A systematic review on improving cognition in schizophrenia: which is the more commonly used type of training, practice or strategy learning?

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Abstract

Background: The purpose of this article was to conduct a review of the types of training offered to people with schizophrenia in order to help them develop strategies to cope with or compensate for neurocognitive or sociocognitive deficits.

Methods: We conducted a search of the literature using keywords such as “schizophrenia”, “training”, and “cognition” with the most popular databases of peer-reviewed journals.

Results: We reviewed 99 controlled studies in total (though nine did not have a control condition). We found that drill and practice training is used more often to retrain neurocognitive deficits while drill and strategy training is used more frequently in the context of sociocognitive remediation.

Conclusions: Hypotheses are suggested to better understand those results and future research is recommended to compare drill and strategy with drill and practice training for both social and neurocognitive deficits in schizophrenia.

Keywords: Schizophrenia, Explicit, Implicit, Training, Cognition, Sociocognition, Neurocognition

Background

About 80% of individuals with a diagnosis of schizophrenia struggle with a variety of neurocognitive and sociocognitive deficits [1,2]. The neurocognitive domains typically affected include speed of processing, attention/vigilance, working memory, verbal learning, reasoning and problem solving [3,4], whereas social cue perception, affect recognition, attribution, and theory of mind are the sociocognitive domains most affected [5,6]. Cognitive dysfunctions are considered to be core features of schizophrenia, since they are strongly correlated with poor functional outcome [7-9] as well as being better predictors of general outcome and rehabilitation than positive symptoms [10,11]. Although pharmacological and psychological treatments can effectively reduce [12] positive symptoms of schizophrenia, they do little to improve cognition [7]. Thus, using cognitive retraining or remediation to create significant improvements has received more attention in recent years [7,13]. According to T Wykes, V Huddy, C Cellard, SR McGurk and P Czobor [14], there are two types of training: 1) “drill and practice,” where there is no explicit component, meaning that learning is based on repeating a task that becomes gradually more difficult and where participants implicitly learn the strategy by trial and error, and 2) “drill and strategy,” where the focus is to teach the explicit use of a determined strategy (see also [12]). While explicit learning impairments have been consistently reported in schizophrenia literature [15,16], there is still a debate over impairments to implicit learning. For example, some studies report that implicit learning is intact for tasks such as probabilistic classification learning (e.g., [17]), weather prediction (e.g., [18]), and artificial grammar learning (e.g., [19]), while others report an impairment in colour pattern learning but not in letter string learning [20]. Adding to this conundrum are a variety of different training procedures currently being tested, both for drill and strategy (includes explicit and implicit
learning) and for drill and practice (implicit learning only). These training procedures focus on a variety of different targets therefore, in this review, we will focus on neurocognitive and sociocognitive domains. For this reason we will not include studies aiming solely to reduce positive or negative symptoms or to improve upon social skills. Contrary to the recently published meta-analyses focusing on efficacy of cognitive training [14,21], this review will analyze and describe which training paradigms were most used to improve neurocognitive and sociocognitive deficits, whether they be drill and practice or drill and strategy methods.

Methods

Review protocol

Inclusion criteria: 1) outcome: either neurocognition or sociocognition, 2) date and journal: peer-reviewed journals from 1995 up to 2013, 3) language: English or French, 4) diagnosis: majority (≥70%) of participants with a schizophrenia diagnosis (others include schizoaffective disorders and first-episode psychosis). We excluded all training types that aimed solely to reduce positive or negative symptoms, improve social skills, increase metacognition, etc. Nevertheless, studies that targeted sociocognition or neurocognition while also aiming to reduce symptoms or improve social skills as secondary objective, were included. Finally, we removed studies that used the training or remediation for evaluation rather than for treatment (i.e., studies assessing the deficits at baseline with no intention of remediation or intervention) as well as meta-analyses and reviews. Our goal was to review studies that had a therapeutic outcome. Since the main objective of our article is to provide a descriptive listing of the training offered and not to conduct an efficacy analysis, we included studies that did not have control conditions. Given the large number of articles included (n = 99), and the fact that our definitions of the types of training were inclusive, the first three authors read, classified, and compared their ratings for each article to ensure reliability of the results. Articles were classified in two categories, according to the targeted deficits: i) Sociocognitive, which included topics such as emotional recognition, Theory of Mind, attributional style, and social cue recognition; ii) Neurocognitive, which included areas such as executive functioning, memory and attention. Importantly, social functioning was excluded from the dichotomy of classification as most, if not all studies, ultimately aim to improve upon work and functional outcomes of individuals. Furthermore, we compared the results of our literature search with articles listed in the meta-analyses of T Wykes, V Huddy, C Cellard, SR McGurk and P Czobor [14], O Grynszpan, S Perbal, A Pelissolo, P Fossati, R Jouvent, S Dubal and F Perez-Diaz [22] and A Medalia and AM Saperstein [23] to ensure that we did not miss any relevant articles.

Article retrieval

We conducted a literature review using the following databases: PsychINFO (1995 to May 2013), MEDLINE (R) (1995 to May 2013) and MEDLINE Daily Update (R). Using the title keywords “schizophrenia and (training or remediation or intervention or practice) and (soci*c or neuro*c or cogniti*c or metacogniti*c or problem-solving or visual or memory)”, we obtained 465 results from all databases. To ensure further precision we added the following filters: a) “limit to English and French language” (to ensure understanding of the content) which yielded 172 results, b) “limit to peer-reviewed journals” resulting in 164 results. The final manipulation was to remove all duplicates, which left us with a total of 121 articles to investigate. Upon final removal of all articles that did not meet our criteria, we reviewed 99 articles. The last date of search for articles was January 2014.

Results

Results are presented in Tables 1, 2 and 3, divided according to the aim of the studies: improving neurocognitive deficits, sociocognitive deficits or both. These were further subdivided by either drill and practice or drill and strategy training methods. First, we will describe the studies that focus on a single area of cognition (i.e., Table 1 for neurocognition and Table 2 for sociocognition) as treatment targets and that used a single training type (drill and practice or drill and strategy). Then, we will describe the results of studies with multiple aims in terms of neurocognitive and sociocognitive deficits (Table 3). There is an important distinction to be made between the targeted deficits – which is how we classified the studies between neurocognition, sociocognition, or both – and the measured variables. Indeed, it is often the case that a variable is measured to assess the impact of the training without having been specifically targeted by the training, which, therefore, gives a sense of the generalization of the results. As seen more explicitly in Table 2, many of the studies aiming to improve sociocognition also measure the impact of the training on more neurocognitive variables.

Neurocognitive deficits

We identified a total of 62 studies pertaining to neurocognitive training. Of these, 58 included randomized controlled trials or placebo conditions, while four had no control. At first glance (see Table 1), it appears that for people with schizophrenia drill and practice training is used more frequently to train neurocognitive deficits (i.e., drill and practice = 35 studies, 33 with controls and two without; drill and strategy = 27 studies, 25 with controls and two without).

Examining the drill and strategy studies, a pattern rapidly emerges when the methods of training are considered.
### Table 1 Training to improve neurocognitive deficits

| Authors | Targeted deficits | Type of training | Measured variables | Results | Control and samples |
|---------|------------------|------------------|--------------------|---------|---------------------|
| [24]    | Memory and problem solving | Cognitive Remediation (CR) and Treatment-As-Usual (TAU) | Psychiatric symptoms | Both CR groups improved on the Positive, negative and general psychopathology subscales but also on the Positive and Depression factors | Control group N = 54 |
| [25]    | Autobiographical memory | Group therapy and exercises to recollect specific events | Autobiographical memory, executive functioning | Improvements on the variables that were preserved after 3 months | Placebo group N = 27 |
| [26]    | Cognitive deficits, and transfert to functional competence | CR + Skills training CR + TAU Skills training + TAU | Cognitive performance (reasoning, problem solving, processing speed, verbal memory, working memory) Social competence, functional competence, real-world functional behaviour | CR produced robust improvements in neurocognition, but not after functional skills training. Social competence improved with both trainings. Functional competence and real-world behavior was more likely when supplemental skills training and cognitive remediation were combined. | Control group N = 107 |
| [27]    | Neurocognition and transfert to social competence | CR and Functional Adaptation skills training (FAST). Control: FAST or CR | Functional competence, information processing, verbal fluency, working memory, executive functioning, verbal memory | The early-course group had larger improvements in measures of processing speed and executive functions, adaptive competence and real-world work skills. Verbal memory, verbal fluency and social competence did not improve | None N = 39 |
| [28]    | Neurocognition at large | CR and one-on-one training and guided practice | Attention, working and episodic memory, executive functioning, processing speed, everyday community functioning | No improvements were found | Placebo group N = 69 |
| [29]    | Psychiatric symptoms and cognition (episodic memory and attention) | Neurcognitive Enhancement Therapy (NET) + Work therapy and Verbal memory task based on a dichotic listening (DL) with distracter paradigm NET + Work therapy alone | Symptoms, attention and memory | Significant effect on memory but not on attention or symptoms. nor at 6 months follow up | Control group N = 125 |
| [30]    | Attention, memory and executive functioning | CR and group therapy | Verbal learning and memory, executive functioning, visual learning and memory, depression, positive and negative symptoms | Significant improvements in neuropsychological functioning, depression and negative symptoms of schizophrenia after CRT | Control group N = 42 |
| [31]    | Executive functioning | Cognitive Adaptation Training (CAT) applied to integrated treatment (IT) consisting of assertive community treatment (ACT) | Social functioning, symptoms and quality of life, executive functioning | Improved social functioning and compliance with IT and ACT. No solid evidence demonstrating that IT improves when adding CAT | Control group N = 62 |
### Table 1 Training to improve neurocognitive deficits (Continued)

| [32] | Verbal and visual memory, sustained attention and executive functioning | CR with Neuropsychological Educational Approach to Remediation (NEAR) | Processing speed, executive functioning, sustained attention, verbal memory, visual memory, reasoning/cognitive flexibility, social/occupational functioning, life skills, quality of life, self-esteem | Experimental group showed improvement in all variables, gains maintained after 4 months | Control group N = 40 |
| [33] | Verbal memory, working memory, motor speed, verbal fluency, attention, processing speed and executive functioning | CR with NEAR | Verbal memory, working memory, motor speed, verbal fluency, attention and speed of information processing, executive functioning | Improvement in all outcomes compared to control with CR | Control group N = 51 |
| [34] | Cognitive deficits to improve work outcomes | Errorless learning Conventional instruction | Work performance, job tenure, personal well-being (self-esteem, job satisfaction, work stress) | The patients in the errorless learning group performed better on work performance | Control group N = 40 |
| [35] | Neurocognition at large | Cognitive (CR) and supported education | Self-esteem, short term memory, verbal learning and memory, executive functioning, sustained attention, psychomotor speed, educational attainment | CR can be successfully integrated into an educational setting, Improvements in concentration, learning, some aspects of executive functioning, psychosis symptomatology | None N=16 |
| [36] | Cognitive deficits to improve work outcomes | Thinking Skills for Work Program (TSWP) + Supported Employment (SE) and Supported Employment only | Attention, psychomotor speed, information processing speed, verbal learning and memory, executive functioning, premorbid academic achievement, symptoms, employment outcomes | For TSWP+SE, improvement in executive functioning and in the composite cognition score. Improved significantly more on Depression and Autistic preoccupation (symptoms). Participants were significantly more likely to work, worked more hours and earned more wages | Control group N = 44 |
| [37] | Cognitive deficits to improve work outcomes | Thinking Skills for Work Program (TSWP) + Supported Employment (SE) and Supported Employment only | Work outcomes | In TSWP+SE, over 2-3 years, participants were more likely to work, held more jobs, worked more weeks, worked more hours, and earned more wages. Cognitive functioning and symptoms not assessed. | Control group N = 44 |
| [38] | Problem-solving | Computer-assisted problem-solving remediation (PS), memory remediation or TAU | Problem-solving, memory, verbal knowledge, independent living | PS improved problem solving skills | Control group N = 54 |
| [39] | Cognitive differentiation, social perception, communication, social skills, and interpersonal problem solving | Integrated Psychological Therapy (IPT) | Intellectual ability, memory, verbal fluency, executive functioning and psychosocial functioning | Improvement in memory and executive functioning for those with cognitive impairments | Control group N = 27 |
| [40] | Social functioning and neurocognitive deficits | CR and Cognitive Behavior Therapy (CBT) for control | Working memory, psychomotor speed, verbal memory, nonverbal memory, and executive functioning, and social functioning | Overall improvement in neurocognition especially in verbal and nonverbal memory and executive functioning. Improvement in social functioning | Control group N = 40 |
**Table 1 Training to improve neurocognitive deficits (Continued)**

| Study | Intervention Details | Intervention Content | Follow-up | Condition |
|-------|----------------------|----------------------|-----------|-----------|
| [41] Verbal and working memory, selective attention and semantic fluency | CR | Verbal and working memory, speed/coordination, selection attention, semantic and letter fluency, executive functioning, sustained attention, interpersonal relations, instrumental role, self-directedness | 3, 6 and months follow up | Placebo condition N = 100 |
| [42] Memory and executive functioning | One program including 1) paper-and-pencil training, 2) computer exercises | Visual attention, cognitive flexibility, sustained attention, inhibition, working memory, long-term verbal memory, executive functioning, planning | CR showed improvements in neuro- and socio-cognitive functions but not on arousal or cognitive flexibility | Placebo group N = 59 |
| [43] Attention | Attention Process Training (APT) and attention-shaping procedure after | Verbal learning, sustained attention | Dramatic improvement in attentiveness in APT but attention-shaping procedure appears to account for the change | Control group N = 31 |
| [44] Neurocognition linked to social competence and behavior | Integrated Psychological Therapy (IPT), supportive therapy and TAU | Social competence, pre-attentional processing, attention, memory, executive functioning and symptoms | IPT improved social competence only | Control group N = 90 |
| [45] Memory, attention, vigilance, executive functioning | CR alone or CR+ pharmacotherapy | Attention, learning, memory, executive functioning, functional capacity, negative symptoms, subjective quality of life | CR improved verbal and visual memory at 3 months, not maintained at 6 months. Verbal learning, executive functioning and attention improved at 6 months. Quality of life improvements at 3 months, increased at 6 months | Control group N = 38 |
| [46] Cognitive deficits and negative symptoms | Cognitive strategy training (CAST) and training of self-management skills for negative symptoms (TSSN) | Attention, verbal memory and planning, social withdrawal/social anhedonia, lack of drive, affect flattening | CAST=Greater improvement on attention and verbal memory but not planning ability. Higher job placement TSSN=no improvement in negative symptoms | Control group N = 138 |
| [47] Memory, cognitive flexibility and planning | Neurocognitive remediation and intensive occupational therapy (control) | Cognitive flexibility, planning and working memory. Social behaviour, self-esteem | Improvements in cognitive flexibility and working memory no changes in symptoms or social functioning, 6 month follow up | Control group N = 33 |
| [48] Memory, cognitive flexibility and planning | CR and Intensive occupational therapy | Memory, working memory, cognitive flexibility, response inhibition, planning, symptoms and functioning, self-esteem | Effects of CR at follow-up are still significant on working memory, there were no more effects on self-esteem, 3 and 6 month follow up | Control group N = 33 |
| [49] Memory, cognitive flexibility and planning | CR and TAU | Working Memory, cognitive flexibility, and planning. Secondary: self-esteem, positive and negative symptoms, social functioning | Improvement in working memory and cognitive flexibility. Memory improvement predicted improvement in social functioning. | Control Group N = 85 |
| [50] Memory, cognitive flexibility and planning | CR with remembering, complex planning, problem-solving and TAU | Memory, cognitive flexibility, planning, social behaviour, quality of life, self-esteem | CR improved cognitive flexibility, social functioning, 14 et 18 weeks follow up | Control group N = 40 |
| DRILL AND PRACTICE | Neurocognitive deficits | Working memory deficits | Cognitive deficits to improve work outcomes | Attention, memory and executive functioning | Functional outcomes (follow up study using the same NET program so classified here instead of in Table 2) | Neurocognition, negative symptoms, self-esteem | Repetition and memory | Attention/ concentration, working memory, logic, and executive functions | Cognitive deficits | Executive functioning (and metacognition) | Attentional deficit |
|-------------------|-------------------------|------------------------|------------------------------------------|---------------------------------------------|-------------------------------------------------|-----------------------------------|-----------------|-------------------------------------------------|-----------------|---------------------------------------------|-----------------|
| [51]              | Neurocognitive enhancement therapy (NET) & working therapy (WT) | Cognitive flexibility, social inference, emotion recognition, abstract thought, verbal learning, memory | NET + WT greater improvements in executive functioning, working memory and affect recognition | Control group N = 65 | [52] Working memory deficits | CR and working therapy (WT) | Attention, memory and executive functioning | CRT+WT yield greater improvements and effects remain over time (6 months) | Control group N = 102 | [53] Cognitive deficits to improve work outcomes | Neurocognitive enhancement therapy (NET) + work therapy | Work productivity (hours and dollars earned) | Patients worked more hours, had more dollars earned and tended to have more competitive-wage employment | Control group N = 145 | [54] Attention, memory and executive functioning | Neurocognitive enhancement therapy (NET) + Work therapy Work therapy alone | Working memory, verbal and nonverbal memory, thought disorder, executive functioning | Significant improvements in working memory and executive functioning. Both groups had a significant effect on memory (verbal and visual) | Control group N = 145 | [55] Functional outcomes (follow up study using the same NET program so classified here instead of in Table 2) | Neurocognitive Enhancement Therapy (NET) + Vocational program (VOC) | Work hours, employment rates | NET+VOC patients worked more hours during the 12 month follow-up period and they had higher rates of employment | Control group N = 72 | [56] Neurocognition, negative symptoms, self-esteem | Computer-assisted cognitive rehabilitation (CACR) | Attentional deficit, verbal and auditory memory, general level of cognitive functioning, negative symptoms, self-esteem | CACR improved verbal/ conceptual learning and memory and executive functioning | Placebo group N = 34 | [57] Repetition and memory | Virtual reality training | Orientation, attention, calculations, constructions, memory, language, and reasoning | Improvement of overall cognition | Control group N = 27 | [58] Attention/ concentration, working memory, logic, and executive functions | CR | Attention/Vigilance, verbal/non-verbal working memory, verbal and visual learning and memory, speed of processing, reasoning, problem-solving, quality of life and social autonomy | Improvements in attention/ vigilance, verbal memory, problem solving | Control group N = 77 | [59] Cognitive deficits | Pharmacotherapy and cognitive retraining (CR) together 1) drug+CR, 2) drug + control CR, 3) placebo + CR, 4) placebo+control CR | Verbal working memory, attention/Vigilance Measures of tolerability and safety | CR- significant improvement in verbal working memory. Trend toward improvement in Attention/Vigilance | Control groups N = 104 | [60] Executive functioning (and metacognition) | Problem Solving and Cognitive Flexibility training (REPFLECF) | Verbal and visual memory. cognitive flexibility, inhibition of impulsive responses, planning and organization, working memory and time-estimation capacity, attention, processing speed and cognitive flexibility social behavior and relationships, autonomy, employment- occupation and leisure, self-care, social behavior and autonomy | Significant improvements in executive function, negative symptoms and Positive change in life skills and psychosocial functioning. Skills maintained at follow-up especially in self-care, social behavior and employment-occupation. | Control group N = 62 | [61] Attentional deficit | Computer-Assisted cognitive rehabilitation or computer games | Various measures of attention such as trail making, letter-cancellation, Stroop, teach-a-word, etc. | Both groups improved in letter-cancellation task due to practice effect | Control group N = 10 |
| [62] | Verbal and global cognition | Auditory training | Global cognition, speed of processing, verbal memory/learning, problem-solving, nonverbal memory, visual learning/memory, social cognition | Strong improvement in verbal and global cognition | Placebo group N = 55 |
| [63] | Cognition in general | Targeted cognitive training (TCT) | Global cognition, speed of processing, verbal working and learning memory and cognitive control | TCT improvements in verbal learning/memory and cognitive control even 6 months after therapy | Control group N = 32 |
| [64] | Cognitive deficits in memory | Computerized cognitive remediation training - digits sequenced recall and words sequenced recall (control: work therapy only) | Cognitive deficits, more specifically memory | Significantly greater improvements on the computerized memory task (digits sequenced recall) remained at the 6 month follow up | Control group N = 94 |
| [65] | Memory, attention, cognitive flexibility | Vocational Program (VOC) and NET+VOC | Cognitive flexibility and executive functioning, working memory, visual and verbal memory, social cognition | VOC+NET greater improvement on all outcomes. No improvement in affect recognition after 1 year | Placebo group N = 72 |
| [66] | Neural correlates of emotion identification | Training of Affect Recognition (TAR) and TAU | Emotion identification, emotion discrimination, digit symbol, digit span, symptoms, neural activation | TAR improved performance in emotion recognition and discrimination more than TAU and controls. Psychopathological status improvements for both TAR and TAU | Control group and healthy controls N = 30 |
| [67] | Effects of age on cognitive functioning | CR and TAU | Working memory, cognitive flexibility and planning. Groups split on age | CR improved working memory only in younger group | Control group N = 134 |
| [68] | Cognitive functioning in general | CR and computer-skills training | Working memory, verbal episodic memory, speed of processing, visual episodic memory, reasoning and problem-solving | CR improved working memory but both groups showed improvement on other measures | Placebo group N = 42 |
| [69] | Cognitive functioning in general | CR | Attention, psychomotor speed, verbal working memory, verbal learning and memory and executive functioning, information processing speed, academic achievement | Cognitive remediation improvements in overall cognitive functioning, psychomotor speed, and verbal learning | Control group N = 85 |
| [70] | Cognitive functioning Attention Process Training (AFT) | Attention and negative symptoms | Attention, memory and executive function | Neither group improved in symptoms and attention and memory measures. APT group had higher performance on executive function | Placebo group N = 24 |
| [71] | Continuous Performance Test (CPT) | Attention and negative symptoms | CPT improved both measures | Control group N = 54 |
| [72] | Memory | Memory remediation (MR), problem-solving remediation and TAU | Memory, verbal learning, problem-solving | MR improved memory but not verbal recall | Control group N = 54 |
| [73] | Cognitive impairment Brain Fitness Program (BFP) | Cognitive performance (CogStat) Functional capacity, auditory processing speed for verbal and non-verbal tasks | BFP training improved auditory processing speed but no effect on cognitive impairments | None N = 55 |
| [74] | Divergent thinking Rock-paper-scissors task, calculation tiles task | Idea, design and letter fluency, digit span, social functioning | Improvements in idea fluency, functioning, and interpersonal relations | Control group N = 17 |
Table 1 Training to improve neurocognitive deficits (Continued)

| [74] | Visual motion processing | Target discrimination | Perceptual motion and direction processing | Greater perceptual improvement in schizophrenia | Healthy controls N = 27 |

| [75] | Cognitive and daily functioning deficits (but concentrating on the neurobiological mechanism that underline them) | CR and Social Skills Training | Functional and structural connectivity brain changes | Brain networks activation pattern significantly changed in patients exposed to the cognitive treatment in the sense of normalizing toward the patterns observed in healthy control subjects | Control group N = 30 |

| [76] | Dysfunctional organization of the auditory/verbal system | Targeted auditory/verbal discrimination Training (TAD) or CRT (CogPack) | Verbal learning and fluency, recall, working memory, clinical symptoms as exploratory measure | Improvement in verbal learning and memory for TAD but no effect on clinical symptoms | Control group N = 39 |

| [77] | Brain oscillatory activity, linked to dysfunctional information processing | Specific cognitive exercises (CE) fostering auditory/verbal discrimination or standard broad-range cognitive training (CP) | Verbal memory, global functioning, brain oscillatory activity | CE improves brain oscillatory activity and reduces information processing dysfunction | Control group and healthy controls N = 51 |

| [78] | Verbal memory and learning, processing speed, working memory and attention | CR | Verbal memory, visual working memory, visuospatial memory, processing speed, psychomotor speed, working memory, verbal fluency, attention, visual-perceptual function | Patients in all groups improved in measures of information processing, verbal memory, and visuospatial memory | One placebo group and one control group N = 44 |

| [79] | Cognitive deficits | CR (Cogpack) | Memory functions, attention, concentration, logical abilities, verbal reasoning | Cogpack improves cognitive functioning in persons at risk. Specifically at risk group improve in long-term memory functions, attention, and concentration. Patients with schizophrenia – no improvement. | Control group N = 16 schizophrenia N = 10 at risk |

| [80] | Planning and problem-solving, processing speed, memory and attention | Plan-a-day And Training for basic cognition | Planning ability, problem-solving, global assessment, functional capacity, working memory, verbal memory, processing speed and inhibition | Both groups improved in measures of cognitive functioning and functional capacity. Plan-a-day improved planning | None N = 89 |

| [81] | Verbal learning and processing speed | CR | Word fluency, memory and recall, | All outcomes improved in CR | Control group N = 42 |

| [82] | Impairment in reality monitoring | CR | Reality monitoring Prefrontal cortex activity | Improvement in reality monitoring that correlated with increased medial prefrontal cortex activity (related to improvement in social functioning 6 months later) | Control group N = 31 (schizophrenia) N = 15 healthy controls |

| [83] | Visual and auditory learning | CR consisting of visual, auditory and cognitive control | Visual memory, visual-spatial memory, auditory verbal memory, verbal and letter learning | Visual training strongly predicts visual learning but not auditory learning | Placebo control N = 14 |

| [84] | Perceptual, memory and motor functions | Sustained and repeated training with no instructions, increasingly demanding tasks | Visual word, visual dot localization, motor processing | After training, most participants performed as well or better than best controls on tasks | Control group and healthy controls N = 22 |

Note. CR = cognitive remediation. NEAR = Neuropsychological Educational Approach to Remediation. TAU = treatment-as-usual, NET = Neurocognitive Enhancement Therapy.
| Authors                          | Targeted deficits                  | Type of training                                      | Measured variables                                                                 | Results                                                                                           | Control and samples |
|---------------------------------|------------------------------------|-------------------------------------------------------|-------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|---------------------|
| [85]                            | Social context appraisal           | Social cognition enhancement training (SCET) and standard psychiatric rehab | Perceptual organization and sequencing in social contexts, emotion recognition       | In SCET, some variables improved after 2 months, others after 6 months                           | Control group N = 34 |
| [86]                            | Social cognition deficits          | social cognition and interaction training (SCIT) and Control: coping skills groups | Emotion and social perception, theory of mind, attributional style, cognitive flexibility, and social relationships | Improved in all sociocognitive measures. Better self-reported social relationships               | Control group N = 28 |
| [87]                            | Emotion perception, attributional style, and theory of mind | SCIT and coping skills groups | Facial emotion identification and discrimination, social perception, theory of mind, attributional style and ambiguity, cognitive flexibility | Improvement in all aspects for participants in SCIT                                                | Control group N = 18 |
| [88]                            | Social cue recognition             | Vigilance+memory training or vigilance alone          | Social cue recognition                                                               | Better recognition of social cues in vigilance+memory                                            | Control group N = 40 |
| [89]                            | Emotional intelligence             | Cognitive enhancement therapy (CET) and enriched supportive therapy (EST) | Emotional Intelligence                                                               | CET group improved in emotional intelligence                                                      | Control group N = 38 |
| [90]                            | Learning and interpretation of social situations | Stimulus identification, interpretation of images and assignment of title | Sustained and selective attention, functional outcome, social perception             | Improvement in all variables in therapy group, maintained at 6 months                             | Control group N = 18 |
| [91]                            | Perception and interpretation of social situations | Integrated Psychological Therapy (IPT) | Social perception, attention, psychopathology and social functioning | IPT improved social perception. No differences in attention or symptoms between groups           | Control group N = 20 |
| [92]                            | Emotion perception                 | Emotion Management Training (EMT) or problem-solving | Emotion perception in self and others, social adjustment, coping strategies, psychopathology | EMT improved emotion perception, social adjustment and psychopathology. At 4 month follow up, gains maintained in social adjustment and psychopathology only | Control group N = 22 |
| [93]                            | Social cognitive skills            | Presentations, group practice and training exercises | Facial emotion identification, social perception, attributional style, theory of mind, speed of processing, attention/vigilance, working memory, verbal and visual learning, reasoning, problem-solving and social cognition | Improvement in facial affect perception only                                                      | Control group N = 31 |
| [94]                            | Social cognitive deficits          | Socio-cognitive skills training (SCST) Other conditions 1: Cognitive Remediation (CR) 2: standard illness management skills training, 3: Hybrid treatment that combined elements of SCST and neurocognitive remediation | Emotional processing, social perception, attributional bias, and mentalizing           | The SCST group demonstrated greater improvements over time than comparison groups in the social cognitive domain of emotional processing, including improvement in measures of facial affect perception and emotion management. | Control group N = 68 |
| [95]  | Theory of Mind (ToM) | Analyses and reasoning about social interaction scenes | ToM, symptoms, psychopathology, attribution | Slight improvement in ToM (not significant) in training group from first to second training session. No improvement in symptoms | Control group N = 14 |
| [96]  | Emotion perception | CR and computerized Emotion Perception intervention compared with CR only | Emotion recognition, emotion discrimination, personal and social performance (also neurocognition) | Combined CR with emotion perception remediation produced greater improvements in emotion recognition, emotion discrimination, social functioning, and neurocognition | Control group N = 59 |
| [97]  | Emotion recognition and ToM | Emotion and ToM Imitation Training and problem-solving | Psychopathology, symptoms, emotion recognition, ToM, neurocognition, flexibility, social functioning, attribution, neurophysiological activation | Training improved sociocognition (strongest was emotion recognition) and social functioning | Control group N = 32 |
| [98]  | Social cognition | State reasoning training for social cognitive impairment (SOCog-MSRT) | Theory of mind, Social understanding, Inference of complex mental states from the eyes Working memory, IQ | Improvement in ability to reason causally about false beliefs, to infer complex mental states from the eyes, and to intuitively understand social situations. However individuals with poorer working memory and lower premorbid IQ did not benefit | None N = 14 |
| [99]  | Social cognition | SCIT | Emotion perception, attributional style and theory of mind | Improved emotion perception, improved theory of mind, and a reduced tendency to attribute hostile intent to others | None N = 17 |
| [100] | Emotion perception, ToM and social skills | SCIT and Treatment-As-Usual (TAU) | Emotion perception, theory of mind, attributional style, social skills in role-play | SCIT+TAU improved emotion perception but improvements on theory of mind inconsistent | Control group N = 31 |
| [101] | Visual attention and facial emotion perception | CR and repeated exposure | Emotion recognition | Improvements in pre-post- means for CRT and maintained one month post-training | Control group N = 40 |
| [102] | Emotion recognition and social perception | Social Cognitive Training Program and TAU | Emotion recognition, psychopathology, social functioning, social perception | Training improved social perception between group but no improvement in emotion recognition | Control group N = 14 |
| [103] | Emotional communication, (Perception of facial emotional expression) | Computerized emotion training program | Identification of emotions, differentiation of facial emotions, working memory | Compared to baseline significantly better at identification of facial emotions. No changes in differentiation of facial emotions and working memory | None N = 20 |
| [104] | Social cognition and quality of life | Family-social-cognition and social stimulation (F-SCIT) | Memory, visual-spatial scanning, divided attention, inhibition, emotion perception, theory of mind, empathy, reasoning, attributional style, insight, social functioning, quality of life | F-SCIT improved social withdrawal, interpersonal communications, prosocial activities, independence/competence, theory of mind, emotion perception | Control group N = 52 |
Twelve of 27 studies used group therapy in their training rather than individual computerized training with therapist assistance. However, there does not seem to be a link between the method of training (individual or group) and the outcome measures. Though it is not the goal of our review, it is important to note that all articles with drill and strategy approaches to training reported between-group improvements of the targeted deficits. Furthermore, eight of the 17 studies with follow up measures at either three, four or six months also reported sustained gains in cognition.

Drill and practice studies most commonly used computerized tasks, done individually. However, there was more variety in the methods of training, for example, at least five studies used pencil-and-paper procedures [60,67,69,73,75]; though Lopez-Luengo utilized both pen-and-paper and audio while five others used a combination of audio and visual tasks [62,63,77,78,83] to reduce the deficits. Furthermore, most studies using drill and practice methodologies (all except [61,69]) reported between-group improvements in cognition between the experimental and control groups, at least for some measures.

The studies we analyzed targeted a variety of neurocognitive deficits - memory, attention/vigilance, reasoning, verbal learning - yet overall, across studies, no single deficit stood out as being resistant to implicit training. Therefore, it would seem that most domains of neurocognition respond well to drill and practice training, even though only seven studies had follow ups at six months, six [52,55,60,63,64,82] confirming that the gains were maintained and one [65] showing that only the affect recognition benefits were not maintained at the 1-year follow up.

### Sociocognitive deficits

In contrast to studies focusing on neurocognition, those aiming to improve sociocognitive deficits used mostly drill and strategy approaches (i.e., drill and practice = two studies with control groups; drill and strategy = 21 studies, 18 with controls and three without). Importantly, all studies included a variety of visual aids such as vignettes, Powerpoint presentations or videos of social situations. Furthermore, visual presentations and explanations by the therapist about the goal of the training were often done in group settings. This method allows modelling by the therapist but also incorporates group exercises and practice as well as role-plays.

Interestingly, for sociocognition, whether the training paradigm was drill and strategy (e.g. [97]) or drill and practice (e.g. [107]), there was a general concern to assess whether remediation of a specific type of deficit would generate generalizable results, not only to functional outcomes but also to broader domains of social cognition such as Theory of Mind.

### Studies that aimed to improve both neuro and sociocognition

It is more difficult to find a pattern in the types of training when the target deficits are broader and span across both neurocognitive (such as memory and attention) and sociocognitive domains (such as social perception and emotion recognition). However, most use drill and strategy paradigms that generally combine computer-assisted programs for neurocognition, and guided practice, modeling and role-play for sociocognition. There is also a mix of individualized and group approaches that seem, again, to follow the trend that neurocognition is trained individually while sociocognition is trained in groups, and

### Table 2 Training to improve sociocognitive deficits (Continued)

| Study | Methodology | Training | Outcome Measures | Placebo group N = | Control group N = |
|-------|-------------|----------|-----------------|-------------------|------------------|
| [105] | Social and emotion perception | CR | Emotion and general perception, attention, memory, executive functioning, visual processing, cognitive flexibility and interference | 42 | 77 |
| [106] | Deficits in facial affect recognition | Training of affect recognition (TAR) | Facial affect recognition, face recognition, and neurocognitive performance | | |
| Controls groups: (TAU or CR) | Patients under TAR (but not CRT or TAU) significantly improved in facial affect recognition. Patients under CRT improved in verbal memory functions. | | |
| [107] | Prosodic affect recognition, theory of mind | Training of Affect Recognition (TAR) and CR | Facial affect recognition, prosodic affect recognition, theory of mind, social competence in role-play | | |
| | | | Larger pre-post-improvements on TAR for all variables | | 38 |

Note: SCIT = social cognition and interaction training. TAU = treatment-as-usual. CR = cognition remediation.
Table 3 Training to improve both neuro- and sociocognitive deficits

| Authors | Targeted deficits | Type of training | Measured variables | Results | Control and samples |
|---------|-------------------|------------------|--------------------|---------|---------------------|
| [27]    | Social competence (interest, affect, fluency, clarity, focus) and neurocognition | Cognitive Remediation (CR) and Functional Adaptation skills training (FAST) Control: FAST or CR | Functional competence, information processing, verbal fluency, working memory, executive functioning, verbal memory | The early-course group had larger improvements in measures of processing speed and executive functions, adaptive competence and real-world work skills. Verbal memory, verbal fluency and social competence did not improve. | None N = 39 |
| [26]    | Cognitive deficits and functional competence deficits | CR + skills training CR + Treatment-As-Usual (TAU) Skills training + TAU | Cognitive performance (reasoning, problem solving, processing speed, verbal memory, working memory), Social competence, functional competence, real-world functional behaviour | CR produced robust improvements in neurocognition, but not after functional skills training. Social competence improved with both type of training. Functional competence higher and more durable with combined treatment. Functional competence and real-world behavior was more likely when supplemental skills training and cognitive remediation were combined. | Control group N = 107 |
| [108]   | Neurocognition, social cognition and symptoms | Cognitive Enhancement Therapy (CET) or Enriched Supportive Therapy (EST) | Neurocognitive ability and processing speed, social cognition and cognitive style, social adjustment and symptomatology | CET improved social cognition, cognitive style, social adjustment and symptomatology during first year and neurocognition benefits were after 2 years | Control group N = 58 |
| [109]   | Sociocognition: social and emotional perception, attention, concentration, verbal memory | One program including 1) CR for neurocognition + 2) Social Skills Training for sociocognition and TAU | Verbal and non-verbal memory, attention, memory, executive functions, verbal fluency, self-care, underactivity, slowness in task execution, social withdrawal, participation in family life, functional outcome | Better efficacy in all measures for combined program compared to usual program | Placebo group N = 60 |
| [110]   | Organization, comparison and organization, orientation in space, relations, social skills, integrative thinking | CR on specific areas: organization, social skills, categorization | Memory, thought process and self-concept, functional outcome | Experimental group showed improvements in cognitive abilities and daily functioning, no difference in self-concept | Placebo group N = 58 |
| [111]   | Sociocognition and neurocognition | Cognitive enhancement therapy (CET) or enriched supported therapy (EST) | Processing speed, neurocognition, cognitive style, social cognition, social adjustment and symptoms | 12 months: improvement in neurocognition and processing speed 24 months: Same as 12 months and increase in cognitive style, social cognition and social adjustment | Control group N = 121 |
| [112]   | Neurocognitive and social-cognitive deficits | Cognitive enhancement therapy (CET) Enriched supportive therapy (EST) | Processing speed, Neurocognition, social cognition, cognitive style, social adjustment | Significant effect of CET on measures of processing speed, cognitive style, social cognition, and social adjustment. Only the neurocognitive composite is not significant at 36 months follow-up compared to the two years follow-up. | Control group N = 106 |
Table 3 Training to improve both neuro- and sociocognitive deficits (Continued)

| Study Reference | Interventions                                                                 | Outcomes                                                                                           | Control Group |
|-----------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------|
| [113]           | Symptoms, social adjustment, social cognition, cognitive style, neurocognition processing speed | CR and enriched supportive therapy (EST)                                                           | N = 58        |
| [114]           | Neurocognition and sociocognition                                             | Computerized neuroplasticity-based auditory training and Social cognition training (SCT)           | None N = 19   |
| [115]           | Cognition (attention, memory), social perception, cognitive differentiation     | CR + psychoeducational programme                                                                 | N = 25        |
| [116]           | Cognitive differentiation, attention, memory and social perception             | CR                                                                                                 | N = 25        |
| [117]           | Social cognition and problem solving, planning and memory                      | Cognitive-emotional rehabilitation (REC) and Problem Solving Training (PST)                         | None N = 24   |
| [118]           | Selective and Sustained attention, memory, conceptualization abilities, cognitive flexibility, social perception, verbal communication, social skills, and interpersonal problem solving | Cognitive remediation component of IPT                                                               | N = 32        |
| [119]           | Selective and Sustained attention, memory, conceptualization abilities, cognitive flexibility, social perception, verbal communication, social skills, and interpersonal problem solving | Cognitive remediation component of IPT (IPT-cog) or computer-assisted cognitive remediation (CACR) Or rehabilitative interventions | N = 90        |
| [120]           | Attention, executive functioning, memory quality of life, interpersonal relations, social abilities, autonomy | CR and Standard Rehabilitation Training (SRT)                                                        | N = 86        |
| [121]           | Emotion recognition deficits in the neural                                    | Auditory-based cognitive training                                                                    | N = 22        |

DRILL AND PRACTICE

| Study Reference | Interventions                                                                 | Outcomes                                                                                           | Control Group |
|-----------------|-------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|---------------|
| [122]           | Verbal + working memory, psychomotor speed and coordination, selective and sustained attention, semantic and letter fluency, cognitive flexibility, daily functioning, interpersonal relations | CR + SRT improvements on executive function, attention and daily functioning                         | N = 86        |
| [123]           | Recognition of negative and positive emotions                                 | Greater pre-to-post intervention increase                                                            | N = 22        |

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Table 3 Training to improve both neuro- and sociocognitive deficits (Continued)

| mechanisms involved in emotion recognition | (AT) [Brain Fitness], social cognition training or non-specific computer games (CQ) | Poscentral gyrus activity (neural region known to support facial emotion recognition) | in postcentral gyrus activity during emotion recognition Results indicate that combined cognition and social cognition training impacts neural mechanisms that support social cognition skills. |

Note. CRT = cognitive remediation training, CBT = cognitive behavioral therapy, TAU = treatment-as-usual, MATRICS = Measurement and Treatment Research to Improve Cognition in Schizophrenia.

discussion

The purpose of this article was to review the type of training – whether drill and practice or drill and strategy – most often offered in clinical studies to people with schizophrenia to help overcome neurocognitive or sociocognitive deficits. We included articles with varying scientific value for both neurocognitive and sociocognitive training; nine of the 99 articles we reviewed had no control condition. However, since we are not presenting a thorough analysis of the efficacy or effectiveness of these training methods (see 14 for details, [22,23]), we opted to include them for descriptive purposes. Although we found a variety of training modalities offered, some more behavioral, some using computer training, real-life situations, indirect training, etc., we were able to determine if a training paradigm was drill and practice or drill and strategy in nature, and which of these methods was used more frequently to improve neurocognitive or sociocognitive deficits. We also planned to describe the patterns and modalities used to train the targeted deficits (i.e., neuro- or sociocognitive).

In our literature search, we found that drill and practice training programs were used more frequently for improving neurocognitive deficits. Of the 62 studies we reviewed, 35 used procedures that mostly involved errorless learning, a type of training where the degree of difficulty of the task increases with the performance of the participant and where no conscious effort is necessary to improve. Studies using drill and strategy (n = 27) seemed particularly interested in the impact of the training on other variables outside of neurocognition, such as symptoms and quality of life. This was not the case for the drill and practice approaches. Another difference was that studies using drill and strategy training almost always measured executive functioning (n = 15), whereas studies using drill and practice training did not. However, we could not determine whether one specific domain of neurocognition was more easily retrained than another with drill and practice vs. drill and strategy procedures. Furthermore, most studies were of short duration and only a few had follow up measures (e.g., drill and strategy n = 8 [25,32,37,41,45,47-49]; drill and practice n = 7 [52,55,60,63-65,82]. This could be improved upon in future studies, since it is difficult under these circumstances to decide whether the observed effects are maintained over time or not.

When attempting to put the findings on neurocognitive deficits into context, we wondered why drill and practice training would be used more often to retrain neurocognitive deficits. The answer may lie in the way these functions interact in our cognitive processes. Some domains, like attention and speed of information processing, seem more implicit by nature – the bottom-up approach. We could posit that these functions are not used consciously and a person would not need to inherently know “how” to use the functions; instead they would simply perform the task repetitively and unconsciously. However, this might imply that drill and practice procedures would only improve neurocognitive deficits, which might not be the case, as judged by the results reported in recent meta-analyses [14,22]. Furthermore, since implicit learning has been reported as being generally intact in schizophrenia [84], some, like Fisher and colleagues [62], suggest that high levels of repetition (e.g., more than 1,000 rehearsals) and a high percentage of reward schedule (e.g.: 85%), will allow for neurological improvements. Yet, studies using drill and strategy procedures in their training methods also seem to generate consistent positive outcomes – the top-down approach. Of note, Wykes and colleagues [14] suggested that drill and strategy training include elements that are explicitly learned (through modeling, explanation or role-play – the “strategy”) but also elements inevitably linked with repetition (the “drill”) and considered implicit learning, which might explain why they are effective.

Tentatively, we suggest that since drill and strategy learning is thought to allow better integration of the rules and, thus, greater association between the various training elements [122], changes in cognition tend to occur over time. Blairy and colleagues [25], who also reported long-lasting improvements on memory and executive functions after explicit training, hypothesized that participants learned to bind different aspects of the
experiment together and that it allowed for better consolidation in memory. Thus, at this time, we cannot draw a conclusion about whether certain domains of neurocognition respond better to one type of training over another. Further studies must be conducted, preferably comparing different forms of training with each other and adding follow up measures to assess whether the benefits of training remain stable through time.

Social cognition is considered by many researchers to have a strong relationship with positive functional outcomes [123,124]. Concurrently, the meta-analysis by McGurk [12] reported that programs using strategy coaching (drill and strategy training) for sociocognitive deficits had strong effects on functional outcomes as well as on the targeted social cognition skills. Consistent with this, we found that drill and strategy training was more frequently used for sociocognitive retraining. It seems intuitive that learning and integrating a social skill requires that it be practiced in a social setting, which was consistent with our findings when analyzing the studies. Most used group settings, where participants received their training then performed and practiced the learned techniques with a therapist to correct the behavior and give feedback. Moreover, it was also reported that integrating rehearsals into the training yields greater functional outcome improvements [23]. Indeed, sociocognitive studies tend to measure social functioning or social adjustment following training more often than studies aiming to improve upon neurocognitive deficits. Yet, a growing field around implicit learning in social cognitive psychology [125] suggests that drill and practice or other forms of more implicit training might be useful for sociocognition as well.

The collection of studies of Bell and colleagues on work and social outcomes using drill and practice [53,55] hint at the importance of generalizing the benefits of training to real-life situations, such as the ability to find and maintain work or to increase work productivity in the form of hours and money earned. However, both of these studies integrated the drill and strategy approach with a program of supported employment, creating a hybrid retraining program which has been efficient in the past [14]. Indeed, while improving cognitive deficits is commendable, functional outcomes are issues that should not be dismissed when considering the difficulties faced by individuals suffering from schizophrenia when trying to reintegrate the work force or create a social network.

We have also discovered that training programs usually target cognitive improvements “at large”, rather than specifically focusing on the individual deficits highlighted by the person’s profile, most likely to allow more people to receive the training without the need for specific neuro-psychological or sociocognitive evaluations. We suggest choosing one type of training over another depending on the overall goal one is trying to achieve: drill and practice for precise deficits and drill and strategy to obtain general gains. More studies are needed to determine if drill and practice could be useful for sociocognition as well.

Furthermore, specific training methodologies seem to benefit specific domains of social cognition. For example, though it appears that Social Cognition and Interaction Training (even when including the family in the training sessions) improves Theory of Mind (ToM), group practices and Powerpoint presentations detailing the concepts of ToM did not improve ToM but did improve emotion recognition. We suggest that ToM is a more complex construct of sociocognition and requires more precise and detailed training than emotion recognition. Horan and colleagues [93] suggest that even defining the different concepts contained within ToM, such as appreciation of humour, is difficult and the training for it is more challenging. Furthermore, a recent meta-analysis of social cognition training in schizophrenia [21] also reported inconsistent effect sizes when ToM is targeted, suggesting that the key elements needed in the training for ToM must be better identified.

When the objectives of the training are broader, meaning that they aim to improve both neurocognitive and sociocognitive deficits through drill and strategy, the variables measured are also more varied and often include certain measures of functional or occupational outcome. Furthermore, these studies often tend to combine training with other types of intervention such as cognitive-behavior therapy, supportive therapy or occupational therapy.

Overall, our review summarizes the current state of research into cognitive training in schizophrenia. In neurocognition, drill and practice training is used more frequently and with a variety of different procedures such as auditory training [62] or target discrimination [74]. Tailoring the training to specifically address precise deficits might be one of the key benefits of drill and practice training. However, from the studies we evaluated, drill and strategy training was more easily generalized to all neurocognitive deficits. Indeed, a recent meta-analysis on the benefits of cognitive remediation in schizophrenia noted that this modality of training produces stable benefits on global cognition [14]. We suggest choosing one type of training over another depending on the overall goal one is trying to achieve: drill and practice for precise deficits and drill and strategy to obtain general gains in neurocognition.

Limitations
There are a few limitations to our review. First, to reflect current trends, we included only studies published between 1995 and 2013, although interest in cognition remediation started as early as the end of the 1970's [126].
Second, the fact that drill and practice or drill and strategy training can involve multiple strategies and training techniques (e.g., times eye tracking, computer programs, paper-pencil tasks, errorless learning, group learning, and various modalities of feedback) prevented us from describing them in detail and some of these specific strategies might explain differences in outcomes. Our goal was to describe what was being offered, not to promote one approach in particular. We also did not include studies described as “metacognitive”, a term that involves cognitive biases, at times social and/or neurocognitive, that are linked to the symptoms of psychosis [127] – for example, focusing on the cognitive bias of jumping to conclusions as linked to delusions. It is important to note that these types of training are not the only modalities offered to help overcome neurocognitive or sociocognitive deficits. Occupational therapy [128], social skills training [129], as well as certain forms of metacognitive psychotherapies [130] have also been documented.

Conclusion
Future research is warranted to compare both drill and strategy and drill and practice programs with one another under control and experimental conditions, as well as to highlight the benefits and limitations of each. This would help to identify which type of deficit would benefit more from which training or to isolate particular participant profiles that respond best to a specific training strategy. Moreover, we suggest that more focus be brought to targeting participants’ specific deficits to tailor the training to those needs. This would increase the potential impact and generalization to “real-life” situations, both in the context of neuro and sociocognitive retraining. Finally, we propose investigating the benefits of both neurocognitive and sociocognitive training in the context of comorbidity. It is well known that schizophrenia is often comorbid with social anxiety (in 30% of cases; [131]) and substance abuse (in 50% of cases; [132]), to name a few. It is conceivable that the interplay of those disorders could be a substantial challenge for training. Nevertheless, very few studies have examined the impact of these presentations and doing so would be of paramount importance as it could increase the ecological validity and generalizability of the results.

Endnote

* stands for truncation.

Competing interests
The authors declare that they have no competing interests.

Authors’ contributions
KP conducted the literature search, selected and classified the appropriate articles, created the tables and wrote the manuscript. ALW read and classified the review articles to double-check KP’s previous work. She was also the first reader of some articles, in which case KP double-checked the classification. CC reviewed the comments from the reviewers and suggested improvements for the manuscript while answering the reviewers concerns. She also read and reviewed some articles that were missing from the first version of the manuscript. TL and SP are KP’s thesis director and co-director, respectively. They provided proof-reading, editing suggestions and feedback on the writing process. All authors read and approved the final manuscript.

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References

1. Meesters PD, Stek ML, Comijs HC, de Haan L, Patterson TL, Eikelenboom P, Breeman AF: Social functioning among older community-dwelling patients with schizophrenia: a review. Am J Geriatr Psychiatry 2010, 18(10):862–878.
2. Roffard S, Gely-Nargeot MC, Capdevielle D, Bayard S, Bouleanger JP: Learning potential and cognitive remediation in schizophrenia. Encephaly 2009, 35(4):353–360.
3. Nuñecheriner KH, Green MF, Kern RS, Baade LE, Barch DM, Cohen JD: The MATRICS consensus cognitive battery, part 1: test selection, reliability, and validity. Am J Psychiatry 2008, 165(2):203–213.
4. Schaefer J, Giangrande E, Weinberger DR, Dickinson D: The global cognitive impairment in schizophrenia: consistent over decades and around the world. Schizophr Res 2013, 150(1):42–50.
5. Lecardeur L, Stip E, Giguerre M, Blouin G, Rodriguez J-P, Champagne-Lavau M: Effects of cognitive remediation therapies on psychotic symptoms and cognitive complaints in patients with schizophrenia and related disorders: a randomized study. Schizophr Res 2009, 111(1–3):153–158.
6. Wolwer W, Frommam N: Social-cognitive remediation in schizophrenia: generalization of effects of the Training of Affect Recognition (TAR). Schizophr Bull 2011, 37(Suppl 3):563–570.
7. Keefe RS, Vinogradov S, Medalia A, Silverstein SM, Bell MD, Dickinson D, Ventura J, Marder SR, Stroup T: Report from the working group conference on multisite trial design for cognitive remediation in schizophrenia. Schizophr Bull 2011, 37(Suppl 3):1057–1065.
8. Kurtz M, Seltzer J, Shagion D, Thime W, Wexler E: Computer-assisted cognitive remediation in schizophrenia: what is the active ingredient? Schizophr Res 2007, 89(1–3):251–260.
9. Revheim N, Schechter I, Kim D, Silipo G, Allingham B, Butler P, Javitt DC: Neurocognitive and symptom correlates of daily problem-solving skills in schizophrenia. Schizophr Res 2006, 83(2–3):237–245.
10. Green MF: What are the functional consequences of neurocognitive deficits in schizophrenia? Am J Psychiatry 1996, 153(3):321–330.
11. Lesh TA, Niemand TA, Minzenberg MJ, Carter CS: Cognitive control deficits in schizophrenia: mechanisms and meaning. Neuropsychopharmacol 2011, 36(1):316–338.
12. McGurk SR, Tantamley EW, Sitzer DJ, McHugh GJ, Mueyer KT: A meta-analysis of cognitive remediation in schizophrenia. Am J Psychiatry 2007, 164(12):1791–1802.
13. Franck N: Cognitive remediation for patients with schizophrenia. Am Medico-Psychol 2007, 165(3):187–190.
14. Wykes T, Huddy V, Cellaad C, McGurk SR, Cobor P: A meta-analysis of cognitive remediation for schizophrenia: methodology and effect sizes. Am J Psychiatry 2011, 168(3):472–485.
15. Aleman A, Hijnman R, de Haanm EHF, Kahn RS: Memory impairment in schizophrenia: a meta-analysis. Am J Psychiatry 1999, 256:1358–1366.

16. Heinrichs RW, Zakanis KK: Neurocognitive deficit in schizophrenia: a quantitative review of the evidence. Neuropsychol 1998, 12:426–445.

17. Kerr S, Kelemen G, Szekeres G, Baczogzy N, Eredlyi R, Antal A, Benedek G, Janka Z: Schizophrenics know more than they can tell: probabilistic classification learning in schizophrenia. Psychol Med 2000, 30:149–155.

18. Weikert TW, Terazas A, Bigelow LB, Malley JD, Hyde T, Egan MF, Weinerbr DR, Goldberg TE: Habit and skill learning in schizophrenia: evidence of normal striatal processing with abnormal cortical input. Learn Mem 2002, 9(6):430–442.

19. Danion JM, Meulemans T, Kauflmuller-F, Vermaat H: Implicit intact learning in schizophrenia. Am J Psychiatry 2001, 158(6):944–948.

20. Hsieh MH, Liu K, Liu S-K, Chu M-L, Hwu H-G, Chen ACN: Memory impairment and auditory evoked potential gating deficit in schizophrenia. Psychiatry Res 2004, 130(1):161–169.

21. Kurtz M, Richardson CL: Social cognitive training for schizophrenia: a meta-analytic investigation of controlled research. Schizophr Bull 2011, 38(5):1092–1104.

22. Gyryszpan Q, Perba S, Pelisolo A, Fossati P, Jouvent R, Dubal S, Perez-Diaz F: Efficacy and specificity of computer-assisted cognitive remediation in schizophrenia: a meta-analytic study. Psychol Med 2011, 41(1):163–173.

23. Medalia A, Saperstein AM: Does cognitive remediation for schizophrenia improve functional outcomes? Curr Opin Psychiatry 2013, 26:151–157.

24. Birk N, Revheim N, Huu F, Khaldorov V, Ganz ZW, Medalia A: The impact of cognitive remediation on psychiatric symptoms of schizophrenia. Schizophr Res 2003, 63:229–235.

25. Blairy S, Grossman M, Gupta M, Oyenurum VK, Harvey PD: Cognitive remediation in schizophrenia: Efficacy and effectiveness in patients with early versus long-term course of illness. Early Interv Psychiatry 2013, 8(3):332–338.

26. Dickens D, Tenhula W, Morris S, Brown C, Peer J, Spencer K, Li L, Gold JM, Bellack AS: A randomized, controlled trial of computer-assisted cognitive remediation for schizophrenia. Am J Psychiatry 2010, 167(2):170–180.

27. Dickens D, Tenhula W, Morris S, Brown C, Peer J, Spencer K, Li L, Gold JM, Bellack AS: A randomized, controlled trial of computer-assisted cognitive remediation for schizophrenia. Schizophr Res 2010, 124(2):161–170.

28. Hansen JP, Ostergaard B, Norderfeldt M, Houngaard L: The feasibility of cognitive adaptation training for outpatients with schizophrenia in integrated treatment. Community Ment Health J 2012, 1–6.

29. Hodge MAR, Siciliano D, Wityey P, Moss B, Moore G, Judd G, Shores EA, Harris A: A randomized controlled trial of cognitive remediation in schizophrenia. Schizophr Bull 2010, 36(2):419–427.

30. Ikeawa S, Mogami T, Hayami Y, Sato I, Kato T, Kimura I, Pu S, Kaneko K, Nakagome K: The pilot study of a neuropsychological educational approach to cognitive remediation for patients with schizophrenia in Japan. Psychiatry Res 2012, 195(3):107–110.

31. Kern RS, Liberman RP, Becker DR, Drake RE, Sugar CA, Green MF: Errorless learning for training individuals with schizophrenia at a community mental health setting providing work experience. Schizophr Bull 2009, 35(4):807–815.

32. Kidd SA, Bajwa JK, McKenzie KJ, Ganguli R, Kamheen BH: Cognitive remediation for individuals with psychosis in a supported education setting: a pilot study. Rehabil Res Pract 2013, 2013:171675.

33. McGurk SR, Mueser KT, Pascaris A: Cognitive training and supported employment for persons with severe mental illness: one-year results from a randomized controlled trial. Schizophr Bull 2005, 31(4):898–909.

34. McGurk SR, Mueser KT, Feldman K, Wolfe R, Pascaris A: Cognitive training for supported employment: 2–3 year outcomes of a randomized controlled trial. Am J Psychiatry 2007, 164(3):437–441.
feasibility, safety, and efficacy of the combination of d-serine and computerized cognitive retraining in schizophrenia: an international collaborative pilot study. Neuropsychopharmacol 2011;12:1-12.

6. Farreny A, Aguado J, Ochoa S, Huerta-Ramos E, Manfa F, Lopez-Carrillo R, Canals V, Haro JM, Usall J. RepFLec cognitive remediation group training in schizophrenia. Looking for an integrative approach. Schizophr Res 2012, 142(1):174-4.

7. Field CD, Gallyery A, Anderson D, Walker P. Computer-aided cognitive rehabilitation: possible application to the attentional deficit of schizophrenia, a report of negative results. Percept Mot Skills 1987, 95(5):995-1002.

8. Fisher M, Holland C, Merzenich MM, Vinogradov S. Using neuroplasticity-based auditory training to improve verbal memory in schizophrenia. Am J Psychiatry 2000, 157(6):805-811.

9. Fisher M, Holland C, Subramaniam K, Vinogradov S. Neurplasticity-based cognitive training in schizophrenia: an interim report on the effects 6 months later. Schizophr Bull 2010, 36(4):869-879.

10. Fiszdon JM, Bryson GJ, Wexler BE, Bell MD: Effects of age and cognitive reserve on cognitive remediation therapy. Psychiatry Res 2007, 145(3):218-219.

11. Fiszdon JM, Bryson GJ, Wexler BE, Bell MD. Improved cognitive function in schizophrenia after one year of cognitive training and vocational services. Schizophr Res 2007, 96(1-3):156-161.

12. Habel U, Koch K, Kellerman T, Reske M, Frommann N, Wolwer W, Zilles K, Shah N, Schneider F. Training of affect recognition in schizophrenia: neurobiological correlates. Soc Neurosci 2010, 5(1):92-104.

13. Konts D, Huddy Y, Reeder C, Landau S, Wikes T. Effects of age and cognitive reserve on cognitive remediation therapy. Am J Geriatr Psychiatry 2013, 21(3):218-230.

14. Lopez-Luengo B, Vázquez C. Effects of attention process training on cognitive functioning of schizophrenic patients. Psychiatry Res 2003, 119(1):41-53.

15. Meadela A, Alumast M, Tryon W, Merriam EA. Effectiveness of attention training in schizophrenia. Schizophr Bull 1998, 24(1):147-152.

16. Meadela A, Rievneum N, Casey M. Remediation of memory disorders in schizophrenia. Psychol Med 2002, 30:1451-1459.

17. Murphy NH, Mancke H, Wexler BE, Maruff P, Ilomandar A, Zucchett M, Lund J, Shabbor S, Sherry L, Shehan M, Kapur S, Lauruselle M, Alexander R. Computerized cognitive remediation training for schizophrenia: an open label, multi-site, multinational methodology study. Schizophr Res 2012, 139(2):91-97.

18. Nemoto T, Yamazawa R, Kobayashi H, Fujita N, Chino B, Fujii C, Kashima H, Ohtsuku Y, Green MF. Cognitive training in schizophrenia: a pilot study. Prog Neuropsychopharmacol Biol Psychiatry 2009, 33(8):1533-1536.

19. Norton DJ, McInaik RB, Ongr D, Chen Y. Perceptual training strongly improves visual motion perception in schizophrenia. Brain Cogn 2011, 77:248-256.

20. Penades R, Pujol N, Catalan R, Massana G, Ruzeta L, Garcia-Rizo C, Bargallo N, Gastro C, Bernardo M, Janque C. Brain effects of cognitive remediation therapy in schizophrenia: a structural and functional neuroimaging study. Biol Psychiatry 2013, 73:1015-1023.

21. Popov T, Jordanov T, Rockstroh B, Elbert T, Merzenich MM, Miller GA. Specific cognitive training normalizes auditory sensory gating in schizophrenia: a randomized trial. Biol Psychiatry 2011, 69:465-471.

22. Popov T, Rockstroh B, Weisz N, Elbert T, Miller GA. Adjusting brain dynamics in schizophrenia by means of perceptual and cognitive training. PLoS One 2012, 7(10):e50951.

23. Rass O, Forsyth JK, Bobecker AR, Hetrick WP, Breier A, Lysaker PH, O'Donnell BF. Computer-aided assisted cognitive remediation for schizophrenia: a randomized single-blind pilot study. Schizophr Res 2012, 139(1-3):92-98.

24. Rauchertstein S, Kawohl W, Ozgurder S, Littmann E, Gudbrandsson Y, Wittels L, Heira A, Jackel G. Test-performance after cognitive training in persons at risk mental state of schizophrenia and patients with schizophrenia. Psychiatry Res 2011, 185:334-339.

25. Rodevald K, Rentrop M, Holt DV, Roehs-Elly D, Backenstas M, Funkke J, Weisbrod M, Kaiser S. Planning and problem-solving training for patients with schizophrenia: a randomized controlled trial. BMC Psychiatry 2011, 11:3.
103. Silver H, Goodman C, Knoll G, Isakov V. Brief emotion training improves recognition of facial emotions in chronic schizophrenia. A pilot study. *Psychiatry Res* 2004, 128:147–154.

104. Tars C, Danaci AE, Cubukcuoglu Z, Brune M. Impact of family involvement on social cognition training in clinically stable outpatients with schizophrenia – A randomized pilot study. *Psychiatry Res* 2012, 195(1):22–28.

105. van der Gaag M, Kem RS, van den Bosch RJ, Liberman RP. A controlled trial of cognitive remediation in schizophrenia. *Schizophr Bull* 2002, 28(1):167–176.

106. Wolwer W, Frommann N, Halfmann S, Plasszcz A, Streit M, Gaebel W. Remediation of impairments in facial affect recognition in schizophrenia: efficacy and specificity of a new training program. *Schizophr Res* 2005, 80:295–303.

107. Wolwer W, Frommann N. Social-cognitive remediation in schizophrenia: generalization of effects of the training of affect recognition (TAR). *Schizophr Bull* 2011, 37(2):663–70.

108. Eack SM, Greenwald DP, Hogarty GE, Greenwald DP, Hogarty SS, Cooley SJ, DiBarry AL, Montrose DM, Wolwer W, Frommann N. Cognitive enhancement therapy for early-course schizophrenia: effects of a two-year randomized controlled trial. *Psychiatrie Serv* 2009, 60(1):1468–1476.

109. Goldersisi S, Piegari G, Mucci A, Acerra A, Luciano L, Rabasca AF, Santucci F, Valente A, Volpe M, Mastantuono P, Maj M. Social skills and neurocognitive individualized training in schizophrenia: comparison with structured leisure activities. *Eur Arch Psychiatry Clin Neurosci* 2010, 260(4):305–315.

110. Hadas-Lidor N, Katz N, Tyano S, Weissman A. Effectiveness of dynamic cognitive intervention in rehabilitation of clients with schizophrenia. *Clin Rehabil* 2001, 15(4):349–359.

111. Hogarty SS, Flesher S, Ulrich R, Carter M, Greenwald DP, Pogue-Geile M, Kechavan M, Cooley SJ, DiBarry AL, Garrett A, Parepally H. Cognitive enhancement therapy for schizophrenia. *Arch Gen Psychiatry* 2004, 61:866–876.

112. Hogarty GE, Greenwald DP, Eack SM. Durability and mechanism of effects of cognitive enhancement therapy. *Psychiatric Serv* 2006, 57(12):1751–1757.

113. Lewandowski KE, Eack SM, Hogarty SS, Greenwald DP, Keshavan M. Is cognitive enhancement therapy equally effective for patients with schizophrenia and schizoaffective disorder? *Schizophr Res* 2011, 125:291–294.

114. Sacks S, Fisher M, Garrett C, Alexander P, Holland C, Rose D, Hooker C, Vinogradov S. Combining computerized social cognitive training with neuroplasticity-based auditory training in schizophrenia. *Clin Schizophr Relat Psychoses* 2013, 7:935–937.

115. Ueland T, Rund BR. A controlled randomized treatment study: the effects of a cognitive remediation program on adolescents with early onset psychosis. *Acta Psychiatr Scand* 2004, 109:76–74.

116. Ueland T, Rund BR. Cognitive remediation for adolescents with early onset psychosis: a 1-year follow-up study. *Acta Psychiatr Scand* 2005, 111:193–201.

117. Veltro F, Maaza M, Vendittelli N, Alberti M, Casacchia M, Roncone R. A comparison of the effectiveness of problem solving training and of cognitive-emotional rehabilitation on neurocognition, social cognition and social functioning in people with schizophrenia. *Clin Pract Epidemiol Ment Health* 2011, 7:123–132.

118. Vita A, De Peri L, Barlati S, Cacciani P, Cisima M, Deste G, Cesana BM, Sacchetti E. Psychopathological, neuropsychological and functional outcome measures during cognitive rehabilitation in schizophrenia: a prospective controlled study in a real-world setting. *Eur Psychiatry* 2011, 26:276–283.

119. Vita A, De Peri L, Barlati S, Cacciani P, Deste G, Poll R, Agrimi E, Cesana BM, Sacchetti E. Effectiveness of different modalities of cognitive remediation on symptomatological, neuropsychological, and functional outcome domains in schizophrenia: a prospective study in a real-world setting. *Schizophr Res* 2011, 133:223–231.

120. Cavallaro R, Anselmetti S, Polletti S, Bechi M, Enrolli E, Cocchi F, Stratta P, Vita A, Rossi A, Smeraldi E. Computer-aided cognitive remediation as an enhancing strategy for schizophrenia rehabilitation. *Psychiatry Res* 2009, 169(3):191–196.

121. Hooker CI, Bruce L, Fisher M, Verosky SC, Miyakawa A, Vinogradov S. Neural activity during emotion recognition after combined cognitive plus social cognitive training in schizophrenia. *Schizophr Res* 2012, 139:53–59.