1) to assess the tolerability and acceptability, and 2) to assess the preliminary efficacy of a VR-ER intervention program denominated *VR-Tóol* in three patients within the schizophrenia spectrum, in order to identify aspects in need of improvement. Both objectives were fulfilled and will be discussed according to the obtained findings.

4.1. Tolerability and Acceptability

VR-Tóol demonstrated adequate tolerability. Patients exhibited a range of symptoms, from none to minimal, related to their exposure to the *VR-Tóol*. This finding suggests that the symptoms, in terms of both frequency and severity, are minimal and clinically non-significant [39]. The minimal symptoms exhibited by the patients could be attributed to the characteristics of the *VR-Tóol*, such as its minimalistic and stable environment, and the absence of rotating cameras or speedy scenes. This observation aligns with the findings reported in the literature, which indicates that rotating cameras, acceleration, locomotion, visual stimulation, and exposure time are associated with heightened levels of cybersickness [51, 52].

Regarding acceptability, patients exhibited adequate motivation toward the VR environment and the intervention tasks. Furthermore, they reported good levels of perceived effectiveness. The present results align with the findings of Rus-Calafell, et al. [53] and Riches, et al. [54] who reported that patients diagnosed with schizophrenia exhibited adequate acceptability of VR-based treatments. It is noteworthy that the patients reported experiencing a significant burden when undertaking the intervention, attributable to the duration of the intervention and the distance required to reach the location of the intervention. Consequently, a potential avenue for enhancement could involve a reduction of the number of sessions. Conducting subsequent studies to assess the training's effectiveness while varying its duration is recommended. In this sense, Nijman, et al. [55] reported that the duration of the intervention does not have an effect on the efficacy of targeted ER training in schizophrenia.

4.2. Efficacy

Regarding intervention efficacy, it must be highlighted that the obtained results are preliminary, so caution for their interpretation is suggested. This is a pilot case-study design, so generalization cannot be guaranteed. Despite these limitations, the results offer initial evidence of the potential effects of *VR-Tóol* as a useful intervention tool in the clinical context.

ER and emotional intelligence/social cognition. Baseline results indicated that two out of three patients (i.e., EC and JA) improved their accuracy for ER stimuli, reaching the highest possible score. On the other hand, EA did not significantly enhance his accuracy, but his response times were significantly reduced. These results are partially consistent with those reported in previous studies [18] since EC and JA did not significantly improve their response times. A possible explanation for the inconsistency among patients' outcomes, may involve the symptomatology severity, whereas higher symptom severity is associated with slower response times. The clinical symptomatology assessment showed that both EC and JA displayed more severe symptoms than EA, so this variable could have influenced the intervention results [56, 57]. Pre-post intervention assessments indicated that EC and JA displayed clinically significant improvement in ER, obtaining similar scores to normative data in both basic and complex emotions. Indeed, JA achieved higher scores than normative data in the former, while EC outperformed the normative group in the latter. On the other hand, post-intervention data from EA showed no improvement in ER for basic emotions, in which the obtained scores were lower than normative data. However, a clinically significant change was observed for complex ER, reaching normative scores. These results are consistent with other studies [26-28] in which it has been demonstrated that ER training in patients with schizophrenia using VR technology is associated with clinically significant improvements in ER. Moreover, evidence has pointed out that schizophrenia patients with high levels of dysfunctionality are more prone to benefit from cognitive training, which could explain the different outcomes observed among patients [58].

Interestingly, EC and EA improved in the social cognition index from the MCCB at the post-intervention assessment. However, only EC's score reached clinical significance. These results are inconsistent with previous reports in which ER-focused interventions did not have a significant positive effect on more complex social cognition domains like theory of mind or empathy. It has been suggested that such domains require a multimodal integration from different sources of information beyond the visual input, in which complex social cues are included [18, 55]. A possible explanation for the discrepancy in the present study could be related to the employed test, which assesses emotional intelligence abilities. In this sense, emotional intelligence improvement could be a result of its strong relationship with basic emotional processes like prosody or ER [59, 60].

Neurocognition and symptomatology. Interestingly, significant changes were observed in different cognitive domains like verbal learning, attention, and the overall MCCB score, even though this was a targeted ER training. In this line, Charernboon [61] reported that ER and ToM are strongly correlated with neurocognition in patients with schizophrenia. Consequently, it can be hypothesized that neurocognition may had been benefited indirectly by ER training. Furthermore, it can be suggested that the enhancement of the cognitive global score would imply an increase in resources that can only be detected overall MCCB and not in all the patient's cognitive domains [61].

The lack of reliable changes in PANSS scores may be due to the fact that the intervention was not designed to manage or reduce these symptoms. However, a decrease in the positive symptoms score was observed in EC. Although it has been reported that negative symptoms are related to neurocognition and social cognition, in some meta-analyses a relationship between social cognition and positive symptoms has been reported. It is probable that this relationship is not explored in depth because the ideal treatment of these symptoms is by means of antipsychotics [62]. However, it is plausible that fluctuations in these symptom scores are associated with variables not included in this study. Consequently, this finding offers a foundation for future research to explore the relationship between these domains.

Functionality. Regarding functionality, our results suggest that the integration of ER strategies within the *VR-Tóol* intervention led to significant improvements. All patients showed reliable changes in specific functionality domains such as autonomy, cognition, finances, and interpersonal relationships. Moreover, all patients showed significant improvements in their overall functionality scores.

These findings align with previous research that emphasizes the critical role of ER in functional outcomes among schizophrenia patients [5] and underscore the therapeutic potential of combined cognitive and social-cognitive interventions. Although earlier studies have reported that ER interventions typically yield moderate to large effects on ER measures, their impact on general and social functionality has been inconsistent [17-19]. In contrast, our study provides evidence that integrating immersive tools, such as the *VR-Tóol,* into ER interventions can yield more pronounced improvements in functionality. By replicating real-world scenarios through dynamic, naturalistic stimuli and incorporating both bottom-up and top-down strategies and psychoeducation, the *VR-Tóol* intervention not only enhanced ER but also facilitated significant gains in key functional domains. This suggests that the realistic, immersive experience provided by VR tools may overcome some of the limitations observed in traditional ER interventions, ultimately leading to more meaningful and transferable improvements in everyday functional outcomes.

5. Conclusions

In conclusion, the present study offers preliminary evidence of the acceptability and efficacy of a targeted VR-ER intervention using *VR-Tóol* in three patients within the schizophrenia spectrum. The study found that the patients exhibited levels of cybersickness symptoms ranging from none to minimal. All patients demonstrated a strong motivation to engage with the intervention, particularly the use of VR. Preliminary evidence suggests clinically significant changes in ER measures, emotional intelligence/social cognition, and overall functionality. Notably, patients exhibited clinical improvements in select measures of attention and verbal learning, as well as an enhancement of the global cognitive score. Finally, these findings offer additional support for the potential efficacy of VR-ER interventions in individuals diagnosed with schizophrenia spectrum disorders.

5.1. Limitations and Future Perspectives

This study has several limitations that must be noted. First, the study design has limitations corresponding to the number of phases (AB) and the absence of randomization processes, whether in the phases, baselines, or sample. It is therefore important to acknowledge that this investigation is a preliminary pilot study. Future studies should employ a more robust design to enhance power and consequently improve the generalizability of the findings. Additionally, it is recommended to assess the observed changes over a follow-up period of at least six months following the intervention. Furthermore, the VR program utilizes a single avatar, which may constrain the range of expressions and lead to monotony. Increasing the number and diversity of the avatars could enhance both ecological validity and intervention efficacy. Another notable limitation of the study is the demographic homogeneity of the sample, comprising three young male adults, which may not fully represent the heterogeneity observed in individuals diagnosed with schizophrenia spectrum disorders. Further research should include participants across a broader age range and diverse clinical profiles to comprehensively assess the acceptability and efficacy of these VR-ER interventions.

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