VOL. 20, No. 3, 1994

Effects of Attention Training on Information Processing in Schizophrenia

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Abstract

This study evaluated the impact of a cognitive retraining intervention designed to enhance the attention skills of schizophrenia patients. The dependent variables included measures of perceptual sensitivity and sustained vigilance derived from a visual continuous performance test, as well as visual span of apprehension and word-list recall. Sixteen subjects received approximately 15 hours of repeated practice with computer-mediated vigilance tasks. Seventeen subjects were assigned to a no-treatment control group. All subjects were rated on measures of negative and positive symptoms before treatment. Despite improved performance on the training tasks, no significant changes on the outcome measures were observed following treatment. Thus, it is suggested that cognitive rehabilitation interventions with schizophrenia patients stress the teaching of behavioral strategies that bypass deficits, rather than remediating deficiencies in basic abilities, such as attention.

Schizophrenia Bulletin, 20(3): 537–546, 1994.

The past decade has witnessed a proliferation of outcome research and case studies investigating the effects of cognitive retraining in patients with traumatic brain injury (for reviews see O'Connor and Cermak 1987; Wilson 1987; Benedict 1989). Surprisingly, there has been relatively little investigation of cognitive retraining in schizophrenia, despite the fact that schizophrenia and brain-injured patients often endure similar cognitive deficits. In a recent volume of this journal devoted specifically to this topic, Spring and Ravdin (1992) urged investigators to pursue cognitive retraining with schizophrenia subjects, citing the few early studies that had yielded positive outcomes (Wagner 1968; Mieselman 1973; Steffy and Galbraith 1980). Although some argue that instituting cognitive retraining with schizophrenia patients either for treatment or research is premature (Bellack 1992), most agree that the issue merits empirical examination (Erickson and Binder 1986; Magaro et al. 1986; Spaulding et al. 1986; Flesher 1990; Liberman and Green 1992; Spring and Ravdin 1992).

In an investigation with schizophrenia patients, Benedict and Harris (1989) examined the impact of repeated practice with computer-mediated cognitive tasks developed for brain-injury cognitive rehabilitation (Gianutsos and Klitzner 1981, 1984; Bracey 1982; Gianutsos 1982). Subjects who received cognitive retraining demonstrated improved reaction time, whereas no improvement was observed in nontreated controls. A strength of this investigation was the inclusion of both an attention-placebo and no-treatment control group. Unfortunately, the experimental group included only five subjects, thereby limiting the generalizability of the findings. In addition, reaction time was probably not the best choice for a dependent measure, because deficits on this task are strongly associated with the presence of psychotic

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symptoms (Nuechterlein and Dawson 1984). In agreement with Liberman and Green (1992), we contend that the impact of cognitive retraining is best evaluated with tasks that are sensitive to impairments in remitted schizophrenia patients. Improving these information-processing "markers of vulnerability" (Zubin and Spring 1977; Spring and Zubin 1978; Nuechterlein and Dawson 1984) could conceivably enhance the remitted patient's capacity to benefit from preventive interventions, such as social skills training (e.g., Wallace and Boone 1984).

Two attention tasks, the Continuous Performance Test (CPT; Wohlberg and Kornetsky 1973) and the forced-choice, partial report, Span of Apprehension Test (SAT; Asarnow and MacCrimmon 1978, 1981), have been employed frequently in studies of schizophrenic cognition because they appear to detect enduring, trait-like deficits in patients with the disorder (Nuechterlein and Dawson 1984). The CPT is a vigilance task requiring rapid information processing, ongoing monitoring of a visual display, and detection of briefly presented target stimuli. To increase the task's processing load, most studies have employed variations of the CPT that use sequences of stimuli (Cornblatt and Erlenmeyer-Kimling 1984), complex stimuli such as playing card faces (Erlenmeyer-Kimling and Cornblatt 1978), or perceptually degraded stimuli (Nuechterlein et al. 1983). The SAT is another visual attention task designed to assess the patient's capacity to detect a briefly presented target letter within a stimulus array. The processing load of the SAT can be augmented by increasing the number of distractor letters included in the display (Asarnow et al., in press). Research has demonstrated that high-processing-load versions of the CPT and SAT consistently discriminate normal subjects from schizophrenia patients, patients in remission, and children at genetic risk for developing the disorder (Wohlberg and Kornetsky 1973; Asarnow et al. 1977; Asarnow and MacCrimmon 1978, 1982; Erlenmeyer-Kimling and Cornblatt 1978; Nuechterlein 1983; Asarnow et al., in press; Nuechterlein, in press). In their review, Nuechterlein and Dawson (1984) proposed that these attention tasks share in common a very high demand for information-processing capacity. They further suggested that reduced attentional capacity is a characteristic feature of individuals vulnerable to schizophrenic illness.

In this study, we hypothesized that information-processing capacity, as measured by the CPT and SAT, would be enhanced following exposure to a cognitive remediation intervention, aimed specifically at improving deficits in attention. A series of engaging, yet capacity-demanding training tasks were assembled and used for cognitive retraining. A visual CPT and SAT were administered as outcome measures before and after treatment, along with a word-list recall task (WLRT; Koh et al. 1973). Standardized symptom measures were also employed to investigate whether changes in performance would be more likely to occur in patients with particular symptoms.

Methods

Subjects. The subjects were 38 patients meeting Research Diagnostic Criteria (RDC; Spitzer et al. 1978) for chronic schizophrenia, randomly selected from an outpatient day-treatment center. Each subject gave written informed consent before his or her participation and the medical record of each subject was reviewed. Evidence of brain damage, mental retardation, or substance dependence as evaluated with *DSM-III-R* criteria (American Psychiatric Association 1987) were exclusionary criteria. The sample consisted of 22 men and 16 women whose average age was 37.9 (standard deviation [SD] = 10.8). The racial composition of the sample was 87 percent white (n = 33) and 13 percent black (n = 5). The mean education level was 11.2 (SD = 2.1) years. The average age at first psychiatric hospitalization was 23.9 (SD = 5.2), and the mean number of days hospitalized (inpatient) before the study was 239.7 (SD = 213.3). The average chlorpromazine equivalent level was 330.5 mg/ml (SD = 393.1). Twenty-eight subjects were prescribed antiparkinson medication; the mean benztropine equivalent level was 2.9 mg/ml (SD = 2.4).

Materials. An IBM compatible Compaq portable computer was used to administer the degraded-stimulus CPT and SAT. This system included a Taxan 620 monitor and a Gravis MK-VI analog controller joystick. An Apple IIe personal computer was used to present the WLRT and the attention training tasks. Additional equipment for this system included an Amdeck color-300 monitor, a Sirius joyport, an Atari joystick, and an Apple IIe game paddle.

Procedures.

Assessment. Each subject was first interviewed by two investigators. Dr. Benedict, two psychologists, and a psychiatry resident served as interviewers. Using the

Schedule for Affective Disorders and Schizophrenia–Lifetime Version (SADS–L; Endicott and Spitzer 1978), raters diagnosed each subject with the RDC. Only subjects meeting criteria for chronic schizophrenia, as judged by both independent raters, were asked to participate. Negative and positive symptoms were assessed with the Scale for the Assessment of Negative Symptoms (SANS; Andreasen 1984*a*) and the Scale for the Assessment of Positive Symptoms (SAPS; Andreasen 1984*b*), respectively. Single numerical values, ranging from 0 (absent) to 5 (severe) were provided by each interviewer. Using the SANS, raters determined the subjects' degree of alogia, affective flattening, avolition-apathy, anhedonia-asociality, and attentional impairment. With the SAPS, subjects were rated on the prevalence of hallucinations, delusions, thought disorder, and bizarre behavior. Since Dr. Benedict participated in each interview, interrater reliability coefficients for SANS and SAPS summary scores were computed using his ratings and the combined ratings of the other interviewers (SANS $r = 0.85$, SAPS $r = 0.89$). Averaged ratings from both raters in each interview were employed in the statistical analyses.

Following the pretreatment interview, each subject was assessed on a degraded-stimulus version of the CPT, a forced-choice SAT, and a WLRT. This cognitive test battery was repeated after the treatment interval. On each occasion, the tasks were administered in the same order: (1) degraded-stimulus CPT, (2) SAT, (3) WLRT.

The degraded-stimulus CPT was presented on the Compaq computer, using a program developed by Drs. Nuechterlein and Asarnow. Subjects, with their eyes positioned 1 meter from the computer screen, were asked to press a response button whenever the number "0" appeared on the computer monitor (signal trials). Other single-digit numbers served as noise trials in a quasi-random sequence. The signal trials comprised 25 percent of stimulus presentations. To increase the processing load of the task, the stimuli were blurred and presented with background visual noise; black/white reversal of a random 40 percent of pixels was used to produce degradation. The stimulus duration was 70 milliseconds and the stimulus event rate was 1 per second. Subjects were first shown 10 examples of the critical stimulus. Then 160 practice trials were administered followed by a short break and 480 experimental trials, presented in a vigilance period lasting 8 minutes. If subjects looked away from the screen or spoke to the examiner during the test, they were reminded to pay attention and press the response button following each "0." The perceptual sensitivity measure A′ (Grier 1971) was derived from the CPT hit rate (proportion of target detections) and false-alarm rate (proportion of errors of commission) indices. Overall A′ level was calculated by averaging the means from the three consecutive 160 trial blocks. The decrement in sensitivity over time (A′ decrement) was calculated by subtracting the average A′ score obtained during the first 160 trials from the average A′ during the last 160 trials.

The forced-choice SAT was also presented with the Compaq system, using a program by Drs. Asarnow and Nuechterlein. As described by Asarnow and MacCrimmon (1978), subjects were instructed to indicate whether a true ("T") or false ("F") was presented in each of 128 stimulus arrays. However, in contrast to Asarnow and MacCrimmon's (1978) verbal report procedure, subjects in the present study were instructed to respond by depressing one of two designated response buttons. Each array included either a "T" or an "F" in addition to distractor letters, with letter positions varying across trials within a 4 × 4 matrix. Half of the arrays included 2 distractors and the other half 11. There were 64 trials (4 blocks of 16 trials) of each letter-array size presented in a counterbalanced order. Equal numbers of each target were presented within each block of trials. As in the CPT procedure, the stimulus duration was 70 milliseconds. The numbers of correct detections on 3-letter and 12-letter arrays derived from the SAT were converted to proportions of correct detections (P[C]) for analysis. The variable of interest was the proportion correct on high-distraction, 12-letter, stimulus arrays (i.e., P[C]-12).

The WLRT was presented on the Apple IIe computer system. The same 20 stimulus words employed by Koh et al. (1973) were presented one at a time on the computer monitor. The words were originally obtained from Battig and Montague (1969) and included four nouns from each of five conceptual categories. As in the Koh et al. (1973) procedure, each stimulus word was presented for 2 seconds and the intertrial interval was 1 second. Subjects were instructed to watch the monitor and to remember as many of the words as possible. The experimenter read each stimulus as it appeared on the monitor. Immediately following the presentation of the 20th word, each subject repeated as many of the words as possible. The same list of 20 words was repeated over 5 trials and the total number of correctly recalled words was recorded as the dependent variable.

Attention training. The subjects were randomly assigned, in sequence, to one of two groups. Control group subjects received no attention training but participated in the same multidisciplinary, day-treatment program as did experimental subjects. Subjects assigned to the experimental group also received a mean of 14.4 (SD = 1.09) 50-minute sessions of guided practice with six computer-based attention tasks. The training tasks were administered by trained undergraduate research assistants. The average treatment interval was 50.0 days (SD = 17.2), and depending on subject availability, three to five training sessions were scheduled per week.

As in a previous study (Benedict and Harris 1989), existing models for brain-injury cognitive rehabilitation (e.g., Ben-Yishay et al. 1987) provided a framework for the attention training intervention. Six training tasks were selected from a large pool of commercial software for brain-injured adults.[1] The selection of training tasks was based on the available literature (Gianutsos and Klitzner 1981, 1984; Bracey 1982; Gianutsos 1982), as well as data collected previously (Benedict and Harris 1989). Each training task required sustained vigilance and a high degree of mental effort. Throughout training, subjects were instructed to ignore irrelevant stimulation, and they received verbal reinforcement for improved performance. A daily log depicting previous scores was also provided in a format easily interpreted by subjects. Using the daily log, experimenters urged each subject to improve during each successive session.

Subjects received practice with each training task during each session. Five of the tasks were presented in graded fashion so that subjects began practice at relatively easy levels and proceeded to more difficult levels with improved performance. In contrast, the serial addition task (Number Manipulations I, Bracey 1982) was administered in precisely the same manner each time. This task is analogous to the Paced Auditory Serial Addition Test, which is known to be highly sensitive to the attentional-capacity deficits of mild, traumatically brain-injured adults (Gronwall and Wrightson 1974). In the present study, subjects were required to monitor single digits displayed on the computer monitor while adding the two most recently displayed numbers. Subjects were encouraged to respond rapidly in order to complete the series of 20 additions as quickly as possible with a minimum of errors. Both the number of errors and time-to-completion were recorded following each administration. These values were used for feedback during training sessions and to track subject's performance over the course of training.

[1]The following six computer-mediated training tasks composed the attention training battery: (1) The Visual Reaction Stimulus Discrimination II program (Bracey 1982) served as a reaction-time task. Yellow and blue squares were presented and subjects were instructed to respond with a button press following the appearance of yellow squares, while inhibiting responses to blue squares. Subjects received feedback regarding their response latency and number of errors following each administration. (2) The Simultaneous Multiple Attention program (Bracey 1982) presented four lines of letters, moving from left to right across the computer screen. Subjects were instructed to continuously monitor and pace the stimuli, and respond with a button press each time a target appeared within brackets positioned in the middle of the screen. The number of hits and false alarms were recorded by the experimenter and presented as feedback. (3) The Driver program (Bracey 1982) presented a visuomotor tracking task that required subjects to operate a car (small moving square) with a game paddle in such a manner as to maintain the car on a moving track (white band in center of screen). The percentage of time "on track" was reported after each trial. (4) The Span program (Gianutsos 1982) was used to present a verbal immediate memory task. A series of words was presented one at a time on the computer monitor. At varying intervals, the word sequence stopped and subjects were asked to report the last two stimuli. The average number of recalled words was calculated and reported by the computer after each administration. (5) The Fast Read program (Gianutsos and Klitzner 1984) was used to briefly present single words on the computer screen, the task of the subject was to simply read each word aloud. The program automatically adjusted the presentation time according to the proportion of correct responses. When subjects attained reliable performance at the fastest level (50 milliseconds), two words were presented. The stimulus presentation time was reported after each trial for feedback. (6) The Number Manipulations I program (Bracey 1982) was employed as a serial addition task. This training task is described fully in the body of this article.

Results

Potential relationships between pretreatment psychiatric symptoms and cognitive test scores were examined with Pearson r correlation coefficients, calculated for the entire sample. No statistically significant correlations were found between the SANS and SAPS summary scores and CPT A', CPT A' decrements, or SAT P(C)-12. WLRT recall was moderately associated with negative symptoms ($r = -0.38$, $p < 0.05$), indicating that negative symptoms were less frequently observed in patients with relatively good verbal recall.

Five subjects withdrew from the study before posttreatment assessment. Of these subjects, one required inpatient hospitalization, another refused to participate after being exposed to the assessment tasks, and three left the day-treatment center for unknown reasons. With the exception of their being exclusively male, these subjects were descriptively similar to the rest of the sample (i.e., demographic, symptom, and medication level means for this subgroup were within 1 SD of the entire sample mean). Of the 33 remaining subjects, 16 had been assigned to the experimental group and 17 to the control group. One way analysis of variances (ANOVAs) comparing group means for age, education, days hospitalized, medication levels, and pretreatment symptom ratings did not reach statistical significance (table 1).

The pretreatment and posttreatment group means for each of the four dependent measures are presented in table 2. The significance of change in performance was evaluated by separate 2 (Group) × 2 (Trials) mixed factor ANOVAs. The ANOVA for CPT A' failed to indicate either a significant Group × Trials interaction or main effect. The ANOVA conducted on the SAT P(C)-12 and WLRT scores revealed a significant main effect for Trials (P[C]-12 $F = 4.98$, $df = 1,31$, $p < 0.05$; WLRT $F = 28.05$, $df = 1,31$, $p < 0.001$), but the predicted Group × Trials interaction did not reach statistical significance for

Table 1. Demographics and pretreatment group means for descriptive and symptom variables

	Experimental group (n = 16)	Control group (n = 17)
Race (white/black)	14/2	15/2
Gender (male/female)	8/8	9/8
Age (mean, SD)	38.1 (11.6)	39.5 (11.1)
Education (mean, SD)	11.3 (1.6)	10.8 (2.7)
Days hospitalized (mean, SD)	269.0 (211.8)	173.8 (200.7)
Chlorpromazine equivalents (mean, SD)	279.7 (196.6)	346.1 (544.1)
Benztropine equivalents (mean, SD)	2.8 (2.2)	3.1 (2.7)
SANS (mean, SD)	11.7 (3.5)	11.7 (3.9)
SAPS (mean, SD)	9.6 (2.9)	8.4 (3.3)

Note.—SANS = Scale for the Assessment of Negative Symptoms (Andreasen 1984*a*); SAPS = Scale for the Assessment of Positive Symptoms (Andreasen 1984*b*); SD = standard deviation.

Table 2. Pretreatment and posttreatment information-processing group means

	Pretreatment mean (SD)	Posttreatment mean (SD)
CPT A'		
Experimental	0.812 (0.13)	0.833 (0.12)
Control	0.820 (0.09)	0.834 (0.09)
CPT A' decrement		
Experimental[1]	−0.057 (0.06)	−0.026 (0.05)[2]
Control[1]	−0.018 (0.07)	−0.040 (0.06)
SAT P(C)-12		
Experimental	0.760 (0.08)	0.821 (0.05)
Control	0.734 (0.07)	0.746 (0.12)
WLRT		
Experimental	51.6 (15.2)	60.7 (17.9)
Control	49.0 (19.1)	58.4 (19.0)

Note.—CPT = Continuous Performance Test (degraded-stimulus); SAT = Span of Apprehension Test, P(C)-12 = proportion correct for 12-letter arrays; WLRT = word-list recall task; SD = standard deviation. The CPT, SAT, and WLRT are unpublished computerized tests

[1] Group means after outliers removed from data.
[2] $p < 0.05$.

either variable. Therefore, improvement on these tasks was attributed to the effects of task-specific practice. The CPT A′ decrement within the experimental group diminished following the attention training intervention, and when compared to the control group, the difference in change was determined to be statistically significant (interaction $F = 6.62$, $df = 1,31$, $p < 0.05$). However, the pretreatment decrement was substantially larger for the experimental group, and closer inspection of the data revealed two outliers whose A′ decrements were –0.22 (experimental subject) and 0.23 (control subject). Removing these outliers from the analysis reduced the pretreatment difference between the groups to a nonsignificant level, while the Group × Trials interaction remained ($F = 4.27$, $df = 1,29$, $p < 0.05$). Analysis of the simple main effects indicated a significant change over time for the experimental group ($F = 5.71$, $df = 1,14$, $p < 0.05$), but not for the control group.

Additional analyses were conducted to control for potentially confounding variables. First, to control for the effects of subject variables, Pearson r correlation coefficients were computed between demographic, medication, and symptom variables and the cognitive change scores. This analysis revealed only two statistically significant correlations (A′ and age $r = -0.43$, $p < 0.05$; A′ and hallucinations $r = 0.34$, $p < 0.05$) and accounting for these variables in subsequent analyses of covariance did not change the results. Second, since it could be argued that the observed improvement in CPT vigilance among experimental subjects was due to a qualitative change in their propensity to respond in a particular direction (i.e., bias toward omission vs. commission errors), the nonparametric bias index B′′ (Grier 1971) was computed for each subject and B′′ decrement scores were computed in similar fashion as described for A′ decrements. Mixed factor ANOVAs on overall CPT B′′ and CPT B′′ decrements revealed no significant effects, indicating that the groups did not differ in terms of their response bias at either pretreatment or posttreatment assessment.[2]

Changes in performance during the course of training in the experimental group were examined with the error and time-to-completion scores derived from the serial addition training task. On session one, the average number of errors was 2.38 (SD = 3.54) and the average time-to-completion was 220.8 (SD = 117.8) seconds. By the end of training, the treated group had improved to an average of 0.75 (SD = 1.13) errors and a time-to-completion of 102.3 (SD = 39.3) seconds. These data suggest that as a group the experimental subjects improved significantly on this training task. There was considerable variability among subjects with regard to this improvement, however, and we speculated that treatment effects on the outcome measures might be discernable only among subjects demonstrating large practice effects. To test this hypothesis, we divided the experimental group into two subgroups of equal numbers, on the basis of serial addition task change scores. Subjects in the improved group had an average change score of 205 (SD = 85.9) seconds, while their poorer responding counterparts improved only 31 (SD = 23.5) seconds. These subgroups differed significantly in their average change in error score (2.6 vs. 0.6, $F = 25.5$, $df = 14$, $p < 0.001$), but no differences were revealed when change scores on the outcome measures were examined. Similarly, Pearson r correlation coefficients revealed no significant relationships between change scores on the serial addition task and the outcome measures.

[2]Snodgrass and Corwin (1988) argued that Grier's (1971) nonparametric measures of perceptual sensitivity and bias are not statistically independent. Therefore, the CPT data obtained in this study were reanalyzed with measures of perceptual accuracy and bias derived from a two-high-threshold model, as per their recommendation. The results were not substantially different from those reported.

Discussion

If the psychosocial and cognitive deficits in schizophrenia are related to an impaired capacity for attention, it seems logical to direct therapeutic efforts at remediating this deficit. Cognitive retraining interventions, such as the one employed here, are based on the notion that basic cognitive deficiencies can be improved with repeated exercises that require the impaired mental operation. Our purpose was to determine whether such an intervention could be useful in a sample of chronic schizophrenia patients. We postulated that through repeated practice on engaging, computer-mediated, capacity-demanding tasks, "effortful" cognitive operations would become more "automatic" in our subjects, leading to improved performance on the degraded-stimulus CPT and SAT. Contrary to our prediction, the participants in this attention training procedure failed to show the expected improvement on these well-known measures of attention. The findings suggest that attention remediation, at least as employed in this study, does not lead to enhanced attentional capacity in schizophrenia.

We were at first inclined to interpret the decreased CPT sensitivity decrements of the experimental group as evidence for a treatment effect. Such a finding would suggest that schizophrenia patients can be taught to sustain their attention over time, despite their residual deficits in overall capacity. However, the interpretation of the significant CPT A' decrement interaction is not at all straightforward. Despite our efforts to correct the discrepancy between the groups on pretreatment decrement scores by removing outliers, the scores remained substantially different. This large pretreatment difference may have predisposed each group to their respective changes in performance, independent of the treatment's influence (i.e., regression to the mean). Indeed, although the experimental group improved after training, their posttreatment decrement score remained below the pretreatment score of the control group. Therefore, while the findings suggest that sustained attention may be modifiable in schizophrenia, we contend that this interpretation be viewed as a hypothesis for future inquiry in a better controlled study with groups matched on pretreatment CPT decrement scores.

The data recorded during the training sessions indicated that the participants improved significantly on the serial addition task. By the end of the training, the experimental subjects completed this task in approximately one-half the time needed in session one. Yet, this improvement should not be viewed as a significant change in attentional capacity. As is well known, improved performance on repeatedly administered training tasks is confounded by the effects of task-specific practice (e.g., familiarity with particular test stimuli), an artifact that requires strict control in cognitive retraining studies (Gordon 1987; Wilson 1987; Benedict 1989; Bellack 1992). Furthermore, change scores on the serial addition task were not correlated with change scores obtained from any of the outcome measures. Therefore, we conclude that this rather substantial practice effect does not denote an improved, fundamental cognitive skill.

Given the positive outcomes reported in previous studies (e.g., Meichenbaum and Cameron 1973; Steffy and Galbraith 1980; Benedict and Harris 1989), our negative findings come as somewhat of a surprise. As noted previously, Benedict and Harris (1989) reported improved reaction time in a small sample of schizophrenia patients, as did Steffy and Galbraith (1980), who employed an extensive reinforcement schedule with repeated practice with cognitive tasks. Meichenbaum and Cameron (1973) found that schizophrenia patients can be taught to verbalize a behavioral strategy to decrease their distractibility. In Kahneman's (1973) terms, the mental operations involved in tasks such as reaction time and the ignoring distraction may have more to do with the allocation of attentional resources than attentional capacity per se. In contrast, the CPT requires continuous attention to successive, rapidly presented stimuli, and subjects must make repeated decisions as to whether or not a target or distractor was presented. These aspects of the task result in a very high demand for information-processing capacity (Nuechterlein and Dawson 1984). When viewed in the context of these previous studies, our findings suggest that the attention deficits identified by the degraded-stimulus CPT and partial-report SAT are relatively resistent to the effects of behavioral treatment, by virtue of their very high demand for information-processing capacity.

There are, however, plausible methodological explanations for the negative findings that merit consideration. First, the relatively small sample size raises the question of whether there was sufficient power to detect treatment effects. While our sample size was sufficient to detect an effect of similar magnitude as was found in our previous reaction time study (effect size $d \approx 1.2$; Benedict and Harris 1989), we did not have the statistical power to detect a more modest effect (cf. Cohen 1988). This raises the possibility of a false-negative result. A second issue concerns the generalizability of training effects, a well-recognized problem in cognitive rehabilitation research (Gordon 1987). Because the training tasks required sustained attention, rapid processing, and a high degree of mental effort, improved cognitive skills following repeated practice with these tasks were assumed to be transferable to CPT and SAT performance. Yet, this assumption rests entirely upon the face validity of the training tasks. It is arguable that the results reflect a lack of generalization of a remediation effect to the outcome measures, rather than a lack of remediation. A stronger research design would include a normal comparison group to ensure that a transfer of training is possible.

These methodological concerns notwithstanding, our overall interpretation of the findings is that this form of cognitive retraining has little impact on the attentional capacity of schizophrenia patients. When considering the clinical implications of the results, it is also noteworthy that the functional significance of deficits on attention tasks such as the CPT and SAT is unknown. Schizophrenia patients may be capable of learning specific skills despite impaired attentional capacity (Wallace and Boone 1984; Bellack 1992). Therefore, until the efficacy of stronger remediation interventions is demonstrated, it makes sense to emphasize interventions that help patients circumvent impaired attentional capacity, instead of attempting to enhance this deficit through remediation strategies. A similar emphasis on compensation interventions is rapidly emerging in the area of cognitive rehabilitation for traumatic brain injury (e.g., Wilson 1987, 1989; Benedict et al. 1993).

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Acknowledgments

This research was supported in part by USPHS grant MH-42266 from the National Institute of Mental Health to Dr. Therese Markow. The authors thank Dr. Jeffrey Ricker for his assistance in interviewing subjects, and Dr. David Schretlen for his comments on a previous draft of this manuscript.

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