A Review of Cognitive Training in Schizophrenia

by Elizabeth W. Twamley, Dilip V. Jeste, and Alan S. Bellack

Abstract

Empirically supported treatments for schizophrenia now include a variety of psychosocial interventions, such as social skills training, vocational rehabilitation, and psychotherapy. As awareness of the functional importance of neurocognitive impairments in schizophrenia has increased, interest in treatments to improve cognition has grown. We review the literature on cognitive training (CT), which has been studied in 17 published randomized, controlled trials to date. The differential effectiveness of noncomputerized and computer-assisted interventions, with and without strategy coaching, and an environmental adaptation intervention, is examined. We conclude that the different types of approaches, whether computer assisted or not, all have effective components that hold promise for improving cognitive performance, symptoms, and everyday functioning. Our recommendations for further research, including the use of functional outcome measures and long-term followup, highlight the importance of improving ecological validity in this area of treatment research.

Keywords: Psychosis, schizophrenia, psychosocial treatment, neuropsychology, rehabilitation.


Our goal in this article is to provide a comprehensive review of the randomized, controlled studies of cognitive training interventions that aim to improve neuropsychological functioning in individuals with schizophrenia. Schizophrenia is generally viewed as a neurodevelopmental cognitive disorder characterized by relatively stable neuropsychological deficits (Hyde et al. 1994; Censits et al. 1997; Gur et al. 1997; Rund 1998; Gur and Nuechterlein 1999; Eyler Zorrilla et al. 2000; Heaton et al. 2001). These deficits include impaired preattentive abilities, attention, memory, learning, conceptualization, organization, planning, self-monitoring, and flexibility of thinking (Heaton et al. 1994; Spaulding et al. 1996; Storzbach and Corrigan 1996; Gur et al. 1997). Neurocognitive impairment has been reported to predict functional outcome in patients with schizophrenia (Bellack et al. 1994; Green 1996; Bellack et al. 1999; Green and Nuechterlein 1999; McGurk et al. 2000; Twamley et al. 2002) and, in a recent meta-analysis, was shown to explain 20 to 60 percent of the variance in measured outcomes (Green et al. 2000). Cognitive deficits are thought to play a central role in the social disability and other problems in daily living experienced by patients with schizophrenia (Bellack et al. 1999). Certain cognitive features, such as perseveration, also have been associated with persistence of delusional beliefs (Spaulding 1978). Furthermore, cognitive impairment appears to be associated with negative symptoms of schizophrenia (Braff et al. 1991), which are socially and vocationally incapacitating to the patients as well as bothersome to their caregivers (Goldberg and Cook 1996). Finally, impaired cognition may be a "rate-limiting factor" in the success of psychosocial interventions for schizophrenia (e.g., work rehabilitation and social skills training) (Liberman and Green 1992; Bell and Bryson 2001). Thus, amelioration of neurocognitive deficits has been posited to be an important treatment goal in schizophrenia.

Although there is evidence that atypical antipsychotic drugs may produce some improvement in selected areas of cognitive performance (Keefe et al. 1999; McGurk 1999; Purdon 1999; Harvey and Keefe 2001; Bilder et al. 2002), antipsychotic medications do not eliminate cognitive deficits (Rund and Borg 1999). Thus, a number of investigators have pursued nonpharmacological means of improving residual cognitive and functional deficits in patients with schizophrenia. In the 6 decades since Goldstein (1939) wrote, "We have to attack the disease underlying schizophrenic symptoms by physical and psychological ways," research on "psychological ways" to treat schizophrenia has advanced considerably. The recent Sur-
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Evidence-based practice guidelines for psychosocial treatment of schizophrenia include psychosocial treatments such as social skills training (Heinssen et al. 2000), cognitive/cognitive-behavioral therapy (Beck and Rector 1998; Garety et al. 2000; McQuaid et al. 2000; Granholm et al. 2002), family psychoeducation (Dixon et al. 2000), and vocational rehabilitation (Cook and Razzano 2000), as indicated by a number of recent empirical articles and reviews (see also Lehman et al. 1997; Kopelowicz and Liberman 1998; Mojtabai et al. 1998; Herz et al. 2000; Huxley et al. 2000). Literature on cognitive training (CT) in schizophrenia has been reviewed in recent publications as well (Storzbach and Corrigan 1996; Bellack et al. 1999; Rund and Borg 1999; Suslow et al. 2001; Wykes and van der Gaag 2001), but we are unaware of any comprehensive review of this topic that has included all randomized, controlled trials of training interventions to improve cognition. (It should be noted that cognitive therapy, which focuses on modification of maladaptive beliefs and schemas [Beck and Rector 1998], is distinguished from cognitive training, which aims to improve neurocognitive abilities such as memory, learning, attention, and executive functioning.)

Bellack and colleagues (1999) discussed previous research on CT for schizophrenia and proposed a new way of choosing areas of cognition to target (i.e., those that differentiate schizophrenia patients with good from those with poor vocational outcomes). Despite the authors' concerns about much of the previous literature and the neurodevelopmental complexity and heterogeneity of schizophrenia, they conveyed a cautious optimism regarding future development of CT programs. Additionally, they concluded that further research must address the question of differential effectiveness among diverse types of CT. The current review aims to begin this process by systematically examining published randomized, controlled trials of CT for schizophrenia. To place this comprehensive critical review in the appropriate context, we will briefly describe the historical development of CT for brain-injured patients in general and for schizophrenia patients in particular. We will then discuss the nomenclature used in this literature and ways of categorizing CT approaches. Next, we will provide a critical review of studies of CT for schizophrenia and a more complete description of four of the methodologically more rigorous trials. We will then summarize the existing knowledge regarding the efficacy of various types of CT, highlighting methodological, theoretical, and pragmatic issues relevant to previous and future investigations in this domain. Finally, we will suggest some strategies for clinical use of CT and make recommendations for further research.

History of CT

Many approaches to CT have come from the field of neurorehabilitation. Attempts to improve cognitive deficits following traumatic brain injury began as early as 1915, when Goldstein founded a hospital for soldiers who had sustained head injuries in World War I. He developed deficit-specific “retraining” programs, aiming to assist soldiers in compensating for their deficits by providing psychological and occupational interventions (Goldstein 1942). In 1944, Goldstein wrote, “Systematic training facilitates greatly the process of improvement even in cases where functions do not improve spontaneously at all; however, success will be achieved only if training is based on careful investigation and understanding of the individual defect and performed systematically” (p. 216). Although, to our knowledge, he did not attempt retraining in schizophrenia patients, Goldstein (1939) commented on the similarity in abstraction deficits among brain-injured patients and those with schizophrenia, and discussed the use of performance on abstraction tasks in choosing psychotherapeutic approaches for schizophrenia patients. The body of empirical research supporting cognitive neurorehabilitation efforts has grown in the past 50 years (Cope 1995; NIH Consensus Statement 1998) and has spawned similar treatments for stroke (see Ottenbacher and Jannell 1993, for a review) as well as for psychiatric disorders.

The literature on CT for schizophrenia grew not only out of research documenting the success of such training in brain-injured patients (see Wilson et al. 1999 for a review) but also out of work in experimental psychopathology laboratories, when investigators observed that manipulations of experimental stimuli (e.g., reduction of attentional demands) could produce improvements on laboratory tasks among individuals with schizophrenia (Cromwell 1975; Cromwell and Spaulding 1978; Spaulding et al. 1986). Many studies, for example, have shown that the performance of schizophrenia patients on the Wisconsin Card Sorting Test (WCST) can improve under various conditions of instruction or reinforcement (for reviews, see Goldberg and Weinberger 1994; Kern and Green 1998; Kurtz et al. 2001). A recent meta-analysis of WCST training studies (Kurtz et al. 2001) suggested that efforts to improve WCST performance in the laboratory generally are successful, with a weighted mean effect size (Cohen’s d) of 0.96. In most of these studies, subjects received training during a single day and were retested that same day or the following day. These studies are important because they show that individuals with schizophrenia can learn to perform better, and they provide clues...
regarding potential therapeutic strategies. The studies do not demonstrate, however, whether improvements on the WCST are sustained over time, generalize to other tests, or have clinically meaningful consequences.

Wagner (1968) and Meichenbaum and Cameron (1973) were among the first researchers to investigate the generalization of CT efforts to tasks other than the training task; the field did not truly begin to grow until the early 1990s, however. Similar to research on brain injury neurorehabilitation, research on CT for schizophrenia initially examined effects of treatment on cognitive tests and is now moving in the direction of seeking effects on broader outcomes, such as symptoms, community and social functioning, and quality of life.

### CT Nomenclature and Classification

Researchers have used various terms to describe efforts to ameliorate cognitive deficits associated with schizophrenia. "Cognitive remediation," "cognitive rehabilitation," and "cognitive (or attention, memory, etc.) training" appear to be the three most commonly used terms. Of the 19 articles included in the current review, 7 referred to "training," 4 used "remediation," 4 "rehabilitation," 1 "therapy," 1 "treatment," 1 "cognitive process targeting approach," and 1 "compensatory strategies."

"Remediation" implies a curative treatment (Taber's Cyclopedic Medical Dictionary 1997). Similarly, Webster's (1986) defines "rehabilitate" as follows: "to restore to a condition of health or normal activity." In medical settings, "rehabilitation" implies a restoration of function to premorbid levels or to a "normal or near normal manner" (Stedman's Medical Dictionary 1995; Taber's Cyclopedic Medical Dictionary 1997). Given that schizophrenia is believed to be a developmental brain disorder (Green and Nuechterlein 1999), a premorbid level of functioning may not be applicable or identifiable, and normal or near-normal functioning may rarely be possible. Thus, "remediation" and "rehabilitation" do not seem appropriate. The term "habilitation," meaning "educating or training persons with disability to improve their ability to function in society" (Taber's 1997), may be more accurate. However, we prefer the more common term "training," as it is more easily understood by professionals and laypersons. Training is defined as "an organized system of education, instruction, or discipline" (Stedman’s 1995) or "the teaching, drill, or discipline by which powers of mind or body are developed" (Webster's 1986).

The literature on CT delineates restorative, compensatory, and environmental approaches to treatment (see Spaulding et al. 1998; Bellack et al. 1999). The restorative model emphasizes elimination of impairments by correction of underlying cognitive deficits. Compensatory strategies, or cognitive prosthetics, teach patients how to "work around" their deficits but do not aim to improve underlying brain function. Environmental approaches involve manipulations of the environment to decrease cognitive demands (e.g., via external reminders such as lists or cue cards). Although these types of approaches are widely recognized, investigations of CT in schizophrenia tend not to use these labels; although environmental interventions are easily identified, other types of CT interventions are not frequently identified as "restorative" or "compensatory." (In part, this apparent lack of theoretical grounding may be due to difficulty determining whether performance improvements on outcome measures reflect the attenuation of deficits or an increased ability to compensate for them.) Because we could not categorize the CT interventions as restorative or compensatory, we have attempted to describe the studies as thoroughly as possible in terms of the type of intervention and the outcome measures used.

### Method of the Literature Review

We searched the MEDLINE (years 1966–2001) and PsycINFO (years 1887–2001) data bases for English language, peer-reviewed reports of randomized, controlled trials of "cognitive training," "cognitive rehabilitation," or "cognitive remediation" in "schizophrenia" using outcome measures that could reflect generalization of CT. Thus, we excluded investigations that relied on only the cognitive tests used in training, such as the WCST, as outcome measures. Similarly, we excluded reports of nonintervention or laboratory studies (e.g., Young and Freyslinger 1995; Bellack et al. 1996, 2001), on the basis that these approaches would not be accurately described as a treatment. We also excluded studies of psychosocial skills training, as these interventions attempted to improve social functioning and not cognition per se. References from identified articles also were reviewed. Using these methods, we found 19 published articles that met our search criteria. Different aspects of studies by Medalia et al. (2000, 2001) and Spaulding et al. (1999a, 1999b) were reported in more than one publication; thus, 17 studies are included in the current review. We examined data from each study regarding the patient population investigated; number, age, gender, and education level of participants; administration and duration of CT; type of control condition; outcome measures; length of followup; group differences; and statistical tests used. When data were available, we calculated effect sizes for each outcome measure. These data are presented in table 1.

### Methodological Aspects of the Reviewed Literature

Most of the 17 studies reviewed provided fairly complete descriptions of the demographics of their samples. The
Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Age (A = mean yrs)</th>
<th>Gender (G = % male)</th>
<th>Duration and modality of training</th>
<th>Experimental condition (EC)</th>
<th>Control condition (CC)</th>
<th>Outcome measures</th>
<th>Effect sizes (not computed if groups were significantly different at pretest)</th>
<th>Group differences</th>
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</thead>
</table>
| Automated task practice interventions

Wagner (1968)
48 inpatients (8 per group); mean length of present hospitalization = 8 yrs
A = 45
G = 100% male
E = NR

CC1: Training placebo
CC2: No contact

EC1: attention training × 2 (matching stimuli)
EC2: abstraction training × 2 (similarities stimuli)
EC3 and EC4: both training programs (counterbalanced for order)
All conditions used visually presented stimuli and used reinforcement (canteen coupons) for correct answers. Strategy coaching was not provided.

3 hrs over 4 days; individual

Proverbs
WAIS Similarities subtest
Peabody Picture Vocabulary Test (PPVT)
Memory for Designs Test
Letter Cancellation

EC group improved on letter cancellation, basic arithmetic, and Embedded Figures Test

0.32
0.67
0.55
(Data not provided)
(Data not provided)

Attention-training group improved on Proverbs (t = 2.22, p < 0.05) and Similarities (f = 2.99, p < 0.01); abstraction-training group improved on Similarities (f = 3.29, p < 0.01) and PPVT (f = 2.81, p < 0.01); attention-training groups performed better than abstraction-training groups on the Memory for Designs Test

Olbrich and Mussgay (1990)
30 inpatients (German sample)
Mean CPZE = 332 mg; mean length of illness = 5 yrs
A = 32, 30
G = 60%, 53% male
E = 10.3, 10.2

EC, CC: Arts and crafts

Math problems, picture problems, copying drawings, verbal and visual memory tasks, with an apparent emphasis on repeated practice rather than strategy coaching

Twelve 1-hr sessions over 3 wks; groups of 2–8

Neuropsychological measures

Sustained attention task
Attention shifting task
Maze task
Embedded Figures Test
Letter cancellation
Letter cancellation errors
Basic arithmetic

0.08
0.04
0.27
1.42
1.00
0.18
0.30

EC group improved on letter cancellation, basic arithmetic, and Embedded Figures Test
<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
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<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
<th>Group differences</th>
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<tbody>
<tr>
<td>Brown et al. (1993)</td>
<td>29 inpatients EC: 14 CC: 15 mean length of present hospitalization = 7 yrs</td>
<td>EC, CC: A = 57, 43 G = NR E = 9, 11</td>
<td>Individual occupational therapy program focusing on attention skills</td>
<td>Mateer's Attention Process Training—a hierarchical program of paper-and-pencil, auditory, and motor tasks addressing focused, sustained, selective, alternating, and divided attention The program emphasized repetition of tasks rather than strategy coaching.</td>
<td>Thirty-six 60-min sessions over 12 wks; individual</td>
<td>Bay Area Functional Performance Evaluation, Digit Span, Digit Symbol, Trail Making Test, Parts A and B WMS-R Visual Span</td>
<td>(Data not provided)</td>
<td>Both groups improved; no differences between groups</td>
</tr>
<tr>
<td>Meichenbaum and Cameron (1973)</td>
<td>10 inpatients all taking medication; mean length of present hospitalization = 15 mos</td>
<td>A = 36 G = 100% male E = NR</td>
<td>Task practice alone</td>
<td>Instruction and task practice using self-talk technique (repetition of instructional set, talking through the task, coping/self-reinforcement); instruction on interpreting social cues and using self-talk in response Practice on several tasks using self-talk, but no practice on digit span or inkblosts</td>
<td>Eight 45-min sessions over 3 wks; individual</td>
<td>Structured interview (% &quot;sick talk&quot; or incoherent speech) Proverbs, Digit span with distraction, Digit span without distraction, Holtzman Inktblot Test, scored for thought disorder (Alternate forms used)</td>
<td>3.49</td>
<td>EC group improved on % sick talk (t = 4.94, p &lt; 0.01; p &lt; 0.001), Digit span with distraction (t = 1.88, p &lt; 0.05; p &lt; 0.01), Holtzman Inktblot Test (t = 2.67, p &lt; 0.05; p &lt; 0.01), trend in Proverbs (t = 1.78, p &lt; 0.10)</td>
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Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions—Continued

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<tr>
<td>Corrigan et al. (1995)</td>
<td>A = 35, G = 45% male E = 12.6</td>
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<td>Vigilance training using Social Cue Recognition Test (SCRT) stimuli (8 videotaped social vignettes)</td>
<td>Vigilance plus memory training emphasizing verbal elaboration strategies (putting the story in their own words) Assistance in emotion labeling was provided.</td>
<td>One 60-min session; NR (assumed individual)</td>
<td>SCRT: 36 true-false questions about each of the 8 vignettes patients were trained on</td>
<td>0.86</td>
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<td>For the 38 patients taking neuroleptics, mean CPZE = 711 mg.</td>
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<td>EC group performed better on the SCRT (F = 6.43, p &lt; 0.05) and the CRT (F = 5.43, p &lt; 0.05), immediately after training; improvement on the SCRT was sustained over 48 hrs (F = 4.30, p &lt; 0.05).</td>
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<td>Spaulding et al. (1999a, 1999b)</td>
<td>A = 35, 36 G = 65%, 57% male E = 11.7; 12.2</td>
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<td>Comprehensive rehabilitation program (medication, supportive therapy, social skills training, contingency management)</td>
<td>CC plus exercises of cognitive abilities (based on Brenner’s Integrated Psychological Therapy cognitive subprogram and addressing attentional skills and concept formation, primarily)</td>
<td>78 sessions lasting 45–60 mins over 6 mos; groups of 8–12</td>
<td>Assessment of Interpersonal Problem-Solving Skills (AIPSS): Identification 0.31, Articulation 0.88, Processing 0.39, Content 0.76, Performance 0.37, Total 0.52</td>
<td>Compared with CC, EC group improved on AIPSS Articulation (F = 14.46, p &lt; 0.001) and Content (F = 10.74, p &lt; 0.005) subscales; skill assessments of Symptom manage-</td>
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<td></td>
<td>Gender (G = % male)</td>
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<tr>
<th>assessments</th>
<th>Effect sizes</th>
<th>Group differences</th>
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<tr>
<td>Symptom management</td>
<td>0.70</td>
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<tr>
<td>Leisure skills</td>
<td>0.36</td>
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<tr>
<td>Conversation skills</td>
<td>0.40</td>
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<tr>
<td>Medication management</td>
<td>0.64</td>
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<tr>
<td>Neurocognitive measures</td>
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<tr>
<td>Span of apprehension/ masking</td>
<td>-0.15</td>
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<td>Reaction time</td>
<td>-0.31</td>
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<tr>
<td>CPT</td>
<td>0.08</td>
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<tr>
<td>Span/CPT</td>
<td>0.68</td>
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<tr>
<td>Trails B</td>
<td>0.35</td>
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<tr>
<td>Tactile Performance Test</td>
<td>0.09</td>
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<tr>
<td>Card sort—random errors</td>
<td>0.48</td>
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<td>Card sort—perseverative errors</td>
<td>0.15</td>
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<tr>
<td>Category Test</td>
<td>-0.20</td>
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<tr>
<td>Rey Auditory Learning</td>
<td>0.05</td>
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<tr>
<td>Rey Visual Learning</td>
<td>0</td>
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<tr>
<td>Denman Auditory Memory</td>
<td>-0.17</td>
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<tr>
<td>Denman Nonverbal Memory</td>
<td>-0.11</td>
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<tr>
<td>BPRS</td>
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<tr>
<td>Disorganization</td>
<td>0.53</td>
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<tr>
<td>Blunting/Retardation</td>
<td>0.08</td>
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<tr>
<td>Paranoia</td>
<td>0.16</td>
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<tr>
<td>Anxious Depression</td>
<td>0.03</td>
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<tr>
<td>Hallucinosis/Delusional</td>
<td>-0.30</td>
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<td>PANSS</td>
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<tr>
<td>General</td>
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<td>Positive</td>
<td>0.05</td>
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Group differences: (F = 7.87, p < 0.010) and Medication management (F = 6.64, p < 0.015); Span/CPT (F = 9.98, p < 0.005) and Card sort—random errors (F = 4.63, p < 0.05); and BPRS Disorganization (F = 5.00, p < 0.05). Improvement on Rey Auditory Test was a predictor of improvement on AIPSS.
Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions—Continued

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<td>Wykes et al. (1999) 33 day program patients with social and cognitive deficits EC: 17 CC: 16 All patients were taking antipsychotic medication, and most had length of illness &gt; 10 yrs.</td>
<td>Negative -0.10 Severe Positive -0.06 Severe Negative 0 TLC 0.11</td>
<td>EC group improved differentially on WCST, Six Elements, and Digit Span; also showed improved self-esteem. Interaction between treatment condition and medication type (EC atypical antipsychotic = more improvement on cognitive tasks; may have been due to larger practice effects on timed tasks in the atypical antipsychotic group.)</td>
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<td>EC, CC: A = 37, 41 G = 76%, 75% male E = 12, 12.7</td>
<td>Manualized intensive occupational therapy</td>
</tr>
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<th>Study</th>
<th>Education level (E = mean yrs)</th>
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<td>Wykes et al. (1999) 33 day program patients with social and cognitive deficits EC: 17 CC: 16 All patients were taking antipsychotic medication, and most had length of illness &gt; 10 yrs.</td>
<td>Individualized Neurocognitive Remediation Program incorporating errorless learning, immediate feedback, and nondidactic training (based on work by Delahunty and Morice 1993); manualized program with 3 modules: cognitive flexibility, working memory, and planning Therapists assisted patients with providing strategies and discussed regulation, organization, and monitoring of each component of the task, providing demonstrations if necessary.</td>
<td>Twenty-four to forty 60-min sessions over 8 wks; NR (assumed individual)</td>
<td>Cognitive flexibility Hayling Sentence Completion Task Trail Making Test Part B minus Part A Response Inhibition Stroop WCST Planning Tower of London Six Elements Working Memory Visual Span Sentence Span Digit Span Dual Span Social Behavior Schedule Present State Examination BPRS Rosenberg Self-Esteem Scale</td>
<td>EC group improved differentially on WCST, Six Elements, and Digit Span; also showed improved self-esteem. Interaction between treatment condition and medication type (EC atypical antipsychotic = more improvement on cognitive tasks; may have been due to larger practice effects on timed tasks in the atypical antipsychotic group.)</td>
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**Study**

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<th><strong>Control condition</strong> (CC)</th>
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<td>CC1: EC</td>
<td>Computerized training (speed, vigilance, memory, concept formation, and problem solving) with advancement criteria (more vigilance training than CC1) Experimenter attention and positive urging were consistent across EC and CC1. Strategy coaching was not described.</td>
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<tr>
<td>CC2: no treatment</td>
<td>Twenty-five 30-min sessions (number of wks NR); NR (assumed individual)</td>
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<tr>
<td>CC1: groups of 3-5</td>
<td>Fifteen 30-min sessions over 3-4 wks; CC1: Cognitive tasks and communication tasks (Brenner's Integrated Psychological Therapy components) CC2: treatment-as-usual</td>
</tr>
<tr>
<td>CC2: individual</td>
<td>d2 Attention test</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Duration and modality of training</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1: Simple RT</td>
</tr>
<tr>
<td>CC2: RT with auditory distraction</td>
</tr>
<tr>
<td>Choice RT</td>
</tr>
<tr>
<td>General measure: component RT</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Outcome measures</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time (RT) tasks:</td>
</tr>
<tr>
<td>Simple RT</td>
</tr>
<tr>
<td>RT with auditory distraction</td>
</tr>
<tr>
<td>Choice RT</td>
</tr>
<tr>
<td>General measure: component RT</td>
</tr>
</tbody>
</table>

**Effect sizes (Cohen's d), where available, comparing EC to CC at posttest**

<table>
<thead>
<tr>
<th><strong>Group differences</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>EC participants showed improved RTs on general RT at posttest (F = 15.26, p &lt; 0.001); findings were attributed to increased training on vigilance tasks in EC.</td>
</tr>
</tbody>
</table>

**Computer-assisted automated task practice interventions**

<table>
<thead>
<tr>
<th><strong>Study</strong></th>
<th><strong>n and type of subjects, including medication data, if reported</strong></th>
<th><strong>Age (A = mean yrs unless otherwise indicated)</strong></th>
<th><strong>Gender (G = % male)</strong></th>
<th><strong>Education level (E = mean yrs)</strong></th>
<th><strong>Control condition (CC)</strong></th>
<th><strong>Experimental condition (EC)</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Benedict and Harris (1989)</td>
<td>20 inpatients; mean CPZE = 709 mg; all patients had been hospitalized more than 1 yr</td>
<td>A = 30 G = NR E = NR</td>
<td>CC1: EC</td>
<td>Computerized training (speed, vigilance, memory, concept formation, and problem solving) with advancement criteria (more vigilance training than CC1) Experimenter attention and positive urging were consistent across EC and CC1. Strategy coaching was not described.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Herma- nutz and Gestrich (1991)</td>
<td>30 inpatients; EC: 10 CC1: 10 CC2: 10 All patients were taking antipsychotic medication.</td>
<td>A = 31 G = NR E = 11</td>
<td>CC1: Cognitive tasks and communication tasks (Brenner's Integrated Psychological Therapy components) CC2: treatment-as-usual</td>
<td>Computer-assisted attention training; practiced CPT, reaction time tasks, auditory attention tasks, vigilance task, and Labyrinth Test Experimenter's were present and guided learning, but the emphasis was on &quot;drill and practice.&quot;</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Outcome measures**

- Reaction time (RT) tasks:
  - Simple RT
  - RT with auditory distraction
  - Choice RT
  - General measure: component RT

**Effect sizes (Cohen's d), where available, comparing EC to CC at posttest**

<table>
<thead>
<tr>
<th><strong>Outcome measures</strong></th>
<th><strong>Effect sizes</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction time (RT) tasks:</td>
<td><strong>EC to CC</strong></td>
</tr>
<tr>
<td>Simple RT</td>
<td>-0.08</td>
</tr>
<tr>
<td>RT with auditory distraction</td>
<td>-0.57</td>
</tr>
<tr>
<td>Choice RT</td>
<td>-0.44</td>
</tr>
<tr>
<td>General measure: component RT</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Outcome measures**

- BPRS Anxiety/depression: 0.14
- Anergia: -0.20
- Thought disturbances: 0.15
- Activation: 0.46
- Hostility/suspiciousness: 0.93
- PD-S scale
  - Hostility/paranoia: 0.02
  - Depression: 0.42

**Effect sizes**

- No differences between EC and CC1
- Effect sizes compare EC to CC2.
Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions — Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Education level (E = mean yrs)</th>
<th>Control condition (CC)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benedict et al. (1994)</td>
<td>33 outpatients EC: 16 mean CPZE = 280 mg CC: 17 mean CPZE = 346 mg Mean length of illness = 14 yrs; mean length of present hospitalization = 240 days</td>
<td>A = 38, 39 (E = 11.3)</td>
<td>Treatment-as-usual (day treatment program)</td>
<td>Day treatment program plus computer-based attention training sessions (guided practice on reaction time, vigilance, visuomotor tracking, immediate verbal memory, speed reading, and serial addition tasks)</td>
<td>Fifteen 50-min sessions over 3–5 wks;</td>
<td>Degraded Stimulus CPT Perceptual sensitivity Decrement over time Span of Apprehension Word List Recall Task</td>
<td>-0.01 0.82 0.12 1.22 0.71 0.44 0.57 0.78 0.89 –0.25 0.56 0.97 1.01</td>
</tr>
<tr>
<td>Burda et al. (1994)</td>
<td>69 inpatients EC: 40 CC: 29 66 patients were taking antipsychotic medication.</td>
<td>A = 47 (E = 12.5)</td>
<td>Treatment-as-usual (medication plus therapeutic community plus psycho-education)</td>
<td>Treatment-as-usual plus computer-assisted training using Captain's Log software—attention, memory, visuospatial, visuomotor, and conceptualization tasks</td>
<td>Twenty-four 30-min sessions over 8 wks;</td>
<td>Total Information Orientation Mental Control Memory Passages Digit Span Visual Recall Associative Learning Trail Making Tests Part A Part B</td>
<td>1.22 0.71 0.44 0.57 0.78 0.89 –0.25 0.56 0.97 1.01</td>
</tr>
</tbody>
</table>

Age (A = mean yrs unless otherwise indicated)
Gender (G = % male)

EC, CC:
A = 38, 39
G = 50%, 53%
E = 11.3, 10.8

Control condition (CC)
Treatment-as-usual (day treatment program)

Experimental condition (EC)
Day treatment program plus computer-based attention training sessions (guided practice on reaction time, vigilance, visuomotor tracking, immediate verbal memory, speed reading, and serial addition tasks)

Duration and modality of training
Fifteen 50-min sessions over 3–5 wks; NR (assumed individual)

Outcome measures
Degraded Stimulus CPT Perceptual sensitivity Decrement over time Span of Apprehension Word List Recall Task

Effect sizes (Cohen's d), where available, comparing EC to CC at posttest

Group differences
No group differences except for improved sustained attention in EC; authors rejected this difference, however, because of group differences in pretest scores.
<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Education level (E = mean yrs)</th>
<th>Control condition (CC)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen’s d), where available, comparing EC to CC at posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Field et al. (1997)</td>
<td>10 outpatients</td>
<td>A = 29 G = 90% male E = NR</td>
<td>Graphics-based computer games</td>
<td>Reaction Time Measure of Visual Field (REACT) and Shape Matching (MATCH) computerized attention and visual matching tasks</td>
<td>Six 1-hr sessions over 3 wks; individual</td>
<td>Cognitive Quotient Self-reported cognitive problems</td>
<td>-0.19 1.31</td>
</tr>
<tr>
<td></td>
<td>EC: 5 CC: 5 Mean length of illness = 8 yrs</td>
<td></td>
<td></td>
<td>Social reinforcement was not provided.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medalia et al. (1998)</td>
<td>54 inpatients impaired on CPT</td>
<td>EC, CC: A = 33, 32 G = 74%, 81% male E = NR</td>
<td>Watched documentaries with clinician present</td>
<td>Ben-Yishay and colleagues’ Orientation Remedial Module program of computerized attention remediation</td>
<td>Eighteen 20-min sessions over 6 wks; NR (assumed individual)</td>
<td>CPT BPRS</td>
<td>0.19 0.24</td>
</tr>
<tr>
<td></td>
<td>EC: 27 CC: 27 All patients were taking antipsychotic medication.</td>
<td></td>
<td></td>
<td>Clinicians provided guidance and support during sessions. Strategy coaching was not described.</td>
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</tbody>
</table>

Baseline difference
Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions—Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Age (A = mean yrs unless otherwise indicated)</th>
<th>Gender (G = % male)</th>
<th>Control condition (CC)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
<th>Group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bell et al. (2001)</td>
<td>65 outpatients EC: 31 CC: 34 Patients were taking antipsychotic medication.</td>
<td>EC, CC: A = 40, 42 G = 68%, 79% male E = 13.3, 13.2</td>
<td></td>
<td>Work therapy alone</td>
<td>Neurocognitive Enhancement Therapy plus Work Therapy</td>
<td>Up to 5 hrs in 2–3 sessions per wk for 26 wks;</td>
<td>WCST Factor</td>
<td>Working Memory Factor</td>
<td>A higher percentage of the EC group than the CC group had improved scores at posttest on the Working Memory Factor (F = 3.08, p = 0.01; Bell Lysaker Emotion Recognition Task, F = 12.84, p &lt; 0.001; Digit Span Backward, F = 3.87, p = 0.05) and the WCST Factor (F = 3.97, p = 0.006; Conceptual Level Responses, F = 10.44, p = 0.002; Categories Correct, F = 4.35, p = 0.04; Nonperseverative Errors, F = 6.78, p = 0.04);</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>individual computerized training plus group activities</td>
<td>Bell Lysaker Emotion Recognition Task</td>
<td>WAIS-III Digit Span, Letter Number Sequencing, and Digit Symbol subtests</td>
<td>(Data not provided)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Trail Making Test, Part B</td>
<td>Thought Disorder Factor</td>
<td>WMS-R Logical Memory Gorham's Proverbs Test Hinting Task Visual and Verbal Recall Factor</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>WMS-R Visual Reproduction and Figural Memory subtests HVLT (Trial 1 and Trial 3) CPT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Age (A = mean yrs unless otherwise indicated)</th>
<th>Gender (G = % male)</th>
<th>Education level (E = mean yrs)</th>
<th>Control condition (CC)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bellucci et al. (2003)</td>
<td>34 outpatients in day treatment EC: 17 CC: 17 Most patients were taking antipsychotic medication.</td>
<td>A = 42 G = 47% male E = 12.6</td>
<td></td>
<td></td>
<td>Wait-list control group</td>
<td>Computer-assisted cognitive rehabilitation program, using Captain's Log software, focusing on attention/concentration, memory, visuospatial and visuomotor skills, and conceptualization</td>
<td>Sixteen 30-min sessions over 8 wks; individual</td>
<td>Trail Making Test Part A time errors Part B time errors WMS—III Verbal Paired Associates Immediate Delayed Digit Span Forward Backward Logical Memory I—Recall Logical Memory II—Thematic Logical Memory II—Recognition MMSE SANS Self-Esteem Scale</td>
<td>Compared with the CC group, the EC group improved on Logical Memory I—Thematic score (F = 6.35, p &lt; 0.01); Logical Memory II—Recall score (F = 5.90, p &lt; 0.05); Logical Memory II—Thematic score (F = 4.21, p &lt; 0.05); Trail Making Test, Part B errors (F = 3.06, p &lt; 0.05); and the SANS (F = 12.56, p &lt; 0.001).</td>
</tr>
</tbody>
</table>

**Computer-assisted strategy-oriented task practice intervention**

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Age (A = mean yrs unless otherwise indicated)</th>
<th>Gender (G = % male)</th>
<th>Education level (E = mean yrs)</th>
<th>Control condition (CC)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medalia et al. (2000, 2001)</td>
<td>54 inpatients impaired on WAIS-R Comprehension and WMS—R Logical Memory I EC1: 18</td>
<td>A = 34, CC A = 36, 39 G = 67%, 44% male Logical Memory I EC1: 18</td>
<td></td>
<td></td>
<td>Treatment-as-usual</td>
<td>EC1: Memory training group using Memory Package software, emphasizing verbal and visual memory</td>
<td>Ten 25-min sessions over 5 wks; individual</td>
<td>Memory CVLT WMS—R Logical Memory I Problem solving WAIS-R Comprehension</td>
<td>There were no significant differences between the EC1, EC2, and CC groups from pretest to either of the two memory posttests.</td>
</tr>
</tbody>
</table>
Table 1. Literature review of cognitive training for patients with schizophrenia: Automated task practice interventions—Continued

<table>
<thead>
<tr>
<th>Study</th>
<th>n and type of subjects, including illness duration and medication data, if reported</th>
<th>Age (A = mean yrs unless otherwise indicated)</th>
<th>Gender (G = % male)</th>
<th>Experimental condition (EC)</th>
<th>Duration and modality of training</th>
<th>Outcome measures</th>
<th>Effect sizes (Cohen's d), where available, comparing EC to CC at posttest</th>
<th>(not computed if groups were significantly different at pretest)</th>
<th>Group differences</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC2: 18</td>
<td>CC: 18</td>
<td>All patients were taking antipsychotic medication.</td>
<td>E = 9.4, 11.4, 11.6</td>
<td>and encouragement.</td>
<td>EC2: Problem-solving training group using “Where in the USA is Carmen Sandiego” software, emphasizing deductive reasoning, planning, organization, and geography</td>
<td>Independent Living Scale, Problem Solving subscale</td>
<td>Tests were administered before, immediately following, and 4 wks following treatment.</td>
<td>provided for these effect sizes or for those comparing EC2 to CC</td>
<td>The EC2 group improved on the Independent Living Scale, Problem Solving subscale, whereas the EC1 and CC groups did not (F = 5.18, p &lt; 0.009); results did not differ when education level was entered as a covariate.</td>
</tr>
</tbody>
</table>

Environmental adaptation intervention

Velligan et al. (2000) 45 outpatients, recruited at discharge (15 per group) | Mean length of illness = 15 yrs; mean length of recent hospitalization = 6 mos | EC, CC1, CC2: attention placebo CC2: standard care | Manualized cognitive adaptation training (compensatory environmental strategies individually tailored to level of apathy, disinhibition, and executive dysfunction) | Weekly home visits for 9 mos (duration of visits NR); Individual | BPRS Positive symptoms Assessment (NSA) Global Assessment of Functioning (GAF) Multnomah Community Ability Scale (MCAS) | 1.37 1.72 0.91 | Compared to control groups, EC group had fewer positive symptoms on BPRS; had higher motivation scores on NSA; improved on GAF and MCAS; and had lower relapse rates. Authors used...
mean sample size in the studies was 41, with a range of 10 to 91. Participants were generally young (weighted mean age = 38 years) and male (71%), and had a weighted mean level of formal education of 11.9 years. Most reports used some type of task practice as the experimental condition, but one study utilized external environmental adaptations. We differentiated the former group of studies on the basis of their approach to task practice, which we conceptualized as varying in terms of how “automated” versus “clinical” the intervention was and whether the intervention was computer based. Three studies used paper-and-pencil and other types of task drills; we labeled this approach “automated task practice.” Four reports employed task practice with strategy coaching, which we called “strategy-oriented task practice.” Eight investigations used computer-assisted techniques to improve attention and other cognitive abilities via extensive repetition or drills, which we termed “computer-assisted automated task practice.” One study investigated a more personalized, contextualized computer-based approach emphasizing strategy coaching; we labeled this approach “computer-assisted strategy-oriented task practice.” The task practice interventions are summarized in table 2.

CT sessions lasted from 20 to 60 minutes in all the studies, but there was wide variation in the number of sessions administered, ranging from one 60-minute session to thirty-six 60-minute sessions. The duration of overall training varied from 1 day to 9 months. Two studies conducted CT in small groups, and one used a combination of group and individual sessions; we assumed that all the other investigations employed individualized training. Most investigations did not report the level of training of those administering the training sessions, whether manuals were utilized, or whether outcome measurement raters were masked to experimental conditions.

Control conditions in these studies included no treatment, treatment-as-usual, attention placebo, training placebo (e.g., exposure to computer training stimuli), occupational therapy, and other therapeutic interventions. The control conditions reviewed varied greatly in their content and in their similarity to the experimental conditions. Four reports included more than one control condition.

The variability in outcome measures used in these studies makes interpretation of their findings complicated. All but one study used cognitive tests as outcome measures, but heterogeneity in the ability areas measured and the tests used adds to the difficulty in comparing findings. Furthermore, some of the cognitive tests appeared to be clearly linked to functional outcomes (e.g., measures of social perception), whereas others measured lower-level cognitive functions (e.g., reaction time tasks). Seven investigations included symptom measures as outcome variables (e.g., Brief Psychiatric Rating Scale; Overall and...
Table 2. Four categories of task practice interventions

<table>
<thead>
<tr>
<th>Automated, drill-oriented approach</th>
<th>Strategy-oriented, clinical approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not computer assisted</td>
<td></td>
</tr>
<tr>
<td>Wagner (1968)¹</td>
<td>Meichenbaum and Cameron (1973)³</td>
</tr>
<tr>
<td>Olbrich and Mussgay (1990)¹</td>
<td>Corrigan et al. (1995)³</td>
</tr>
<tr>
<td>Brown et al. (1993)²</td>
<td>Spaulding et al. (1999a, 1999b)³</td>
</tr>
<tr>
<td>Computer assisted</td>
<td>Wykes et al. (1999)³</td>
</tr>
<tr>
<td>Benedict and Harris (1989)</td>
<td></td>
</tr>
<tr>
<td>Hermanutz and Gestrich (1991)²,⁴</td>
<td></td>
</tr>
<tr>
<td>Benedict et al. (1994)⁴</td>
<td></td>
</tr>
<tr>
<td>Burda et al. (1994)⁴</td>
<td></td>
</tr>
<tr>
<td>Field et al. (1997)²,⁴</td>
<td></td>
</tr>
<tr>
<td>Medalia et al. (1998)⁴</td>
<td></td>
</tr>
<tr>
<td>Bell et al. (2001)</td>
<td></td>
</tr>
<tr>
<td>Bellucci et al. (in press)⁴</td>
<td></td>
</tr>
</tbody>
</table>

¹ Weighted mean effect size: $d = 0.42$.
² Study reported negative results of CT. All other studies reported positive results on at least one outcome measure.
³ Weighted mean effect size: $d = 0.23$.
⁴ Weighted mean effect size: $d = 0.49$.
⁵ Mean effect size: $d = -0.38$.

Of the 17 studies reviewed (see table 1), 14 reported positive results with CT, as indicated by significant differences between experimental and control groups on at least one outcome measure. In one of these 14 studies, however, the authors rejected a significant finding because of group differences in pretest scores (Benedict et al. 1994). Three trials reported no significant differences between groups, based on an alpha level of 0.05.

Findings From the Reviewed Literature

Across studies (when appropriate data were provided) we calculated weighted mean effect sizes for three types of outcomes: improvements in neuropsychological performance, reductions in symptom severity, and improvement in everyday functioning. The weighted mean effect sizes (Cohen's $d$) in these domains were rather similar (0.32, 0.26, and 0.51, respectively) and represent small-to-medium effects, according to Cohen (1977).

As mentioned above, we divided the task practice interventions into four categories (see table 2): (1) automated task practice, (2) strategy-oriented task practice, (3) computer-assisted automated task practice, and (4) computer-assisted strategy-oriented task practice. The environmental adaptation study (5) was considered separately. We review these approaches below.

Automated Task Practice. Of the three investigations using this type of technique, two reported positive findings. The one study reporting negative results (Brown et al. 1993) used an occupational therapy program focusing on attention skills as the control condition; the experimental and comparison groups both improved in terms of cognitive test performance and functional evaluation. In the two positive studies, effects of automated task practice yielded improvements in the cognitive domains of vigilance (Olbrich and Mussgay 1990), verbal abstraction (Wagner 1968), arithmetic (Olbrich and Mussgay 1990), and visuospatial ability (Olbrich and Mussgay 1990). The weighted mean effect size (Cohen's $d$) for this subset of trials was 0.42.
Strategy-Oriented Task Practice. All four studies in this category reported positive findings in at least one outcome domain. Cognitive improvements were reported on tests of attention and working memory (Meichenbaum and Cameron 1973; Wykes et al. 1999), preattentive processing (Spaulding et al. 1999a, 1999b), cognitive flexibility (Wykes et al. 1999), planning (Wykes et al. 1999), and social cue recognition (Corrigan et al. 1995). Psychological and symptom-related improvements included enhanced self-esteem (Wykes et al. 1999), increased coherence and relevance of speech (Meichenbaum and Cameron 1973), reduction in thought disorder (Meichenbaum and Cameron 1973), and decreased disorganization (Spaulding et al. 1999a, 1999b). In the functional domain of interpersonal problem solving, Spaulding et al. (1999a, 1999b) reported improvement in their CT group. The weighted mean effect size (Cohen’s $d$) for this group of studies was 0.23.

Computer-Assisted Automated Task Practice. Six of the eight investigations in this category reported positive results. Improvements were found in the areas of reaction time (Benedict and Harris 1989), problem-solving ability (Bell et al. 2001), vigilance (Medalia et al. 1998), working memory (Bell et al. 2001), long-term memory (Burda et al. 1994), self-reported cognitive problems (Burda et al. 1994), and overall psychiatric symptoms (Medalia et al. 1998). One trial reported an improvement in sustained attention, but the authors rejected this finding because of pretreatment differences between groups (Benedict et al. 1994). Of the two negative studies, one (Hermanutz and Gestrich 1991) compared computer-assisted training to a noncomputerized CT program; thus, both the experimental and the comparison groups received CT. Effect sizes comparing the computer-assisted training group to a treatment-as-usual (no CT) group, however, showed some positive effects on symptom ratings (table 1). The other negative study (Field et al. 1997) was the only one in this category in which CT subjects were given no guidance or social reinforcement from an examiner or clinician. The weighted mean effect size (Cohen’s $d$) for this subset of studies was 0.49.

Computer-Assisted Strategy-Oriented Task Practice. The only study in this category (Medalia et al. 2000, 2001) compared the effects of computer-assisted CT (a memory training intervention and a problem-solving intervention) to treatment-as-usual. Experimenters provided the participants with support and encouragement but also provided feedback and strategy coaching relevant to the task at hand (i.e., memory or problem solving). Results of the trial indicated that, when compared with the treatment-as-usual control group, the memory training group did not demonstrate improved memory scores at either of two posttests, but the problem-solving group demonstrated improved scores on the Problem-Solving subscale of the Independent Living Scale at immediate posttest. Neither group exhibited generalization of training effects (i.e., improvement on test performance in the domain not trained). The mean effect size (Cohen’s $d$) of outcomes for this study was −0.38. However, it should be noted that this effect size was computed from only data pertaining to the memory training condition compared to the treatment-as-usual condition.

Environmental Intervention. The only environmental intervention investigation (Velligan et al. 2000) compared a cognitive adaptation training program to two control conditions: an attention placebo and standard outpatient care. The CT approach provided patients with home-based compensatory environmental strategies (e.g., posted lists or instructions) that were individually tailored to the patients’ levels of apathy, disinhibition, and executive dysfunction. The intervention took place over a 9-month period, making it the longest intervention among the studies we reviewed. The authors reported positive results in terms of positive symptoms, negative symptoms, motivation, community functioning, global functioning, and incidence of rehospitalization. The mean effect size (Cohen’s $d$) of outcomes for this study was 1.22.

Description of Four Methodologically Rigorous CT Trials

We selected four studies (Meichenbaum and Cameron 1973; Spaulding et al. 1999a, 1999b; Wykes et al. 1999; Bellucci et al. 2003) to review in greater detail as examples of methodologically sound, typical research in this area.

In one of the earliest investigations in this field, Meichenbaum and Cameron (1973) compared the effect of task practice with instruction in strategy use to that of task practice alone, incorporating several different types of tasks. During a 3-week period, inpatients in the experimental group ($n = 5$) were provided eight 45-minute sessions of practice in a self-talk technique that included repeating task instructions, talking aloud during tasks, and using self-reinforcement during tasks; instruction regarding utilization of self-talk in the interpretation of social cues also was provided. Experimental subjects improved differentially on a measure of relevance and coherence of speech during a structured interview, as well as on a digit span with distraction task and conceptualization on the Holtzman Inkblot Test. Although the sample size was very small, this study was well designed and its
practice CT programs showed positive effects in multiple
conventional antipsychotics. ing atypical antipsychotic medication were more likely to
change and reported that participants in the CT group tak-
ing differentially on 4 of 16 measured outcomes,
changes in the cognitive domains of interest as well as mea-
sures assessing functional outcomes, but identified posi-
tive effects of computer-assisted CT on both cognitive
tasks and negative symptom severity.

Discussion
The number of empirical studies of CT for schizophrenia
is limited, but we hope that our review of the literature will
provide an impetus to devise new investigations. In light
of a number of positive findings, we also are encouraged
that future research in this area will be fruitful. In our dis-
cussion of the aggregated findings of this literature, we
will focus on methodological factors, theoretical consid-
erations, and pragmatic issues. Finally, we will make recom-
mendations for further research in this area.

Certain methodological limitations existed across dif-
ferent studies. One common problem was small sample
size, with six trials including 30 or fewer patients. Another
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mental and control conditions. For example, very few
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These three investigations of strategy-oriented task
practice CT programs showed positive effects in multiple
areas, including cognitive performance, symptoms, and
functioning. These studies, especially the latter two,
demonstrated breadth of outcome measurement rarely
seen in this literature. That positive effects were found on
25 percent or fewer of the measured outcomes is striking,
leading one to wonder about specific components of these
programs that might yield these effects. Surprisingly, only
one study (Meichenbaum and Cameron 1973) used a fol-
lowup assessment to establish whether the effects of CT
were lasting.

Bellucci et al. (2003) compared the effect of 16 thirty-
minute sessions of computer-assisted CT over an 8-week
period to that of a wait-list control group in a day treat-
ment setting. Participants in the experimental condition (n
= 17) received computer-assisted cognitive rehabilitation
using Captain’s Log software, which focused on attention
and concentration, memory, visuospatial and visuomotor
skills, and conceptualization. Thus, as opposed to the
training in discrete domains used by Medalia’s group
(2000, 2001), Bellucci et al. employed a CT approach
addressing a wide range of cognitive domains. Outcome
measures included the Mini-Mental State Examination
(MMSE); three subtests of the Wechsler Memory
Scale—Third Edition (WMS—III); the Trail Making Test,
Parts A and B; and measures of negative symptoms and
self-esteem. Compared with the control group, CT partici-
ants improved on immediate and delayed “gist” recall of
stories, as well as total delayed recall of stories. They also
showed improvement on the Trail Making Test, Part B,
which requires speeded switching of cognitive set. The
most dramatic improvement, though, was in severity of
negative symptoms. This study did not include any mea-
sures assessing functional outcomes, but identified posi-
tive effects of computer-assisted CT on both cognitive
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mental and control conditions. For example, very few
reports provided information regarding the types of thera-
pists who administered the training conditions. More complete reporting of descriptive data would also have been desirable (e.g., means and standard deviations of change scores, such that pre-post effect sizes could be computed). Finally, although the statistics used in most reports appeared generally appropriate, proper interpretation of findings needed to incorporate corrections for multiple comparisons. Bonferroni corrections may be too conservative, given the exploratory nature of the studies, but other means of controlling for alpha inflation (e.g., multivariate statistics, Tukey's or Dunnett's test) are advisable.

Samples were generally well described in the studies we reviewed, with the exception of information regarding ethnicity of the participants. Additionally, most participants were young to middle-aged adult males. Thus, information regarding age, gender, and ethnicity differences in response to CT is lacking. In fact, only two of the studies we reviewed reported data regarding predictors of success or failure of CT (Spaulding et al. 1999a/1999b; Wykes et al. 1999). Knowledge regarding who does and who does not respond well to CT will be critical in the next phase of research in this area.

From a more theoretical standpoint, differences in control conditions made the findings of some studies difficult to interpret. Better studies used both standard care and attention-placebo control groups (e.g., Velligan et al. 2000), or control conditions that provided a contact placebo combined with a training placebo; for instance, Wagner (1968) used a control condition that provided exposure to the same apparatus and visually presented stimuli as those in the experimental condition; Field et al. (1997) utilized graphics-based computer games to control for exposure to the computer and to provide control participants with the opportunity to practice skills. Several trials included treatment-as-usual control groups; this is understandable, based upon the exploratory nature of most of these studies. At the other end of the continuum, some investigations employed control conditions that could be considered equivalent to CT conditions. For example, Brown et al. (1993) compared CT with occupational therapy emphasizing attention skills; their finding that both groups improved was not surprising.

One of the most serious concerns regarding this literature arises in considering outcome measurement. It has been demonstrated that patients with schizophrenia can learn to improve performance on specific cognitive tasks (e.g., the WCST); there is evidence that CT can lead to more generalized improvements in cognitive test performance as well. Assessment of change on cognitive tests is necessary, but more critical is measurement of real-world change in functioning. Fewer than one-third of the studies reviewed, however, included any assessment of everyday functioning in their outcome measures. Consequently, this literature can improve in terms of external validity. Ideally, outcome measures should include assessments of everyday functioning in multiple settings and roles; only then can CT's impact on specific types of functioning, the "gold standard" to which behavioral science research must be held, be understood (NIMH 2000). We believe the best instruments to assess functioning are objective, performance-based measures of real-world capacities, such as social communication, medication management, and the ability to use transportation, handle money, prepare food, and the like. Patterson et al. (2001) have developed three such instruments that will be useful in examining level of impairment in real-world abilities in populations with severe mental illness (the UCSD Performance-Based Skills Assessment, the Medication Management Ability Assessment, and the Social Skills Performance Assessment). Long-term followup measurement of such constructs would further establish whether CT results in lasting improvements. Along these lines, longer studies would allow for investigation of the effects of "booster sessions" (Green and Nuechterlein 1999) and other interventions designed to facilitate generalization of treatment gains in the lab to real-world functioning.

Finally, many of the current reports are not clear about the goals of their approaches to CT. One would like to see more theoretically grounded studies that describe the putative mechanisms underlying the interventions (e.g., restorative, compensatory, environmental). It may be assumed that CT approaches emphasizing repeated practice or drills attempt to improve basic, underlying cognitive deficits, whereas strategy-oriented CT approaches (whether computer assisted or not) attempt to provide compensatory strategies along with such practice. On a related note, there is only one randomized, controlled trial of an environmental approach to CT; it found that individually tailored environmental adaptation strategies, such as posted checklists, timers to cue behaviors, and organizational assistance, were helpful (Velligan et al. 2000). This work deserves replication and extension.

From a pragmatic perspective, in today's managed care environment, it is important to understand the costs associated with treatment choices. Thus, investigation of the cost-effectiveness of CT as an adjunctive treatment to pharmacotherapy is warranted. In addition, further CT research should focus on length of treatment as a predictor of change. Some of the trials reviewed had very short CT interventions (e.g., 1-4 days); these investigations did not aim to produce lasting changes in functional status, however. Some of the longer studies (e.g., 6-9 months) yielded positive findings in terms of functioning, but the length of time needed to provide an effective CT intervention has not been established. Thus, length of followup measurement and potential need for CT "booster sessions" (Green
and Nuechterlein 1999) are other pragmatic issues warranting further consideration. The need for bridging the gap between clinical research and service has been emphasized in recent mental health research (NIMH 1999), and we recommend that future research on CT address these issues in the process of disseminating CT interventions in nonresearch settings.

Conclusions

Based on our overall literature review and a more detailed discussion of the methodologically more rigorous studies of CT, it may be concluded that there are effective elements of computer-assisted CT, automated and strategy-oriented practice CT, and environmental adaptation CT. There is no compelling evidence that the cognitive impairments that characterize schizophrenia can be eliminated by any available treatment. Indeed, few would suggest that short-term CT can permanently resolve long-standing neuropsychological deficits in any population (Green and Nuechterlein 1999). There is evidence that CT, whether computer assisted or not, can yield some positive effects in terms of cognitive performance, psychiatric symptoms, and everyday functioning, but it is not known whether these effects are sustainable. Finally, environmental adaptation CT represents a promising new area of research, such that replication and extension of the findings of Velligan et al. (2000) are warranted. Although the question of the mechanism of action underlying the effects of CT has not been empirically investigated, we believe that the primary mechanism is probably compensatory.

It can be argued that strategy-oriented CT and Velligan’s environmental adaptation intervention both belong to the category of “compensatory” approaches. However, Velligan’s intervention used external (environmental) compensations, whereas the others attempted to teach “internal” compensatory strategies (e.g., repeating task instructions out loud to maintain attention on a task). Both the interventions and the issues related to generalization and maintenance of treatment gains are different. For example, an environmental approach may foster maintenance as long as the environmental supports are in place, but generalization may be limited. Internal compensatory strategies may be easier to generalize in the short term but more difficult to maintain over time if people fail to initiate in the real world the strategies they learned during the intervention.

CT efforts should focus on improving everyday functioning via compensatory strategies or overlearning of tasks, rather than restoring cognitive abilities per se (see also Bellack et al. 1999). Given the positive findings of the task practice approaches (whether computer assisted or not) and the encouraging findings regarding environmental adaptations, clinicians may consider using these tools in appropriate settings while awaiting more definitive research. Another possibility is that CT may be useful in conjunction with other interventions, to maximize learning, for example, social skills training or vocational rehabilitation (e.g., Bell et al. 2001).

We close with recommendations for future research:

1. Adequate sample sizes are needed, based on anticipated effect sizes for different outcome measures.
2. Research on more representative samples of patients with schizophrenia, including women, ethnic minorities, and older patients, would improve the generalizability of findings.
3. Both standard care and attention/training placebo control conditions should be employed.
4. Controlling for type of antipsychotic drug treatment (e.g., conventional vs. atypical agents) will be an important advance in this literature; drug treatments could also be investigated as predictors of response to CT.
5. CT manuals should be developed to enhance fidelity of treatment.
6. Outcome measures should include assessments of cognitive performance, psychiatric symptoms, and everyday functioning.
7. Furthermore, these assessments should be carried out longitudinally to (1) establish whether there are clinically meaningful lasting effects of CT, and (2) investigate the mechanisms of action underlying these effects (e.g., to test mediators of the relationship between changes in cognition and changes in everyday functioning).
8. Given the relatively large number of possible outcome measures, correction for multiple statistical comparisons is warranted in order to avoid type I errors.
9. Establishing which patients benefit from CT, which ones do not, and what costs are associated with CT will be important in the dissemination of CT as a clinical treatment for schizophrenia. Examination of subgroups of patients (e.g., based on demographic variables, severity and chronicity of disease and associated disability, disease subtype, current medication type, and cognitive deficit profile) will allow for better matching of treatment to the individual patient. Regarding cost-of-treatment issues, establishing the efficacy of group-based CT treatments may increase the value of CT in the managed care environment.
10. Theoretically driven research that attempts to delineate restorative, compensatory, or environmental adaptation effects will be helpful in determining which component works in CT for schizophrenia. Acceptance of a common nomenclature (e.g., restorative, compensatory, environmental) and theoretical
background may also allow this field to move forward more quickly.

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