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Published in:
Schizophrenia Bulletin

DOI:
10.1093/schbul/sbac166

Schizophrenia Bulletin vol. 49 no. 2 pp. 518–530, 2023
https://doi.org/10.1093/schbul/sbac166
Advance Access publication November 22, 2022

Dynamic Interactive Social Cognition Training in Virtual Reality (DiSCoVR) versus Virtual Reality Relaxation (VRelax) for People With a Psychotic Disorder: A Single-Blind Multicenter Randomized Controlled Trial

S. A. Nijman[*,1,2,3], G. H. M. Pijnenborg[1,3], R. R. Vermeer[4], C. E. R. Zandee[4], D. C. Zandstra[5], D. van der Vorm[6], A. C. de Wit - de Visser[6,7], I. A. Meins[1,2,3], C. N. W. Geraets[2], and W. Veling[2]

[1]Department of Psychotic Disorders, GGZ Drenthe, Dennenweg 9, PO Box 30007, 9404 LA, Assen, The Netherlands; [2]University Center of Psychiatry, University Medical Center Groningen, University of Groningen, Hanzeplein 1, PO Box 30.001, 9700 RB, Groningen, The Netherlands; [3]Department of Clinical and Developmental Neuropsychology, University of Groningen, Grote Kruisstraat 2/1, 9712 TS, Groningen, The Netherlands; [4]GGZ Delfland, Sint Jorisweg 2, 2612 GA, Delft, The Netherlands; [5]Zeeuwse Gronden, Axelsestraat 8/A, 4537 AJ, Terneuzen, The Netherlands; [6]GGZ Westelijk Noord-Brabant, Hoofdlaan 8, PO Box 371, 4600AJ, Bergen op Zoom, The Netherlands; [7]Tranzo, Tilburg School of Social and Behavioral Sciences, Tilburg University, Professor Cobbenhagenlaan 125, PO Box 90153, 5000LE Tilburg, The Netherlands

[*]To whom correspondence should be addressed; Department of Psychotic Disorders, GGZ Drenthe, Dennenweg 9, PO Box 30007, 9404 LA, Assen, The Netherlands; tel: 0031-592334703, e-mail: s.a.nijman@umcg.nl

***Background and Hypothesis*: Social cognition training (SCT), an intervention for social cognition and social functioning, might be improved by using virtual reality (VR), because VR may offer better opportunities to practice in a potentially more realistic environment. To date, no controlled studies have investigated VR-SCT. This study investigated a VR-SCT, "DiSCoVR". We hypothesized that DiSCoVR would improve social cognition and social functioning. *Study Design*: Participants were randomized to DiSCoVR ($n = 41$) or VR relaxation ('VRelax', $n = 40$), an active control condition, and completed 16 twice-weekly sessions. Three assessments (baseline, posttreatment, and 3-month follow-up) were performed by blinded assessors. The primary outcome was social cognition (emotion perception and theory of mind). Secondary outcomes included social functioning (measured with an interview and experience sampling), psychiatric symptoms, information processing, and self-esteem. Data were analyzed using mixed-models regression analysis. Treatment effects were evaluated by the time by condition interaction terms. *Study Results*: No significant time by condition interactions were found for any of the outcome variables, indicating an absence of treatment effects. Between-group effect sizes ranged from negligible to moderate (Cohen's $d < |0.53|$). Main effects of time were found for several outcomes. *Conclusions*: These results suggest that DiSCoVR was not effective, possibly because of inadequate simulation of emotional expressions in VR. This lack of efficacy may indicate that current SCT protocols are relatively unsuitable for improving social functioning. Previous studies showed small to moderate effects on higher order social cognition, but the SCT approach may need critical reevaluation, as it may not sufficiently lead to functional improvement.**

Key words: cognitive remediation therapy/e-health/theory of mind/facial affect recognition/mentalization

Introduction

Social dysfunction, that is, problems in adequately fulfilling appropriate social roles in daily life, is common in people with a psychotic disorder.[1] An important factor in the onset and maintenance of social dysfunction is social cognition.[2,3] The term social cognition refers to the cognitive and emotional processes involved in (thinking about) social interactions and other people, such as emotion perception, social perception, Theory of Mind (ToM), and attribution style. Social Cognition Training (SCT) aims to improve social cognition, generally through repeated practice with social stimuli and/or social strategy training.[4] Meta-analyses have found SCT to be effective at improving social cognition and social functioning, although its efficacy varies across studies, measurement instruments, and intervention methods.[5–10]

Virtual Reality (VR) has emerged as a potential tool to improve SCT,[11] offering several advantages over conventional SCT. VR-SCT facilitates training in a safe, controlled environment, that can be tailored (eg, the difficulty and content) to the individual. VR also offers a dynamic, complex training environment, eliciting social

behavior resembling real-world interactions.[11,12] With VR, social situations can be simulated, repeated, and altered, including situations that might be impractical or impossible to practice in a conventional therapeutic setting. Currently, however, no controlled studies of VR-SCT are available.

In one study, investigating a manualized group SCT (Social Cognition and Interaction Training[13]) in an online virtual environment, improvement was found[14] in emotion recognition and anxiety, but not in other measures (eg, ToM). A VR-SCT case study[15] (n = 2) reported improvement in emotion recognition, ToM, attribution style, and social intelligence. To the best of our knowledge, no further empirical studies of VR-SCT for people with a psychotic disorder are available. However, for VR social skills training (an intervention likewise focusing on social situations, but not primarily targeting social cognition) encouraging results have been found[16,17]), as well as for pilot studies investigating VR-SCT for people with autism spectrum disorder.[18,19]

Our research group has developed an immersive VR-SCT ("Dynamic Interactive Social Cognition Training in Virtual Reality": "DiSCoVR"). In an uncontrolled pilot study,[20] we found that this approach was feasible and acceptable. We observed improvement in emotion recognition, but not in ToM, social perception, empathy, or clinical measures. Subsequently, we upgraded to a more reliable and graphically advanced version of the VR software, used broader social goal setting methods and altered the VR exercises to use open-ended questions (for specific changes, cf. ref.[20]). In this study, we investigated the efficacy of DiSCoVR, comparing it to VR relaxation therapy ('VRelax').

We hypothesized that DiSCoVR would lead to greater improvements than VRelax in (1) social cognition (ie, emotion perception, social perception, and ToM), and (2) social functioning, measured by both an interview and experience sampling in daily life. We also expected DiSCoVR to have greater effects on other secondary outcomes (eg, paranoid ideation, social anxiety), through improvements in social cognition and exposure to social situations.

Method

Study Design

This study was a single-blind RCT with an experimental group, DiSCoVR, and an active control condition, VRelax. All participants continued to receive treatment as usual. Participants completed 3 measurements (baseline/T_0, posttreatment/T_1, and 3-month follow-up/T_2).

Participants

Participants were inpatients and outpatients from 5 mental healthcare institutions in the Netherlands. Inclusion criteria were: (1) diagnosis of a psychotic disorder as established with a structured clinical interview within the past 3 years, or as verified with the Mini International Neuropsychiatric Interview Plus[21]; (2) deficits in social cognition, as indicated by a treating clinician; (3) age 18–65 years. Exclusion criteria were: (1) epilepsy; (2) estimated IQ < 70, and/or a diagnosis of intellectual disability; and (4) insufficient Dutch proficiency. Participants received €30 per measurement.

Interventions

Both interventions encompassed 16 individual 45–60-minute twice weekly on-site sessions. Therapists received 8 h of training, and monthly group supervision by the principal investigators. Technical support was available by telephone. For protocol fidelity evaluation, therapists completed a short form after every session.

DiSCoVR was modeled after existing, effective SCT protocols (eg, ref.[13,22]). DiSCoVR was provided by psychologists with minimally a master's degree. Treatment goals were identified, which were explicitly related to the training content, reflected upon at the end of each session and altered, if necessary, at the end of each module. Examples of goals were "Recognizing other people's social boundaries better" and "Meeting new people and feeling more at ease in interactions". Participants practiced individually with social-cognitive strategies throughout the intervention (eg, verbalization of salient facial features), both in VR and at home; homework exercises were discussed at the beginning of each session. Since these (individual) exercises (cf. supplementary materials) were optional, though strongly encouraged, compliance was not recorded.

DiSCoVR consisted of 3 modules:

- Module 1 (sessions 1–5): facial affect recognition. Outside VR, participants formulated personal social goals and received psychoeducation about social cognition and strategy use. In VR, participants explored a shopping street using a joystick (Microsoft Xbox One) and identified facial expressions on stationary virtual characters ("avatars"), using a multiple-choice menu. At home, participants practiced recognizing emotions.
- Module 2 (sessions 6–9): social perception and ToM. Outside VR, participants learned about the connection between behavior, emotions, and thoughts, applied to themselves, other people, and in interactions. This technique was adapted from the model of emotions in cognitive behavioral therapy (CBT). In VR, participants viewed animated interactions between virtual characters (containing misunderstandings, ambiguity, faux pas, hinting, and lies) and answered open-ended questions about their behavior, thoughts, and emotions. Scenarios took place in everyday environments (a supermarket, a cafe, on the street).

As homework, participants were encouraged to note their own and others' thoughts, behavior, and emotions.

- Module 3 (sessions 10–16): application of social cognition in social interactions. Outside VR, participants learned a social cognitive problem-solving technique, adapted from CBT. in this technique, participants considered their and others' thoughts, behavior, and emotions, generated different possible ways to react, chose the most appropriate response, and evaluated the chosen solution afterwards. In VR, participants role-played personally relevant social scenarios. Therapists controlled a virtual character and spoke to participants in real time using a transformed voice. Therapists could control the environment, gender, ethnicity, appearance, voice, emotions, and gestures of the avatar. As homework, participants were encouraged to practice the problem-solving technique.

The VR environments were created by CleVR BV and were displayed using an Oculus Rift head-mounted-display (Consumer Version 1). Therapists controlled the environment and avatars through a tablet interface and viewed participants' field of vision using a second monitor. Time spent in VR was increased gradually and ranged from 5 min (session 1) to 35 minutes (modules 2/3).

VRelax was aimed at stress reduction, coping, and relaxation. VRelax was provided by therapists with minimally a psychology bachelor's degree, or clinical experience (>3 years) with the target population. Outside VR, participants received psychoeducation about stress, coping, rumination, and stress reduction. Participants learned to identify personal stressors, choose appropriate coping responses, and utilize relaxation techniques. Approximately 50% of each session was dedicated to VR relaxation. Participants explored relaxing 360° VR videos of nature scenes (eg, swimming with dolphins, coral reef, beach at sunset, mountain meadow).[23] The VR environment contained several relaxation exercises (eg, breathing exercises, progressive relaxation), using audio guidance while looking at relaxing nature scenes. Participants controlled the environment (navigation and exercises) using gaze. VRelax was developed by Viemr BV and was displayed using a Samsung Gear VR headset with a Samsung Galaxy S7 smartphone.

Outcomes

Measurements were carried out on-site by independent assessors (master's students in clinical psychology or medicine, and experienced clinical research assistants), who received ±24 h of training and received regular supervision. To ensure reliable scoring, assessors conducted consensus meetings.

Social Cognition. We assessed facial emotion recognition using the Ekman 60 Faces Test,[24] a computerized measure in which participants rate 60 pictures showing basic emotions (fear, anger, disgust, happiness, sadness, or surprise).

Social perception and ToM were measured using The Awareness of Social Inference Task (TASIT[25,26]), Part III. Eight video vignettes are presented, portraying social situations containing lies or sarcasm. After each video, participants answer 4 questions, about the intentions, message, beliefs, and emotions of the actors. Total scores (0–32) were analyzed.

Social Functioning. We measured overall social functioning using the Personal and Social Performance (PSP) scale,[27] an interview on functioning in four areas (socially relevant activities, social relationships, self-care, and disruptive/aggressive behavior). Ratings of dysfunction on a five-point scale are combined into a single score of social functioning (0–100); higher scores indicate better functioning.

Social functioning in daily life was measured using experience sampling method (ESM) diaries. Participants received 10 daily text messages at semirandom moments for 7 days. The messages contained a link to a questionnaire with 21–33 items (depending on answers given) on current positive affect (4 items, 0–400, $\alpha = 0.89$), negative affect (7 items, 0–700, $\alpha = 0.89$), stress (4 items; 0–400, $\alpha = 0.82$); overall and in company of others. Enjoyment of current and recent activities (1 item each, 0–100), current and recent company of another person (yes, 1/no, 0), and how the company was experienced (sense of being accepted, 4 items, 0–400, $\alpha = 0.86$; and participant's perceived social cognition, 2 items, 0–200, $\alpha = 0.88$) were measured. Preferences for more social contact since the last beep (1 item, 0–100) and initiative for social contact since the last beep were also assessed (1 item, 0–100). The ESM questionnaire took approximately 2–3 min to complete; it has been published previously.[28]

Neurocognitive and Clinical Measures. Demographic and clinical characteristics were investigated using questions and premorbid intelligence was assessed with the National Adult Reading Test (NART[29,30]). Information processing and mental set switching were evaluated using the Trail Making Test (TMT[31]). Clinical outcome measures included the Positive and Negative Syndrome Scale (PANSS[32]), the Social Interaction Anxiety Scale (SIAS[33]), the Green et al. Paranoid Thought Scales[34] (including part A, ideas of social reference, and part B, ideas of persecution), the Beck Depression Inventory (BDI[35]), the Beck Anxiety Inventory (BAI[36]), the Perceived Stress Scale (PSS[37]), the Self Esteem Rating Scale (SERS[38]). The Simulator Sickness Questionnaire (SSQ[39]) was administered in treatment session 3.

Randomization and Blinding

The randomization list was generated using the R package "blockrand,"[40] using block randomization with random block size (2, 4, or 6), stratified by gender, age (strata of 9 years), and treatment center. Randomization was performed by an independent UMCG employee. Assessors were blinded to treatment condition. In case of unblinding, assessors were replaced, if possible. Blinding was verified with a postassessment questionnaire.

Statistical Methods

Based upon previous meta-analyses[5,6] we assumed an effect size of 0.5. Using $\beta = 0.80$, $\alpha = 0.05$, 2 groups and 3 measurements, yielded a sample size of $n = 86$. Assuming a 13% drop-out rate,[41] we determined that we would need 100 participants.

We evaluated all outcome, demographic, and clinical measures for baseline group differences using *t*-tests, Mann–Whitney *U* tests, or χ^2-tests. Variables with significant baseline differences were added to analyses as covariates. A dummy variable for COVID-19 (0/1: before/after pandemic onset) was added to ESM models, given its impact on daily social interactions. To evaluate treatment effects, we conducted a multilevel linear mixed-model regression analysis, in accordance with the intention-to-treat principle, with repeated measurements (Level 1) nested within individuals (Level 2). We used the Maximum Likelihood method to estimate the models using the MIXED procedure in IBM SPSS Statistics 28. For ESM outcomes, models were estimated using the Restricted Maximum Likelihood method. The lme4[42] and lmerTest[43] R packages were used to analyze ESM data.

Treatment effects were investigated by evaluating the significance and magnitude of the time by condition interaction. We originally planned to conduct separate regression analyses for T_1 and T_2, but to preserve statistical power and reduce the number of regression analyses, T_1 and T_2 were analyzed simultaneously, by adding the time variable (T_0–T_1–T_2) as an unordered factor. This yielded separate regression coefficients for T_1 and T_2. Random intercepts were estimated for individuals, and a random slope for time if it improved the model, as determined by the AIC value. We conducted sensitivity analyses for treatment completers (≥12 sessions; 75%), and for subjective assessments where assessors reported being completely blinded. For multiple instruments within the same domain, we applied a Bonferroni correction to α. Between-group effect sizes for treatment effects were determined with Cohen's *d*.[44] Positive effect sizes reflect greater improvement for DiSCoVR.

For missing questionnaire items, the participant's mean at that time point was imputed if overall missingness on that item was low (<5%) and participants had fewer than 1 missing item for every 10 items.

Procedures

A screening guideline of 4 questions (eg, "Does this person have problems understanding what other people mean?") was provided to clinicians to gauge participant eligibility. Eligible patients were approached by their clinician and contacted by the researchers. Participants were further informed and screened for eligibility by telephone and received written information. After a one-week consideration period, participants signed informed consent and completed a baseline assessment (T_0; ±2.5 h) and 1 week of ESM questionnaires. Next, randomization took place and treatment started. Within 2 weeks of finishing treatment, a posttreatment (T_1) assessment (±2 h) and another week of ESM took place. Three months later, participants completed the follow-up (T_2) assessment (±2 h) and a final week of ESM. After the outbreak of the COVID-19 pandemic, assessments ($n = 53$; 24.4%) were split to minimize face-to-face exposure: questionnaires, completed at home, interviews by telephone/videoconferencing, and face-to-face performance-based tasks.

This study was approved by the Medical Ethical Committee of the UMCG (METc file number: 2017/573, ABR: NL63206.042.17). It was registered prospectively in the Dutch Trial Register (NTR6863). The study protocol was published previously.[28] An independent monitor audited each treatment center for compliance with research procedures.

Results

Participants

In total, 83 participants were included between April 9, 2018 and December 9, 2020. The number of inclusions was lower than intended due to suspension of research activities because of the COVID-19 pandemic. Demographic and clinical characteristics of the sample can be found in table 1. We added volunteering hours per week to all models as a covariate, because VRelax participants had a significantly higher mean at baseline. Participant flow is shown in figure 1. There was no significant difference between dropouts and nondropouts on any of the demographic, clinical, or outcome measures at baseline, nor a difference in dropout across interventions ($\chi^2(1) = 1.927$, $P = .165$).

Treatment Effects

Means and standard deviations of outcomes at all 3 time points are shown in table 2. Estimates of time and treatment effects are shown in table 3. For our intention-to-treat (ITT) analysis, none of the time by condition interactions were significant, indicating an absence of treatment effects. At T_1, significant time effects were observed for SERS ($b = 6.98$, $P = .002$) and positive affect (ESM; $b = 26.87$, $P < .001$). At T_2, significant time

Table 1. Sociodemographic and Clinical Characteristics of the Sample

		DiSCoVR (n = 41)[a]		VRelax (n = 40)[a]			
		M or n	SD or %	M or n	SD or %	Test statistic	P
Age		35.9	10.4	39.7	12.4	W = 1530.0	.154
Gender	Male	30	73.2	26	65.0	$\chi^2(1) = 0.633$	.426
	Female	11	26.8	14	35.0		
Education	None or primary	2	4.9	5	12.5	$\chi^2(4) = 3.390$	.495
	Vocational	23	56.1	19	47.5		
	Secondary	12	29.3	14	35.0		
	Higher	4	9.8	2	5.0		
Premorbid intelligence (NART)		77.8	14.6	80.8	10.8	W = 1649.0	.766
Paid employment	Employed	8.0	19.5	7.0	17.5	$\chi^2(1) = 0.054$	.816
	Not employed	33.0	80.5	33.0	82.5		
	Hours worked per week	3.8	8.1	2.4	6.5	W = 1709.5	.691
	Work history (years)	7.0	5.6	8.2	10.4	W = 333.0	.733
Living arrangement	Independent	22	53.7	26	65.0	$\chi^2(3) = 2.083$	.555
	Assisted living	12	29.3	9	22.5		
	Family	6	14.6	3	7.5		
	Clinic	1	2.4	2	5.0		
Day activities/ Volunteering	Engages in day activities/ volunteering	13	32.5	26	65.0	$\chi^2(1) = 8.455$	.004*
	Hours spent per week on day activities/volunteering	4.2	15.7	6.5	10.4	W = 1359.0	.017*
Substance use (units per week)	Alcohol	1.5	2.8	4.2	15.7	W = 1549.5	.182
	Nicotine	45.2	76.3	38.7	66.9	W = 1671.0	.915
	Marijuana/Cannabis	.5	2.3	.6	3.3	W = 1680.0	.980
	Hard drugs	0	0	0	0	W = 1681.0	>0.999
Diagnosis	Schizophrenia	25	61.0	23	59.0	$\chi^2(5) = 3.854$	.571
	Schizoaffective disorder	9	22.0	9	23.1		
	Brief psychotic disorder (substance induced)	0	0.0	1	2.6		
	Schizophreniform disorder	0	0.0	1	2.6		
	Delusional disorder	0	0.0	1	2.6		
	Other psychotic disorder	7	17.1	4	10.3		
Illness duration (years)		11.0	8.8	14.3	12.0	W = 1428.0	.343
(Past) Psychotic episodes		2.6	2.9	3.1	3.5	W = 1463.0	.532
Hospitalization status	Never hospitalized	8	20.5	12	30.0	$\chi^2(2) = 1.407$	.495
	Currently hospitalized	1	2.6	2	5.0		
	Previously hospitalized	30	76.9	26	65.0		
Hospitalizations		2.9	2.5	4.2	4.2	W = 741.0	.221
Medication	Uses medication	39	95.1	36	90.0	$\chi^2(1) = 0.208$	.649
	Typical antipsychotics	3	7.3	7	17.5	$\chi^2(1) = 1.940$	.164
	Atypical antipsychotics	32	78.0	28	70.0	$\chi^2(1) = 0.683$	.409
	Antidepressants	13	31.7	9	22.5	$\chi^2(1) = 0.868$	.352
	Mood stabilizers	1	2.4	3	7.5	$\chi^2(1) = 1.105$	.293
	Anxiolytics	6	14.6	5	12.5	$\chi^2(1) = 0.079$	.779
	Benzodiazepines	20	48.8	22	55.0	$\chi^2(1) = 0.314$	.575
	Stimulants	2	4.9	0	.0	$\chi^2(1) = 2.001$	.157
Family history of psychiatric disorders	Yes	24	58.5	24	60.0	$\chi^2(1) = 0.018$	.893
	No	17	41.5	16	40.0		

[a]There were 83 included participants. However, 1 participant presented a screening failure, and 1 participant dropped out during the baseline assessment, leaving the final sample at baseline at n = 81.
*Significant difference at $\alpha = 0.05$.

effects were observed for the total Ekman 60 Faces score (b = 2.34, P = .019), total PSP score (b = 4.08, P = .027), TMT-A (b = −6.11, P = .001), and positive affect (ESM; b = 24.15, P = .004), indicating increases in the total Ekman 60 Faces score, PSP and positive affect score, and improved TMT-A performance across both groups.

Consistent with the lack of significant time by condition interactions, nearly all ITT between-group effect sizes were negligible or small for both time points. Small to moderate (but statistically nonsignificant) effect sizes (ie, d > |0.3|) were observed favoring VRelax for PSP (T_2 d = −0.38), BDI (T_1 d = −0.53), PANSS-P (T_2 d = −0.42),

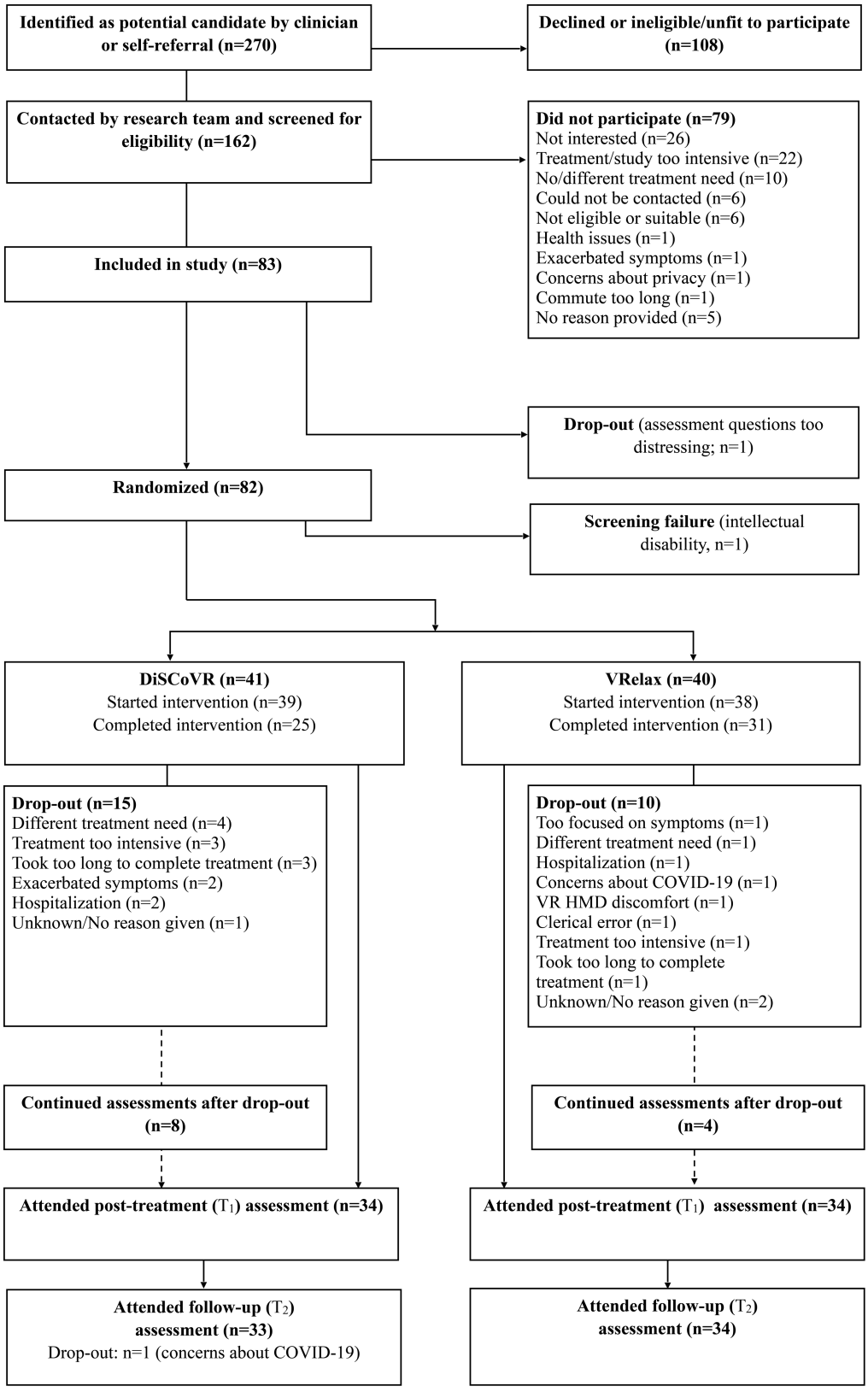

Fig. 1. Participant flow diagram.

Table 2. Descriptive Statistics of Outcome Measures

Outcome	DiSCoVR			VRelax		
	T_0	T_1	T_2	T_0	T_1	T_2
	n = 41	*n* = 34	*n* = 33	*n* = 40	*n* = 34	*n* = 34
	M (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)	*M* (SD)
Social cognition						
Ekman 60 Faces	44.6 (6.8)	46.2 (5.7)	47 (6.4)	45.4 (7.3)	47 (6.2)	47.8 (8.6)
TASIT-III	22.1 (4.2)	21.9 (3.9)	22.3 (3.6)	22.4 (3.2)	22.4 (4.2)	22.4 (3.5)
Social functioning						
PSP	54.7 (14.4)	55.6 (12.9)	57 (13.1)	52.7 (11.9)	53.6 (15.1)	56.9 (16.2)
Neurocognitive measures						
TMT-A	36 (12.1)	33.4 (12.8)	30.3 (11.5)	41.4 (19.9)	35 (13.5)	35.1 (18)
TMT-B	93.4 (44.7)	92.8 (50.3)	75.5 (29.8)	90.5 (48.2)	74.5 (29.4)	75.7 (50.7)
Psychiatric symptoms						
SIAS	37.3 (15.3)	34.8 (15.9)	34 (17.2)	34.1 (13.7)	31.5 (15.3)	30.4 (15.1)
GPTS-A	37.1 (18.5)	35.5 (15.9)	33.1 (16.3)	31.5 (12.1)	29 (11.9)	28.4 (13)
GPTS-B	31.7 (17.8)	31.1 (19.2)	29.3 (17.7)	28.1 (13.8)	27.3 (13.3)	26.6 (13.8)
PSS	27.4 (6)	26.5 (7.9)	25.2 (7)	25 (6.7)	23.4 (7.3)	26 (7.5)
BAI	18.7 (11)	16.5 (12)	15.2 (11.4)	15.5 (9)	13.2 (8.5)	14.7 (12.6)
BDI	16.7 (9.1)	15 (9.6)	14.5 (10.7)	14.4 (8.5)	11.8 (7.2)	13.8 (9.1)
PANSS-P	14.7 (5.6)	15 (6.3)	14.4 (5.8)	15.1 (5.1)	14.5 (5)	13.4 (4.6)
PANSS-N	16.5 (6.1)	14.9 (5.7)	14 (5.4)	16.4 (6.4)	15.2 (6.4)	15.2 (6)
PANSS-G	33.9 (10.3)	33.5 (10.3)	31.5 (9)	33.7 (9.4)	30.8 (8.9)	30.3 (8.2)
Self-esteem						
SERS	82.6 (20.5)	86.5 (22.8)	85.8 (22.6)	88.4 (19.1)	95.2 (19.4)	92.4 (20.9)
ESM: momentary emotions						
Positive affect	270.2 (91.9)	284.9 (79.2)	290.5 (84.3)	276.7 (99.1)	304.6 (102.8)	301.7 (102.7)
Negative affect	153.5 (111.2)	156.3 (116.5)	162.9 (122.7)	138.7 (122.7)	130.8 (130.8)	131.1 (125.7)
Stress	109.3 (59.6)	110.7 (59)	112.8 (60.4)	101.7 (65.5)	90.9 (71.1)	91.2 (67.4)
ESM: momentary emotions (social)						
Positive affect	290.4 (96.9)	283.6 (89.6)	286.2 (86.5)	303.2 (103.8)	334.4 (105.4)	323.9 (106.5)
Negative affect	148.9 (122.2)	150.6 (129.5)	183.7 (135.7)	122.2 (114.5)	116.3 (125.4)	126.7 (126.5)
Stress	103.8 (65.5)	107.9 (68.8)	120.5 (67.6)	93.5 (69.2)	80.4 (69.8)	84.4 (70.2)
ESM: activities						
Enjoyment of activity (time of beep)	65.1 (19.8)	67.5 (17.7)	67.8 (17.9)	66.5 (19.5)	68.4 (18.8)	68.9 (19)
Enjoyment of activity (at time of beep, social)	67.3 (17.9)	66.5 (17.1)	66.1 (17)	68.3 (21.7)	70.3 (19)	70.9 (19.2)
Enjoyment of activity (since last beep)	64.6 (19.2)	66.5 (18.3)	67.9 (18.1)	67.5 (18.8)	68.6 (18.7)	70.1 (18.7)
ESM: social interaction						
Accompanied at time of beep (y/n)	32% (46.7)	23.3% (42.3)	27.6% (44.7)	29.3% (45.5)	27.9% (44.9)	29% (45.4)
Accompanied since last beep (y/n)	30.4% (46)	28.6% (45.2)	33.6% (47.2)	26.7% (44.3)	22.2% (41.5)	25% (43.3)
Perceived acceptance by other (at time of beep)	276.7 (68.4)	291.2 (51.3)	277 (60.5)	288.6 (72)	302 (67.5)	300.1 (69.6)
Perceived acceptance by other (since last beep)	262 (62.7)	264.4 (52.5)	264.3 (54.4)	270.8 (75.4)	270.1 (79.1)	278.3 (74.3)
Perceived social cognitive ability (at time of beep)	119 (43.6)	131.1 (35.2)	121.5 (35.3)	126.3 (42.2)	131.8 (41.6)	131 (42.5)
Perceived social cognitive ability (since last beep)	111.8 (40)	119.6 (32.2)	118.3 (31.3)	121.2 (43.5)	118.6 (44.6)	122.3 (43.9)
Preference for more social contact	33.8 (25.1)	34.6 (24.5)	36.4 (25.6)	29.6 (27.4)	26.1 (25.5)	25.9 (25.9)
Social initiative since last beep	34.9 (28.3)	36.9 (27.9)	40.8 (27.8)	35.8 (30.7)	39.3 (30.8)	39.6 (31.8)

Note: TASIT, The Awareness of Social Inference Test; PSP, Personal & Social Performance; TMT, Trailmaking Test; SIAS, Social Interaction Anxiety Scale; GPTS, Green et al. Paranoid Thought Scales; PSS, Perceived Stress Scale; BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; PANSS, Positive And Negative Syndrome Scale; SERS, Self-Esteem Rating Scale; ESM, Experience Sampling Method(ology).

and PANSS-G (T_1 $d = -0.32$). Effect sizes for PSS (T_2 $d = 0.59$), BAI (T_2 $d = 0.33$), and PANSS-N (T_2 $d = 0.41$) were in favor of DiSCoVR.

For ESM, statistically nonsignificant, but notable effect sizes favoring VRelax were found for positive affect (T_1 $d = -0.38$, T_2 $d = -0.42$), positive affect (social, ie,

Table 3. Estimates of Time and Treatment Effects from Multilevel Linear Mixed-Model Regression Analysis

Outcome[d]	Time[a,b]				Time × Treatment[a,b]					
	T_1		T_2		T_1[c]			T_2[c]		
	b (95% CI)	*P*	*b* (95% CI)	*P*	*b* (95% CI)	*P*	*d*	*b* (95% CI)	*P*	*d*
Social cognition (α =.025)[d]										
Ekman 60 Faces	1.38 (−0.57,3.32)	.164	2.34 (0.39,4.28)	.019	0.01 (−2.71,2.73)	.994	−0.06	−0.31 (−3.07,2.44)	.823	−0.10
TASIT-III	0.04 (−1.33,1.41)	.956	.08 (−1.29,1.45)	.910	−0.35 (−2.27,1.58)	.722	0.00	.06 (−1.89,2.01)	.950	0.06
Social functioning (α =.05)[d]										
PSP	0.6 (−3.02,4.21)	.744	4.08 (0.46,7.7)	.027	−1.98 (−7.12,3.15)	.447	−0.23	−3.85 (−8.99,1.3)	.141	−0.38
Neurocognitive measures (α =.025)[d]										
TMT-A	−4.49 (−8.18,−0.81)	.017	−6.11 (−9.8,−2.42)	.001	2.02 (−3.16,7.2)	.442	−0.21	0.05 (−5.23,5.33)	.985	0.06
TMT-B	−12.38 (−26.1,1.34)	.076	−16.89 (−30.46,−3.32)	.015	14.18 (−5.08,33.44)	.148	−0.29	−0.88 (−20.4,18.65)	.929	0.08
Psychiatric symptoms (α =.006)[d]										
SIAS	−1.52 (−4.49,1.45)	.313	−2.76 (−5.7,0.17)	.015	−0.37 (−4.57,3.83)	.861	0.02	0.21 (−4,4.43)	.920	−0.06
GPTS-A	−2.68 (−5.96,0.59)	.108	−3.39 (−6.64,−0.15)	.065	1.42 (−3.22,6.06)	.547	−0.09	0.21 (−4.44,4.86)	.929	−0.06
GPTS-B	−1.42 (−5.34,2.5)	.476	−2.37 (−6.25,1.51)	.041	1.14 (−4.41,6.69)	.685	−0.10	−0.03 (−5.59,5.54)	.992	−0.09
PSS	−1.78 (−3.8,0.25)	.085	0.8 (−1.2,2.8)	.230	0.7 (−2.17,3.56)	.632	−0.05	−3.18 (−6.05,−0.31)	.030	0.59
BAI	−2.57 (−5.07,−0.08)	.043	−0.67 (−3.09,1.74)	.431	0.88 (−2.62,4.39)	.618	−0.07	−2.5 (−5.98,0.97)	.157	0.33
BDI	−3.71 (−5.75,−1.68)	< 0.001	−0.91 (−2.97,1.16)	.582	2.68 (−0.16,5.52)	.064	−0.53	0 (−2.86,2.86)	1.000	−0.04
PANSS-P	−0.63 (−1.91,0.65)	.330	−1.72 (−3,−0.44)	.387	0.73 (−1.07,2.53)	.422	−0.26	1.24 (−0.58,3.05)	.180	−0.42
PANSS-N	−0.76 (−2.29,0.76)	.325	−0.8 (−2.32,0.73)	.009	−0.94 (−3.09,1.21)	.388	0.25	−1.53 (−3.69,0.63)	.164	0.41
PANSS-G	−2.68 (−5.15,−0.21)	.033	−3.11 (−5.58,−0.64)	.304	2.58 (−0.89,6.04)	.144	−0.32	1.13 (−2.36,4.62)	.522	−0.18
Self-esteem (α =.05)[d]										
SERS	6.98 (2.62,11.35)	.002	4.15 (−0.17,8.47)	.060	−4.24 (−10.5,2.02)	.183	−0.35	−1.7 (−7.94,4.54)	.591	−0.13
ESM: momentary emotions (α = .008)[d]										
Positive affect	26.87 (13.39,40.48)	.000	24.15 (8.46,39.82)	.004	−17.07 (−36.33,2.2)	.088	−0.38	−18.89 (−41.3,3.51)	.104	−0.42
Negative affect	2.04 (−16.33,20.35)	.829	13.02 (−9.06,35.21)	.255	−3.04 (−29.09,22.92)	.820	0.02	−14.27 (−45.75,17.29)	.380	0.25
Stress	−6.56 (−16.87,3.72)	.217	.32 (−11.36,12.09)	.957	5.34 (−9.31,19.92)	.478	−0.20	.3 (−16.37,17)	.972	0.05
Positive affect (social)	19.62 (4.02,35.11)	.017	16.15 (−2.15,34.64)	.091	−13.75 (−35.38,8.21)	.222	−0.34	−17.31 (−43.98,8.62)	.201	−0.07
Negative affect (social)	6.01 (−17.57,29.48)	.619	18.05 (−8.81,44.83)	.195	4.83 (−27.91,37.56)	.774	−0.17	−8.85 (−46.49,29.45)	.651	0.16
Stress (social)	−4.78 (−17.79,8.21)	.476	2.42 (−11.24,15.92)	.728	12.27 (−5.97,30.36)	.193	−0.41	9.03 (−10.07,28.57)	.366	−0.07
ESM: Activities (α = .017)[d]										
Enjoyment of activity (time of beep)	2.03 (−0.1,4.18)	.069	.3 (−2.29,2.9)	.823	−1.94 (−5.03,1.14)	.219	−0.27	.53 (−3.22,4.26)	.783	0.13
Enjoyment of activity (at time of beep, social)	2.18 (−1.05,5.34)	.189	−0.73 (−4.11,2.66)	.675	−4.1 (−8.57,0.48)	.084	−0.36	2.13 (−2.83,7.05)	.403	0.48
Enjoyment of activity (since last beep)	2.12 (−0.16,4.4)	.075	−0.49 (−3.12,2.14)	.715	−1.01 (−4.28,2.26)	.546	−0.10	1.43 (−2.34,5.24)	.460	0.20
ESM: social interaction (α = .006)[d]										
Accompanied at time of beep (y/n)	−0.23 (−0.7,0.23)	.320	−0.19 (−0.72,0.33)	.465	0.06 (−0.57,0.7)	.857	0.09	−0.18 (−0.89,0.52)	.616	−0.02
Accompanied since last beep (y/n)	−0.19 (−0.62,0.23)	.381	−0.36 (−0.84,0.13)	.140	0.32 (−0.27,0.93)	.287	−0.02	.2 (−0.48,0.89)	.556	0.35
Perceived acceptance by other (at time of beep)	2.96 (−8.43,14.4)	.614	3.81 (−7.03,14.6)	.494	4.05 (−11.88,20.09)	.623	0.38	6.1 (−9.65,21.76)	.452	0.24
Perceived acceptance by other (since last beep)	10.03 (0.39,19.55)	.047	−3.22 (−15.04,8.55)	.598	0.85 (−12.57,14.71)	.903	0.35	6.68 (−10.3,23.68)	.446	0.14

Table 3. Continued

Outcome[d]	Time[a,b]				Time × Treatment[a,b]					
	T_1		T_2		T_1[c]			T_2[c]		
	b (95% CI)	*P*	*b* (95% CI)	*P*	*b* (95% CI)	*P*	*d*	*b* (95% CI)	*P*	*d*
Perceived social cognitive ability (at time of beep)	1.4 (−6.52,9.4)	.731	1.31 (−7.2,9.9)	.765	3.06 (−8.06,14.13)	.593	0.31	6.37 (−6.03,18.61)	.317	0.31
Perceived social cognitive ability (since last beep)	2.76 (−4.42,9.98)	.457	−5.48 (−13.9,3.04)	.212	4.15 (−6.03,14.32)	.429	0.24	8.15 (−4.01,20.2)	.194	0.23
Preference for more social contact	−0.41 (−4.9,4.11)	.861	−0.52 (−5.46,4.41)	.836	0.34 (−6.05,6.73)	.917	0.03	−0.3 (−7.31,6.74)	.933	−0.08
Social initiative since last beep	1.31 (−3.58,6.3)	.605	1.4 (−4.07,6.92)	.622	4.03 (−2.95,11.02)	.265	0.14	2.67 (−5.15,10.53)	.509	0.14

Note: TASIT, The Awareness of Social Inference Test; PSP, Personal & Social Performance; TMT, Trailmaking Test; SIAS, Social Interaction Anxiety Scale; GPTS, Green et al. Paranoid Thought Scales; PSS, Perceived Stress Scale; BAI, Beck Anxiety Inventory; BDI, Beck Depression Inventory; PANSS, Positive And Negative Syndrome Scale; SERS, Self-Esteem Rating Scale; ESM, Experience Sampling Method(ology).

[a]The reference groups used are VRelax (treatment variable) and the baseline measurement (time variable, T_0). Thus, time * condition interactions represent the coefficient for DiSCoVR * T_1 or T_2.

[b]In this table, only time and time * condition effects are presented. The full analyses also included random effects (a random intercept for individuals for all models, and a random slope for time nested within individuals in ESM models), an intercept and a centered covariate (baseline volunteering hours). In the case of ESM models, it also included a dummy variable indicating whether the measurement took place after the onset of the COVID-19 pandemic.

[c]Positive effect sizes favor DiSCoVR. Negative effect sizes favor VRelax. For measures where lower score = better outcome (eg, symptom measures), effect sizes were multiplied by −1.

[d]Alpha after applying a Bonferroni correction.

while accompanied by another person; T_1 $d = -0.34$), stress (social; T_1 $d = -0.41$), enjoyment of activities (social; T_1 $d = -0.36$). Notable ESM effect sizes favoring DiSCoVR were greater enjoyment of activities (at time of measurement, social; T_2 $d = 0.48$), more perceived acceptance by others (at time of measurement, T_1 $d = 0.38$; since last measurement, T_1 $d = 0.35$), and better perceived social cognitive ability (at time of measurement, T_1 and T_2 $d = 0.31$).

Sensitivity Analyses and Blinding

A sensitivity analysis of completers (≥12 sessions; table 4, supplementary material) showed similar results to the ITT analysis. Unblinding was reported in 10 assessments (7.8%). Group allocation was guessed correctly in 59.4% of measurements (DiSCoVR: 64.1%, VRelax: 54.7%); assessors performed significantly above chance level ($\chi^2(1) = 4.540$, $P = 0.033$), indicating that blinding was unsuccessful. A sensitivity analysis of blinded assessors showed no meaningful differences to the ITT analysis (cf. table 5, supplementary material).

Safety and Protocol Fidelity

Two serious adverse events (SAE) were reported in the DiSCoVR group and one SAE in the VRelax group, all concerning psychiatric hospitalization deemed unrelated to study participation by treating clinicians. The mean nausea SSQ score was 2.5 (SD = 2.2); reported nausea was significantly higher in the DiSCoVR group (DiSCoVR $M = 3.1$, VRelax $M = 2.0$, $P = .036$). The average oculomotor SSQ score was 3.9 (SD = 3.2), with no significant difference between groups (DiSCoVR $M = 3.2$, VRelax $M = 4.26$, $P = .262$). Protocol deviations were reported in 96 of 994 sessions with available session data (9.7%; DiSCoVR $n = 59$, 13.2%; VRelax $n = 37$, 7.2%). Further protocol fidelity data can be found in the supplementary materials (table 6).

Discussion

In this RCT, we compared a VR-SCT (DiSCoVR) to an active control VR relaxation condition (VRelax), to investigate its effects on social cognition, social functioning, and other clinical outcomes. No significant treatment effects were found. An analysis of completers showed no relevant differences from the intention-to-treat analysis.

Efficacy of DiSCoVR

One way to interpret these results is that DiSCoVR does not improve social cognition. This could be due the treatment protocol and/or the use of VR. Other potential causes involve the study design and outcome measures.

While DiSCoVR was modeled after existing, effective SCTs and used established training principles such as

repeated practice and strategy use,[4] it is possible that it failed in the execution of these principles. Although the protocol stressed application of social cognitive strategies, exercises were possibly too broad or focused on other processes (eg, social anxiety, general social skills). Conversely, our exercises possibly adequately targeted social cognition, but processes other than social cognition (eg, anxiety) may have caused the social deficits observed by referring clinicians. Thus, (some) participants may not have shown improvement because they did not need SCT in the first place.

Another possibility is that our VR program inadequately simulated reality. In our pilot study, insufficient realism was a point of criticism.[20] Previous literature[45] has pointed out limitations in virtual facial emotions due to limited wrinkling in virtual faces. Virtual emotions mimic major traits of basic emotions, but might lack more subtle traits of natural facial emotions.[45,46] It is therefore possible that improvements in VR did not generalize due to insufficient resemblance to real-world emotions. Given that virtual stimuli were the main training material, more advanced virtual emotions might be necessary. Nevertheless, a study of VR-CBT for paranoid delusions, using an older version of our virtual environments,[47] found large, generalized improvements in paranoia and social anxiety. In that study, a narrower range of exercises was used (ie, exposure in four daily environments), and an established therapeutic protocol. This could imply that not the realism, but rather the treatment goal and type of exercises performed in it, caused the lack of efficacy. For example, it is possible that VR is (currently) an appropriate tool to target emotions and cognitions, but not (yet) sufficiently realistic for improving perceptual processes.

It is also possible that DiSCoVR could have been effective, but that the treatment and study period was too short to observe meaningful changes. Furthermore, outcome measures may have been insufficiently sensitive to detect improvements, particularly the TASIT. Factor analysis showed the TASIT to be on a separate factor from simpler, perceptual social cognitive tasks (eg, Ekman 60 Faces). The authors concluded that TASIT may be more ecologically valid and representative of complex, higher-order mentalizing abilities than text-based ToM tasks such as the Hinting Task.[48] Notably, SCT studies reporting improvements in ToM have most commonly used the Hinting Task[49–51] or similar tasks, while several found no effect on TASIT.[51–54] This raises the question whether tests that demonstrate higher-order social cognition improvements of SCT truly capture higher-order processes, and consequently, whether it is justified to conclude that SCT improves these.

Our null findings could also reflect inconsistencies in results of SCT in general. While improvements in social cognition have been found in meta-analyses, they are not ubiquitous in individual RCTs. Several did not find an effect on emotion perception[51,55–57] or ToM.[51,56–59] Effects of SCT are more pronounced for lower-order social cognitive processes than higher-order processes.[10] Thus, SCT has a bigger impact on processes requiring less integration of complex social information (eg, emotion perception) than relatively complex social cognitive processes. Another meta-analysis[60] found moderate effects of SCT on social cognition, but not on any domain of social functioning. It is therefore possible that SCT improves lower-order social cognition but fails to impact higher-order processes and social functioning. This does not explain the absence of lower-order social cognition improvements in this study, but it could explain the lack of effects on ToM, social functioning, and daily social interactions.

Strengths and Limitations

To the best of our knowledge, this was the first RCT on VR-SCT. The study had high methodological quality, as it included randomization, an active control group, the practice and evaluation of assessor blinding (though only partly successfully), regular supervision and consensus meetings, assessment of protocol fidelity and assessor blinding, and sensitivity analyses. This study was also unique in its use of ESM, providing novel insight in effects of SCT on daily life.

The COVID-19 pandemic negatively impacted recruitment, leading to failure in reaching our planned sample size. Drop-out rates were higher than anticipated; our a priori estimate of 13% dropout may have been too low, as similar trials reported higher drop-out rates (eg, 24%–28%[59]). While insufficient statistical power could explain statistical insignificance, most outcomes showed trivial mean score differences, suggesting a genuine absence of effects. The pandemic also affected enrolled participants, since face-to-face meetings and societal activities were restricted, affecting treatment, outcome assessment and possibly treatment outcomes. Finally, we did not use the recommended SCOPE measures,[61,62] because they were not validated in Dutch. We cannot rule out that our measures were insufficiently sensitive or reliable to find effects.

Implications for Clinical Practice and Future Research

While pilot studies have found encouraging results for VR-SCT, in this first RCT, it failed to live up to its promise. Since it is unclear why, it is premature to draw conclusions about the merit of VR for SCT.

Directly adapting an established protocol to VR (eg, Social Cognition & Interaction Training[51,57,63,64]), utilizing the same measures of social cognition, a similar sample, and both "conventional" SCT and treatment as usual control groups, could further elucidate the merit of VR as a tool. To evaluate different forms of SCT, it is important to standardize measurements, eg, using SCOPE[62]

measures. Standardization of treatments and assessment could also facilitate investigation of therapeutic mechanisms. Finally, the use of ESM could provide more insight in generalization to daily life social interactions.

The mixed findings regarding generalization to social functioning[60] raise important questions regarding the efficacy and utility of SCT. More research is therefore needed to investigate effective components of SCT and how SCT impacts social functioning. The relationship between social cognition and social functioning is complex and involves several other, mutually interacting variables, such as motivation,[65] negative symptoms,[66] neurocognition,[67] and self-efficacy.[68]

Therefore, as has been shown for CRT,[69] integration of SCT with other treatments may be necessary, such as CBT, CRT, behavioral activation, and/or psychosocial rehabilitation programs such as Individual Placement and Support.[70] Ultimately, focusing on any single process may be insufficient, as social dysfunction is caused by an interplay of many different factors. A more holistic approach may be necessary, and whether or how SCT fits into this approach, requires further investigation.

Supplementary Material

Supplementary material is available at https://academic.oup.com/schizophreniabulletin/.

Acknowledgments

W.V. is cofounder, chief scientific officer, and shareholder of VRelax BV, the company that has developed VRelax. The remaining authors declare no potential conflicts of interest. We thank all participants and therapists, and our research assistants/coordinators, particularly Meike Bak, Bart Lestestuiver, Lisa van Os, and Jordi Lander, for their efforts.

Funding

This work was supported by the Nederlandse Organisatie voor Wetenschappelijk Onderzoek (Dutch Research Council) (grant 628.005.007); GGZ Drenthe funded the position of S.A.N., study supplies and a research assistant; and the University of Groningen funded participant compensation (staff grant). These organizations played no further role in this study.

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