# Attentional Vulnerability Indicators, Thought Disorder, and Negative Symptoms

*by Keith H. Nuechterlein, William S. Edell, Margaret Norris, and Michael E. Dawson*

## Abstract

Deficits on two continuous performance test versions and the forced-choice span of apprehension task, which are potential vulnerability factors for schizophrenic disorders, were examined in relationship to particular symptoms of schizophrenic disorders, with emphasis on hypothesized relationships to formal thought disorder and negative symptoms. These interrelationships were determined concurrently within a group of 40 schizophrenic patients at an inpatient point. In addition, 32 of these patients were retested at a stabilized outpatient point to address the extent to which continued attentional deficits were associated with specific symptomatology during the hospitalized period. Signal-discrimination deficits on the three tasks were consistently associated with inpatient negative symptoms of schizophrenia as measured by the Anergia factor of the Brief Psychiatric Rating Scale (BPRS), across both the inpatient and outpatient assessments. The outpatient signal-discrimination deficits also showed significant, but less consistent, correlations with inpatient schizophrenic modes of thinking measured by the Rorschach Thought Disorder Index and with formal thought disorder measured by the BPRS Conceptual Disorganization rating. In contrast, no relationship with inpatient hallucinations or delusions was found. Combined with previous findings from high-risk samples, these results are consistent with the view that signal-discrimination deficits in situations demanding high levels of effortful processing are enduring vulnerability factors for schizophrenic negative symptoms and possibly for certain schizophrenic forms of thought disorder.

A series of recent studies has examined the possibility that certain deficits in attentional functioning and information processing might serve as indicators of personal vulnerability to schizophrenic disorders among some individuals within groups at increased statistical risk for these disorders (see reviews by Erlenmeyer-Kimling et al. 1982; Asarnow 1983; Nuechterlein and Dawson 1984). These studies have found that impairments that are present among many adult schizophrenic patients on specific laboratory performance tasks, such as the continuous performance test (CPT) and the forced-choice span of apprehension, are also found among a subgroup of the offspring of a schizophrenic parent and among nonpsychotic individuals at hypothesized risk due to schizotypal personality characteristics.

One important issue that has been raised recently is the extent to which such laboratory measures of cognitive processing are related to specific overt symptoms of schizophrenic disorders, as contrasted with the global diagnosis of schizophrenic disorder (George and Neufeld 1985; Neale, Oltmanns, and Harvey 1985). Associations with specific types of symptoms would help to explain the frequent observation that only certain schizophrenic patients show impairment on individual attentional or information-processing tasks (e.g., Kornetsky and Orzack 1978; Asarnow and MacCrimmon 1981) and would aid development of more specific models of the role of basic information-processing deficits in schizophrenic disorder. In the present study, we examine the extent to

Reprint requests should be sent to Dr K H Nuechterlein, UCLA Neuropsychiatric Institute, Box 18, 760 Westwood Plaza, Los Angeles, CA 90024

which signal-discrimination deficits in the CPT and the forced-choice span of apprehension, assessed during inpatient and stabilized outpatient periods, are related to specific symptom clusters among schizophrenic patients, particularly formal thought disorder and negative symptoms.

## CPT and Forced-Choice Span of Apprehension Impairments

The CPT was originally developed by Rosvold et al. (1956) to detect deficits in sustained alertness in subjects with brain damage. The phrase "continuous performance test" suggests a single standardized testing procedure, but actually has referred to a group of visual vigilance tasks in which subjects monitor a continuous series of single letters or numbers that are presented very briefly (40–200 ms) one at a time with a relatively short, fixed interstimulus interval (1-1.5 seconds). The subject's task is to respond with a button press each time that a predesignated target stimulus appears in a random stimulus series. Variations of the task have included target stimuli that are single letters or numbers (Rosvold et al. 1956), sequences of two consecutive letters or numbers (Rosvold et al. 1956), or playing cards (Erlenmeyer-Kimling and Cornblatt 1978), perceptually degraded numbers (Nuechterlein 1983; Nuechterlein, Parasuraman, and Jiang 1983), or picture stimuli (Anderson et al. 1969).

Versions of the CPT that produce a relatively high momentary processing load through use of degraded stimuli or sequential targets have identified deficits in signal/noise discrimination (perceptual sensitivity) during vigilance in samples identified as at risk for schizophrenia on the basis of parental schizophrenia (Rutschmann, Cornblatt, and Erlenmeyer-Kimling 1977; Nuechterlein 1983; Cornblatt and Erlenmeyer-Kimling 1985) or personality test criteria for schizotypal features (Nuechterlein, Edell, and West, submitted for publication). Actively symptomatic schizophrenic patients (Asarnow and MacCrimmon 1978; Walker 1981) and relatively remitted schizophrenic patients (Wohlberg and Kornetsky 1973; Asarnow and MacCrimmon 1978) show similar target detection deficits on difficult versions of the CPT. Versions of the CPT that involve detection of a single, familiar target letter or number involve much more limited moment-to-moment processing load and have been successful in detecting deficits among chronic schizophrenic patients (Orzack and Kornetsky 1966) but not among children at risk for schizophrenia (Asarnow et al. 1977). Thus, signal/noise discrimination impairment during CPT versions with high processing loads, but not in versions with low processing loads, seems to reflect a vulnerability factor in schizophrenic disorder rather than any transient deficit that is secondary to psychotic symptomatology. In addition, inpatients with affective disorder and children of patients with affective disorder or with nonpsychotic disorders outside the schizophrenia spectrum do not appear to have this CPT performance deficit (Walker 1981; Nuechterlein 1983; Erlenmeyer-Kimling et al. 1984). Some hyperactive children (O'Dougherty, Nuechterlein, and Drew 1984) but not others (Nuechterlein 1983) do show this signal/noise discrimination deficit, so the deficit is not wholly specific to risk for schizophrenia, but hyperactive children show accompanying lower response criterion scores in signal detection theory analyses that suggest an additional impulsive responding component.

The forced-choice span of apprehension task has shown similar promise as a vulnerability indicator for schizophrenia. This procedure was developed to examine the efficiency of visual search in initial, sensory memory without burdening active short-term memory (Estes and Taylor 1964). Subjects are required to identify which of two target letters (usually T or F) appears in tachistoscopic presentations of letter arrays of varying sizes. Efficient target recognition in this task involves very rapid rejection of irrelevant, nontarget letters, without full processing to awareness, and effective discrimination of the critical features of the target letter.

The forced-choice span of apprehension task has detected a deficit in signal-discrimination accuracy among children at genetic risk due to parental schizophrenia (Asarnow et al. 1977) and among adults with schizotypal characteristics on personality inventory scales (Asarnow, Nuechterlein, and Marder 1983). Symptomatic schizophrenic inpatients (Neale et al. 1969; Neale 1971; Asarnow and MacCrimmon 1978) and relatively remitted schizophrenic outpatients (Asarnow and MacCrimmon 1978, 1981) show the same deficit. Schizophrenic inpatients score more deviantly than nonpsychotic inpatients (Neale 1971), and schizophrenic patients show greater deficits than manic-depressive patients among relatively recovered outpatients (Asarnow and MacCrimmon 1981).

The forced-choice span of apprehension shares with most CPT versions an emphasis on initial perceptual discrimination of briefly presented alphanumeric characters. Demands for acquisition of new information are minimal. Responses are relatively immediate, so long-term memory demands are limited to access to the stored representations of alphanumeric characters. One major difference concerns whether targets and nontargets are presented simultaneously in brief information bursts or sequentially in continuous trials. For this reason, the CPT has usually been referred to as a measure of sustained attention. However, the signal/noise discrimination deficit in the CPT among children at risk for schizophrenia appears to be present across all time periods of the task and the drop in signal/noise discrimination over time within task has not been significantly greater than normal (Nuechterlein 1983, 1985), so the schizophrenia-relevant deficit appears to be related to ongoing selection of target stimuli rather than to deficient target selection specifically at the end of a vigilance period. Thus, we will emphasize common features of the CPT and forced-choice span of apprehension by referring to the deficits on these two types of task as signal/noise discrimination impairments, or for convenience, as signal-discrimination impairments, while recognizing that the temporal nature of the discrimination demands are very distinctive. The lack of significant association between the forced-choice span of apprehension and a CPT version among schizophrenic outpatients in one report (Asarnow and MacCrimmon 1978) indicates that their differences are sufficient to merit separate examination of the clinical, symptomatic correlates of each of these potential indices of a vulnerability factor for schizophrenia.

## Thought Disorder Index (TDI) and Schizophrenia

Formal thought disorder has long been considered a central clinical feature of the schizophrenic disorders (Bleuler 1911/1950; Kraepelin 1913/1919) and has been the most frequent focus of models that relate basic attentional and information-processing deficits to particular schizophrenic symptoms (Maher 1972; Neale and Oltmanns 1980; Schwartz 1982). In early research, the measurement of disordered thinking was based largely on global judgments of clinicians interacting in a relatively unstructured interview format with disturbed individuals. Concerns regarding reliability and validity of measurement were less salient. The seminal work of Rapaport, Gill, and Schafer (1946) involving extensive psychodiagnostic evaluations of individuals with various psychiatric disorders produced several categories of deviant verbalizations obtained from psychological test performance. Borrowing from this earlier work, Watkins and Stauffacher (1952) devised an index of pathological thinking called the "Delta Index," assigning weights from .25 to 1.0 to each type of verbalization to reflect degree of deviancy. This quantification of disordered thinking proved quite successful in discriminating schizophrenic from nonpsychotic populations using the Rorschach inkblot test (Powers and Hamlin 1955; Kataguchi 1959; Quirk et al. 1962).

To allow for the assessment of a wider range of types of thought slippage as expressed through verbal samples, Johnston and Holzman (1979) revised the Delta Index, renaming the refined measure the Thought Disorder Index (TDI). Categories which were felt to provide inadequate evidence of thought disorder, or which occurred too infrequently or were difficult to identify, were dropped. Categories which could be applied to the verbal subscales of the Wechsler Adult Intelligence Scale (WAIS), in addition to the Rorschach inkblot test, were added. Twenty scoring categories at four levels of severity were included, ranging from fairly subtle instances of cognitive slippage (e.g., vagueness, peculiar verbalizations, word-finding difficulties) to more grossly disturbed and psychotic levels of disordered thinking (e.g., contamination, incoherence, neologisms). The development of a fairly comprehensive, clearly written scoring manual containing multiple examples of each category of deviant verbalization resulted in quite respectable interrater reliability coefficients generally in the .80 to .90 range when applied to various diagnostic groups (Johnston and Holzman 1979).

Johnston and Holzman (1979) successfully discriminated chronic schizophrenics from groups of bipolar psychotic, neurotic, personality disordered, and normal control subjects based on overall TDI scores. A group of recently hospitalized schizophrenics with less than 1 year of lifetime hospitalization also scored more deviantly than the normal comparison subjects, but not more so than the other patient groups tested. The nonpsychotic patients were indistinguishable from the normal control subjects. The elevated scores of schizophrenic patients on the TDI were reflected in more grossly disturbed responses from the higher-level categories of deviant verbalizations. Interestingly, the TDI also discriminated the parents, but not the siblings, of recently hospitalized schizophrenic patients from those of the normal comparison subjects Almost 90 percent of the schizophrenic patients with deviant TDI scores had at least one parent with high TDI scores as well, suggesting familial transmission of thought disorder. TDI scores were not significantly related to sex, ethnicity, socioeconomic status, IQ, Phillips ratings of premorbid adjustment, medication status at time of testing, or ratings of paranoia.

Further evidence for the usefulness of the TDI as a sensitive index of thought disorder has been reported by Holzman and colleagues. Hurt, Holzman, and Davis (1983) examined changes in thought disorder and symptom behavior, as measured by the TDI and the Brief Psychiatric Rating Scale (BPRS), respectively, following the initiation of neuroleptic (haloperidol) or placebo treatment in schizophrenic inpatients. Significant reductions in scores on the TDI and on the BPRS were evident by the third day following the initiation of drug treatment. Changes on two BPRS factors, Thought Disorder and Hostility-Suspicion, closely followed the rate of change on the TDI. Other BPRS subscale factors, such as Anergia, Activity, and Anxiety-Depression, followed different time courses. Residual thought disorder in the drug-treated patients was evident in the fact that, despite almost a 50 percent drop in overall mean TDI scores in the schizophrenic patients after 3 weeks, these patients remained significantly more thought disordered than normal control subjects. These findings support the efficacy of the TDI as a reliable index of cognitive slippage as a function of time, treatment, and clinical manifestations of psychotic behavior.

Finally, using a slightly revised version of the TDI with 22 scoring categories (Solovay et al. 1985), Holzman, Solovay, and Shenton (1985) examined possible qualitative distinctions in the thought disorder of carefully diagnosed manic and schizophrenic patients. Overall TDI scores were not significantly different for these psychotic groups, although each exceeded the normal control group. A principal components analysis with varimax rotation with all psychotic subjects resulted in six interpretable factors: Idiosyncratic Verbalizations, Expansive Thinking, Autistic Thinking, Fluid Thinking, Absurdity, and Confusion. Expansive Thinking was clearly most common in the manic group, while the schizophrenic subjects produced most of the thought-disordered responses from the other categories. As an alternative method of producing scores on qualitatively different forms of thought disorder, a post hoc rational clustering of TDI categories that individually discriminated manic and schizophrenic patients was organized into five factors. Combinatory Thinking and Irrelevant Intrusions best characterized the manic patients, whereas Confused Thinking, Fluid Thinking, and Peculiar Verbalizations were more common in schizophrenic patients. These findings are consistent with the notion that overall levels of thought disturbance do not distinguish psychotic patients. However, more fine-grained qualitative investigations do suggest important differences in the ways that schizophrenic and manic individuals organize their thoughts.

Combining these findings, one can reasonably conclude that the TDI is a highly reliable and most promising measure of formal thought disorder among psychotic patients, including both overall thought disturbance level and fine-grained distinctions among categories of disturbance. This instrument should allow a more thorough examination of the relationship of deficits in laboratory cognitive measures with clinical forms of thought disorder than has been possible with previous broader measures. Within this study, we investigate the extent to which the CPT and span of apprehension signal-discrimination deficits that are hypothesized to be vulnerability factors for schizophrenic disorders are related to those TDI features that are more characteristically schizophrenic than manic disturbances.

## Schizophrenic Negative Symptoms and Attentional Impairment

In addition to the possible contributions of fundamental attentional and information-processing deficits to formal thought disorder, recent emphasis on the distinction between positive and negative symptoms of schizophrenia (Strauss, Carpenter, and Bartko 1974; Crow 1980; Andreasen and Olsen 1982) raises the possibility that certain laboratory measures of attentional functioning may be more relevant to negative symptoms of schizophrenia than to the more florid positive symptoms. Andreasen (1982) included clinically rated attentional impairment with affective flattening, alogia, avolition-apathy, and anhedonia-asociality in her Schedule for the Assessment of Negative Symptoms (SANS). This symptom complex is represented by individual ratings for work inattentiveness, inattentiveness during the mental status testing, and subjective complaints of inattentiveness as well as a global rating across these areas. In the initial sample of 26 patients, these ratings correlated .49, .35, .19, and .51, respectively, with the composite score from all five major areas of proposed negative symptoms, suggesting that, except for the subjective complaints rating, moderate correlations with a negative symptom summary score were present (Andreasen 1982).

Further evidence of the possible association of clinically rated attentional impairment with other negative symptoms of schizophrenia comes from a sample of 52 *DSM-III* schizophrenic inpatients (Andreasen and Olsen 1982). The SANS rating of attentional impairment correlated .56, .56, and .53 with avolition-apathy, alogia, and anhedonia-asociality, respectively, but not at all (−.01) with a clinical rating of positive formal thought disorder. Two other positive symptom complexes, delusions and hallucinations, actually correlated negatively (−.56 and −.36, respectively) with clinically rated attentional impairment. Thus, the relationship of laboratory measures of attentional functioning with negative symptoms of schizophrenia clearly needs evaluation to determine whether these more objective and fine-grained measures of attentional deficit show a similar predominant relationship to presence of negative symptoms of schizophrenia.

A possible theoretical link between schizophrenic attentional impairment and negative symptoms derives from the recent suggestion that the pattern of deficits in attentional functioning and information processing in schizophrenic patients and groups at risk for schizophrenia is consistent with a reduction in available processing capacity (Nuechterlein and Dawson 1984). This hypothesis regarding the nature of an attentional impairment in schizophrenic disorder follows from observations that cognitive tasks that demand relatively high levels of effortful, capacity-loading processing (Kahneman 1973; Posner 1978; Beatty 1982) appear most likely to detect a deficit across schizophrenic patients and risk populations. A reduction in the pool of nonspecific processing resources that is available for task-relevant cognitive processing might be expected to contribute to clinical symptoms of apathy, alogia, affective flattening, and emotional withdrawal through restrictions on the depth and breadth of cognitive processing.

## Hypotheses

Drawing on this background information, we used the degraded-stimulus CPT (Nuechterlein, Parasuraman, and Jiang 1983), a CPT with an alphanumeric sequence as the target (Rosvold et al. 1956), and a standard version of the forced-choice span of apprehension (Asarnow and MacCrimmon 1978) as laboratory measures of attentional and information-processing impairments in schizophrenia that also have promise as vulnerability indicators among risk populations. To summarize performance on each of the CPTs, we focused particularly on a signal-detection-theory index of overall signal/noise discrimination level, d′ (Green and Swets 1966; McNicol 1972), that has been productive in specifying the nature of CPT deficits in recent studies of children at risk for schizophrenia (Rutschmann, Cornblatt, and Erlenmeyer-Kimling 1977; Nuechterlein 1983). The span of apprehension performance was indexed by the target discrimination accuracy for the largest (10-letter) array, which has been found to be the most sensitive measure of schizophrenic deficits within this paradigm (Asarnow and MacCrimmon 1978, 1981).

We hypothesized that deficits in signal-noise discrimination on these tasks are contributory factors (1) to the types of formal thought disorder that are more frequent in schizophrenia than in mania and (2) to schizophrenic negative symptoms. We examined these hypotheses within a schizophrenic sample to determine whether the broad range of deficits on these laboratory measures within the schizophrenic population could be linked to the presence of formal thought disorder and negative symptoms in subgroups of schizophrenic patients. Specifically, for thought disorder assessed through the Rorschach, we hypothesized that signal-discrimination deficits on the CPT and span of apprehension would be related to the TDI factors that Holzman, Solovay, and Shenton (1985) found to be more characteristic of schizophrenic patients than of manic patients. We also hypothesized that these signal-discrimination impairments would be associated with thought disorder assessed through clinical ratings, specifically the Thought Disturbance factor and particularly the Conceptual Disorganization item of the Brief Psychiatric Rating Scale (BPRS) (Overall and Gorham 1962; Guy 1976).

Schizophrenic negative symptomatology was assessed by the Anergia factor of the BPRS (Overall and Gorham 1962). We hypothesized that within a schizophrenic sample, the signal-discrimination deficits on the CPT and the forced-choice span of apprehension would be associated with high ratings on the Anergia factor, which reflects affective flattening, motor retardation, emotional withdrawal, and disorientation.

The signal-discrimination deficits are hypothesized to serve as ongoing vulnerability factors rather than only temporary concomitants of acute schizophrenic symptoms. Therefore, to examine the association between the signal-discrimination deficits and schizophrenic symptomatology in a way that might shed light on whether the signal-discrimination deficits are more than secondary components of acute symptomatology, we evaluated the CPT and span of apprehension performance of a group of schizophrenic patients both during an inpatient period and a subsequent stabilized, outpatient period. Associations between signal-discrimination deficits during the stabilized outpatient period and clinical symptomatology during the inpatient period are particularly relevant to the hypothesis that the signal-discrimination deficits serve as enduring vulnerability factors.

## Methods

**Subjects.** The 40 schizophrenic subjects are participants in a larger longitudinal follow-through study of the early phase of schizophrenic disorders entitled "Developmental Processes in Schizophrenic Disorders" (Principal Investigator: Keith H. Nuechterlein, Ph.D.; Co-Principal Investigator: Michael E. Dawson, Ph.D.). These patients were selected from the western and San Fernando Valley regions of the Los Angeles metropolitan region during an index hospitalization at one of the following public hospitals: UCLA Neuropsychiatric Hospital, Camarillo State Hospital, Harbor/UCLA Medical Center, and Olive View Medical Center. These subjects were required to have the following characteristics: (1) a diagnosis of schizophrenia or schizoaffective disorder, mainly schizophrenic, by Research Diagnostic Criteria (Spitzer, Endicott, and Robins 1978), based on an expanded version of the Present State Examination administered to the patient and consideration of any additional data gathered from relatives; (2) a recent onset of major psychosis lasting at least 2 weeks (first episode not longer than 2 years before project contact); (3) age between 16 and 45 years; and (4) Caucasian or acculturated Asian or Hispanic in ethnic background. Subjects with any of the following were excluded: (1) evidence of an organic central nervous system disorder (e.g., epilepsy, traumatic brain injury, infectious or toxic cerebrovascular disease); (2) significant and habitual drug or alcohol abuse in the 6 months preceding the current episode, or past drug or alcohol abuse that clouded the diagnostic picture; or (3) mental retardation (premorbid IQ $< 70$).

This schizophrenic sample was young, with an average age of 22.3 years ($SD = 3.5$; range = 18–32 years). The mean educational level was 12.3 years ($SD = 2.1$, range = 5–16 years). Ninety-five percent of the patients were Caucasian and 5 percent, acculturated Hispanic. Eighty-five percent of these patients were male.

**Test Instruments.** Two versions of the CPT, a forced-choice span of apprehension task, and the Rorschach were administered to each patient. Ratings of symptomatology were obtained on the BPRS.

The adult version of degraded-stimulus CPT (Nuechterlein, Parasuraman, and Jiang 1983) and a numeral version of the conventional A-X CPT (Rosvold et al. 1956) were used. The processing load of the degraded-stimulus CPT involves discrimination of the highly blurred numeric stimuli, whereas that of the conventional sequential-target CPT derives from the short-term-memory burden associated with detection of the stimulus sequences that comprise the target. Both were administered using an automated system in which a Kodak Ektagraphic E-2 Carousel Slide Projector and Ilex No. 4 Synchro-Electronic Shutter, under the control of a microcomputer, presented numeric stimuli on a 12 × 12 inch (30.5 × 30.5 cm) Carroll rear projection screen. Single digits "0" through "9" were presented one at a time with a duration of 40 ms and an interstimulus interval of 1 second. The projected digits were 6.3 cm high and 4.8 cm wide when clearly focused. The subject, with eyes 1 meter from the screen, was told to monitor the rapid series of numerals and to respond as quickly as possible by pressing a hand-held button to each target stimulus. Any subject whose eyes were directed away from the screen long enough to miss a stimulus was immediately reminded to focus on the numeric stimuli until the task was completed.

In the degraded-stimulus CPT, the numerals were blurred to an extent that required a 2.8 diopter lens correction to refocus the image at the same screen distance.[1] The degradation level also requires the use of the fully open setting (40 mm) of the shutter. (The authors thank Enoch Callaway, M.D., for pointing out the relevance of aperture size.) A visual mask, which consisted of typed + characters on a transparency, was mounted on the back of the screen to decrease figure-ground contrast and visual persistence. The subject was told to respond to each "0," which occurred in a quasi-random 20 of the 81

[1] The diopter correction value was derived through direct measurement, using an optical lens placed immediately in front of the lens barrel. Values derived from direct measurement were found to be somewhat higher than the values from the equation reported by Nuechterlein, Parasuraman, and Jiang (1983), which uses screen-to-lens and slide-to-lens distances. Direct measurement of the degree of blurring with optical lenses is recommended to avoid the need to estimate placement of the projector lens within the lens barrel.

positions in the slide carousel. Identical digits never followed one another, and nontarget digits preceding target numerals were balanced to eliminate recognition of stimulus sequences. Subjects were instructed that it was equally important to press to targets and to avoid pressing to nontargets. After two carousel revolutions for practice, six continuous carousel revolutions were administered, including 120 targets and 366 nontargets, over a 8.1-minute period.

In the numeric adaptation of the A-X CPT, the subject was required to respond to each successive sequence of a "3" followed by a "7" in a quasi-random series of clearly focused single digits. This "3-7" sequence appeared 10 times (20 slide positions) within an 81-slide carousel. Additional processing load was presented in the form of auditory distraction, using an audiotaped male voice reading rapidly the same quasi-random series of digits, but lagged substantially in starting point, on a counterbalanced half of the carousel revolutions.[2] To increase difficulty level and alleviate the ceiling effects that typify the conventional CPT, 10 additional "3" stimuli and 10 additional "7" stimuli were included among the nontargets in the carousel in quasi-random order. To have sufficient target stimuli for signal-detection-theory analyses of changes over time within task in later analyses, the task was made somewhat longer than the degraded-stimulus CPT. After two practice carousel revolutions, eight continuous revolutions were administered, including 80 target sequences and 568 nontargets, over a 10.8-minute period. This 3-7 version of the CPT was not available for the first six inpatient assessments because it was developed after an easier conventional CPT with a single, clearly focused target digit was found to yield extreme ceiling effects.

The forced-choice span of apprehension was administered with the same apparatus, with the projector-to-screen distance adjusted to make the individual letters within arrays 1-inch (2.5-cm) high. Stimulus conditions replicated those of Asarnow and MacCrimmon (1978, 1981), except that exposure duration was 70 ms rather than 50 ms and that a small arrow appeared in the center of the screen from 1000 ms to 500 ms before each array to serve as a fixation point.[3] Each stimulus array contained the letter "T" or "F" in one of 16 locations produced by dividing the stimulus area into a 4 × 4 matrix. Either 0, 2, 4, or 9 nontarget letters were placed randomly in other positions of the matrix, with the constraint that no two letters in a given array be identical. Twenty stimuli were presented for each array size. Blocks of 10 for each array size were arranged in two counterbalanced orders. Order was alternated across subjects and was also alternated within each subject across two testing sessions. Equal numbers of the two targets appeared in each array size. The subject, seated with eyes 1 meter from the screen, was told that either a "T" or an "F" would be flashed on the screen, usually with other letters. The subject's task was to report verbally after each trial which of the two target letters was present, using the following rating scale to allow a later finer-grained analysis of performance: "certainly T," "probably T," "probably F," and "certainly F." After 20 practice trials, the 160 experimental trials were administered with approximately 3 seconds between trials. The experimenter did not initiate a trial unless the subject's eyes were directed to the screen. Testing time was approximately 20 minutes.

The Rorschach was administered by the procedure indicated in Johnston and Holzman (1979). The sessions were recorded on audiotape. The experimenter also recorded the responses in writing as the session proceeded. All audiotapes were carefully transcribed verbatim for scoring, using the handwritten record as a cross-check on accuracy.

An expanded version of the BPRS was used. Developed by David Lukoff, Ph.D., Keith Nuechterlein, Ph.D., and Joseph Ventura, M.A., of the UCLA Mental Health Clinical Research Center for the Study of Schizophrenia, this expanded BPRS includes structured questions for each of 25 items and behavioral anchors for the scale points "1" through "7" to improve applicability and reliability in outpatient assessments. Only the commonly employed 18 items (Guy 1976) were used for the present study. Interrater reliability coefficients of four raters with a criterion rater for 15 co-rated interviews had a mean of .85 across these scales, with a range from .60 to 1.00.

**Test Sessions.** The initial testing occasion with each patient occurred during the inpatient period as soon as diagnosis was assessed through the administration of the expanded Present State Examination. This occasion focused on the assessment of the patient during a psychotic

[2] A distractibility index was also derived from this 3-7 CPT for use in the larger longitudinal study, but was not included in data analyses for this report.

[3] The authors are very grateful to Dr. Robert F. Asarnow for his generous help in providing copies of slides and administration instructions for this forced-choice span of apprehension task.

episode and was therefore completed as soon as the patient was judged able to understand task instructions. The first inpatient occasion included the two versions of the CPT, the forced-choice span of apprehension, the Rorschach, and the BPRS, as well as other psychophysiological and psychological assessments that are components of the larger longitudinal project. The first session included the two CPTs, the span of apprehension, and the BPRS, with the order of the two CPT versions and the span of apprehension counterbalanced across subjects and within subjects across sessions. The Rorschach was administered in a second session as soon as possible after this session, usually within 3 days. Thirty-six of 40 patients were on antipsychotic medication at this inpatient assessment, with mean chlorpromazine equivalent dosage of 645 mg (SD = 512; range = 143–1875 mg). Antiparkinsonian medications were withheld for 48 hours before testing whenever possible clinically (29 of 40 cases) to avoid possible associated anticholinergic effects on information processing.

The outpatient attentional assessment occurred after subjects had been clinically stabilized and after a standardized, injectable, maintenance dosage of fluphenazine (Prolixin) decanoate, 12.5 mg every 2 weeks, had been established for 1 month. This standardized medication is a component of the protocol of the outpatient longitudinal study. Three patients who showed intolerable side effects on 12.5 mg fluphenazine decanoate were placed on a lower fixed dosage (7.5 or 10 mg). Of the 40 schizophrenic patients who were assessed at the inpatient point, 32 were enrolled in the outpatient, standardized-medication, longitudinal study and were, therefore, assessed at the outpatient occasion. One of these subjects did not complete the 3–7 CPT or span of apprehension. Antiparkinsonian medications were again withheld 48 hours before testing whenever possible clinically (26 of 32 cases). This outpatient assessment occurred at a mean of 86 days subsequent to hospital discharge (SD = 54), as soon as clinical stabilization and standardized medication could be established. The two CPTs and the forced-choice span of apprehension administered at this assessment point were used in this report.

## Results

**Data Reduction.** The signal detection indices, d′ and natural log of $\beta$ (ln $\beta$), were derived from the hit rate and false alarm rate for each of the time periods of the two CPTs (Green and Swets 1966; Nuechterlein 1983). The degraded-stimulus CPT was divided into three time periods for purposes of analysis, each consisting of 40 targets and 122 nontargets presented over a 162-second period. To maintain this same number of targets in each time period, the 3–7 CPT was divided into two time periods, each consisting of 40 targets and 244 nontargets presented over a 324-second period. To allow the signal detection indices to be calculated for the occasional instances of perfect hit or false alarm rates during a time period, the hit rates were estimated as $2^{-1/t}$ and false alarms rates as $1 - 2^{-1/t}$, where t = the number of trials on which the relevant stimulus type (target or nontarget) occurred, as suggested by Davies and Parasuraman (1982). An overall hit rate, false alarm rate, d′ level, and ln $\beta$ level were calculated by taking the mean of the time periods within each of these CPT conditions. For the degraded-stimulus CPT, which has been shown to elicit unusually rapid d′ decrements over time (Nuechterlein, Parasuraman, and Jiang 1983), the first time period was subtracted from the last to yield an index of d′ change over time. The means, standard deviations, and ranges for the CPT variables are listed in table 1 for the inpatient testing and table 2 for the outpatient testing.

The proportion of correct detections, P(C), for the forced-choice span of apprehension task was calculated for each array size. This variable is a criterion-free index of sensitivity analogous to the d′ index (Green and Swets 1966; McNicol 1972). The proportion of correct detections for the 10-letter arrays was used as the performance index for this report. The mean, standard deviation, and range for this variable are shown in tables 1 and 2 for the inpatient and outpatient testings, respectively.

The five BPRS factor scores (Guy 1976) were calculated from the 18 scales using the conventional unit-weighting procedures to yield Anxiety-Depression, Anergia, Thought Disturbance, Activation, and Hostile-Suspiciousness scores. Each sum of item scores was divided by the number of items composing the factor to make each factor score have a range from 1 to 7, identical to that of the individual items. A total BPRS score was created by summing the 18 individual item scores. Means, standard deviations, and ranges for these scores are presented in table 1.

The Rorschach was scored by the third author using the Thought Disorder Index (TDI) procedures of Johnston and Holzman (1979) as recently modified by Solovay et al. (submitted for publication). Interrater reliability between the third author and another trained scorer on the first 18 protocols was .95 for the

**Table 1. Means, standard deviations, and ranges for key variables at the inpatient testing**[1]

| Variable | Mean | SD | Range |
|---|---|---|---|
| **Degraded-stimulus continuous performance test (CPT)** | | | |
| d′ level | 2.11 | .94 | .40-4.03 |
| ln β level | .82 | .81 | −.99-2.54 |
| d′ change over time | −.61 | .64 | −3.05-.49 |
| Hit rate | .67 | .22 | .18-.98 |
| False alarm rate | .09 | .10 | .005-.54 |
| **3-7 CPT** | | | |
| d′ level | 3.58 | .80 | 2.02-4.87 |
| ln β level | 2.52 | .81 | −.14-3.67 |
| Hit rate | .80 | .17 | .41-1.00 |
| False alarm rate | .007 | .012 | .00-.065 |
| **Forced-choice span of apprehension** | | | |
| 10-letter array P(C) | .82 | .09 | .63-.98 |
| **Brief Psychiatric Rating Scale (BPRS)** | | | |
| Anxiety-Depression | 2.47 | 1.03 | 1.00-6.00 |
| Anergia | 1.67 | .76 | 1.00-3.50 |
| Thought Disturbance | 2.33 | 1.24 | 1.00-5.00 |
| Activation | 1.54 | .73 | 1.00-4.33 |
| Hostile-Suspiciousness | 1.66 | .80 | 1.00-3.67 |
| BPRS Total (18 scales) | 35.28 | 10.12 | 22-60 |
| **Rorschach** | | | |
| Total Thought Disorder Index | 23.24 | 25.35 | .00-133.40 |
| Total no. of responses | 22.85 | 9.53 | 6-44 |

[1] $n$ = 40, except for 3-7 CPT variables, for which $n$ = 34

total TDI, which indicates that a high level of agreement was achieved.

In addition to the total TDI score, scores on two sets of TDI factors were derived. For the primary analyses, five post hoc rational factors constructed by Holzman, Solovay, and Shenton (1985) to maximize the discrimination of schizophrenic and manic patients, as well as the conceptual relatedness of items within factors, were scored by a procedure comparable to that of Holzman, Solovay, and Shenton (1985). Square root transformation of the scores on the 22 categories of thought disorder was used to reduce the prominent skew of the distributions. Scores were then standardized to equate means and standard deviations. These square-root-transformed, standardized item scores were summed to achieve factor scores for the manic factors of Combinatory Thinking and Irrelevant Intrusions and for the schizophrenic factors of Fluid Thinking, Confused Thinking, and Peculiar Verbalizations.

For secondary analyses, empirical factors were also derived. To determine whether the current data set could be summarized well by the varimax factors that Holzman, Solovay, and Shenton (1985) derived through principal components analysis of 97 psychotic patients, we subjected the 22 square-root-transformed, standardized category scores for our 41 schizophrenic patients[4] to the same form of analysis using the Statistical Analysis System (SAS) FACTOR program (SAS Institute, Inc., 1982). This analysis would be expected to yield factors that are less generalizable than those derived by Holzman, Solovay, and Shenton (1985) due to the very lean subject-to-variable ratio, and would be unlikely to yield the manic factor, Expansive Thinking, because no manic patients were included. Nevertheless, it provides a useful summary of the most prominent dimensions in this TDI data set.

Three factors were found to account for 49 percent of the variance and were identified as an appropriate number for rotation by a scree plot. The varimax factors accounted for 27, 11, and 10 percent of the variance, respectively, and were named Associative Disorganization, Perceptual/Cognitive Fluidity, and Combinatory Cognition. Items loading above .50 on these factors are shown in table 3. Because each factor was well-defined, having at least five items with loadings above .50, and was reasonably coherent conceptually, these factors were used to summarize this data set in an efficient fashion for secondary analyses. Factor scores were compiled with standardized scoring coefficients to keep the three factor scores uncorrelated. On the basis of patterns found by Holzman, Solovay, and Shenton (1985), the first two of these three factors would

[4] One additional schizophrenic subject who had Rorschach data but not inpatient CPT and span of apprehension data was included in this principal components analysis

**Table 2. Means, standard deviations, and ranges for key variables at the outpatient testing**[1]

| Variable | Mean | SD | Range |
|---|---|---|---|
| **Degraded-stimulus continuous performance test (CPT)** | | | |
| d′ level | 2.24 | 1.08 | .30–4.65 |
| ln β level | .86 | .83 | –.55–2.39 |
| d′ change over time | –.34 | .49 | –1.30–.74 |
| Hit rate | .68 | .25 | .11–1.00 |
| False alarm rate | .08 | .08 | .00–.38 |
| **3-7 CPT** | | | |
| d′ level | 3.80 | .74 | 2.28–4.87 |
| ln β level | 2.36 | .84 | .04–3.77 |
| Hit rate | .85 | .16 | .33–1.00 |
| False alarm rate | .007 | .010 | .00–.048 |
| **Forced-choice span of apprehension** | | | |
| 10-letter array P(C) | .84 | .08 | .70–.95 |

[1] $n = 32$ for degraded-stimulus CPT; $n = 31$ for 3–7 CPT and span of apprehension.

be expected to reflect schizophrenic thought patterns and were hypothesized to be related to CPT and span of apprehension performance.

The fact that these three varimax factors differ rather substantially in item composition from those of Holzman, Solovay, and Shenton (1985) may reflect the smaller subject-to-variable ratio or the more homogeneous subject diagnostic composition (no affective psychoses) of the present analysis. Another probable influential contributor to such analyses is the presence of a few severely thought-disordered subjects whose particular combination of high TDI categories is unduly weighted in factor analyses, despite the attempt to reduce such influence by square root or other similar transformations. Because the empirical factors have these limitations, the combined use of Holzman, Solovay, and Shenton's (1985) post hoc rational factors and the present empirical factors was judged the best way to represent the major TDI dimensions for this study.

**Relationship of CPT and Span of Apprehension Performance to TDI Scores.** To examine the predicted relationship of the CPT d′ levels and the span of apprehension 10-letter array P(C) to the schizophrenic TDI factors of Fluid Thinking, Confused Thinking, and Peculiar Verbalizations, Pearson product-moment correlations were calculated. During the inpatient period, none of these nine correlations were statistically significant, suggesting an absence of concurrent relationship between these hypothesized vulnerability indicators for schizophrenic disorder and the severity of formal thought disorder during the inpatient psychotic period. A parallel set of correlations used the outpatient CPT and span of apprehension performance, which should represent a more stable, residual level of the CPT and span of apprehension vulnerability factors. Low outpatient degraded-stimulus CPT d′ level was related, as hypothesized, to high inpatient Fluid Thinking ($r = -.34$, $p < .05$, one-tailed) and showed a nonsignificant tendency to be related to high Confused Thinking ($r = -.28$, $p < .10$, one-tailed). This predicted relationship of the outpatient degraded-stimulus CPT performance to inpatient formal thought disorder was also evident in the correlation of d′ and the total TDI ($r = -.34$, $p < .05$, one-tailed). As predicted, none of the correlations between the CPT and span of apprehension indices and manic TDI factor scores were significant.

**Table 3. TDI item loadings on factors from varimax rotation of PCA**[1]

| | |
|---|---|
| **Factor 1: Associative Disorganization** | |
| Incoherent | .92 |
| Relationship verbalization | .79 |
| Perseveration | .63 |
| Vagueness | .60 |
| Queer | .60 |
| Confusion | .56 |
| Looseness | .55 |
| Absurd | .55 |
| **Factor 2: Perceptual/ Cognitive Fluidity** | |
| Fluidity | .73 |
| Autistic logic | .71 |
| Peculiar | .63 |
| Word-finding difficulty | .60 |
| Confusion | .58 |
| **Factor 3: Combinatory Cognition** | |
| Inappropriate distance (excluding flippant) | .74 |
| Confabulation (excluding playful confabulation) | .70 |
| Incongruous combination | .65 |
| Idiosyncratic symbolism | .62 |
| Contamination | .58 |

[1] TDI = Thought Disorder Index; PCA = principal components analysis; all loadings > 50 are listed

Secondary analyses that used the TDI factor scores from the principal components analysis yielded a similar picture. None of the predicted concurrent relationships with the Associative Disorganization or Perceptual/Cognitive Fluidity factor were significant, although low inpatient degraded-stimulus CPT d′ level showed a tendency to correlate with high inpatient Associative Disorganization ($r = -.25$, $p < .10$, one-tailed). This same relationship with high Associative Disorganization became slightly stronger and significant when the outpatient degraded-stimulus CPT d′ level was examined ($r = -.30$, $p < .05$, one-tailed). Correlations of the 3-7 CPT d′ and span of apprehension P(C) with these TDI factors were not significant.

In light of the fact that the significant correlations with inpatient schizophrenic TDI factors were restricted to the degraded-stimulus CPT performance during the outpatient period, the results provide only limited support for the hypothesis that the CPT and span of apprehension vulnerability indicators are directly related to schizophrenic formal thought disorder during psychotic periods. To the extent that relationships were found, the degraded-stimulus CPT tended to be associated with schizophrenic rather than manic TDI factors.

**Relationship of Inpatient CPT and Span of Apprehension Performance to Inpatient BPRS Thought Disturbance and Anergia Factors.** Pearson product-moment correlations were used to examine the concurrent BPRS ratings to test the hypotheses that low CPT d′ level and span of apprehension P(C) level would be related to higher clinical ratings of positive schizophrenic symptoms (BPRS Thought Disturbance) and negative schizophrenic symptoms (BPRS Anergia). The d′ change over time with degraded-stimulus CPT and the CPT response criterion levels (ln $\beta$) were expected to be uncorrelated with these BPRS factors, because they have not been found to be deviant in schizophrenic patients or persons at risk for schizophrenia. Correlations with other BPRS factor scores will be presented as evidence for discriminative validity. Because these other scales have less relevance to core positive and negative symptoms of schizophrenia, they were expected to be unrelated with the CPT and span of apprehension performance. In light of the number of BPRS factor scores and individual scales that needed to be examined, correlations were evaluated with two-tailed tests of significance despite this pattern of hypothesized relationships.

**Table 4. Correlations of signal detection indices from inpatient CPTs and span of apprehension task with BPRS factor scores during inpatient period [1]**

| | BPRS factor | | | | |
|---|---|---|---|---|---|
| Task | Anxiety-Depression | Anergia | Thought Disturbance | Activation | Hostile-Suspiciousness |
| **Degraded-stimulus CPT** | | | | | |
| d′ level | −.24 | −36[3] | −.08 | −.05 | −.36[3] |
| **3-7 CPT** | | | | | |
| d′ level | −.30[2] | −.38[3] | −.03 | −.01 | −.11 |
| **Forced-choice span of apprehension** | | | | | |
| 10-letter array | | | | | |
| P(C) | −.20 | −.36[3] | .02 | .04 | −.06 |

[1] CPT = continuous performance test, BPRS = Brief Psychiatric Rating Scale, correlations are based on $n$ = 40, except for those involving 3-7 CPT, for which $n$ = 34
[2] $p <$ 10, 2-tailed
[3] $p <$ 05, 2-tailed

As shown in table 4, the hypothesis that concurrent low CPT d′ and span of apprehension P(C) would be related to high BPRS Anergia ratings was supported for each of the three laboratory signal-discrimination measures. The degraded-stimulus CPT d′ level, the 3-7 CPT d′ level, and the span of apprehension P(C) were correlated −.36, −.38, and − 36, respectively, with concurrent BPRS Anergia ratings. Correlations of these three laboratory signal-discrimination indices with the BPRS Thought Disturbance scores were, contrary to our hypothesis, near zero. The expected lack of significant relationship of the CPT and span of apprehension performance with the other BPRS factors was observed, with minor exceptions.

Secondary analyses to determine the separate contributions of CPT hits and false alarms to the significant d′ level correlations indicated that high Anergia ratings were associated with low hit rate for the degraded-stimulus CPT and 3-7 CPT and also high false alarm rate for the latter ($r$'s = −.39, −.34, and 34, all $p < .05$). Correlations of the

BPRS factor scores with response criterion levels were, as expected, not significant. A significant relationship was found between the Anergia factor and d′ change over time in the degraded-stimulus CPT ($r = .35$, $p < .05$). This correlation suggests that high Anergia scores were related to relatively uniform d′ across time periods, as opposed to the substantial d′ decrements over time that are indicated by large negative numbers for this d′ change index. Although initially this association seems counterintuitive, it becomes sensible when the relationship between d′ level and d′ change over time in the degraded-stimulus CPT in this schizophrenic sample is considered ($r = -.44$, $p < .01$). Schizophrenic patients with high overall d′ levels had large d′ decrements over time, whereas patients with low overall d′ levels showed uniformly low d′ levels across time periods.

To examine further the specific nature of the symptoms that contribute to the relationship between CPT and span of apprehension performance and the BPRS Anergia factor, correlations with the individual scales of this factor were calculated. As shown in table 5, low d′ on the degraded-stimulus CPT and low P(C) on the span of apprehension were related to significantly higher BPRS Blunted Affect and Motor Retardation ratings. Low 3-7 CPT d′ showed nonsignificant tendencies to be related to higher BPRS Emotional Withdrawal, Blunted Affect, and Motor Retardation ratings that were similar in magnitude but based on somewhat fewer subjects than the correlations with the degraded-stimulus CPT and span of apprehension.

To ensure that the lack of relationship of the information-processing indices with the BPRS Thought Disturbance factor did not obscure an association with one of the BPRS component scales, particularly Conceptual Disorganization, correlations with the four individual scales (Conceptual Disorganization, Hallucinations, Unusual Thought Content, and Grandiosity) were examined. None of these BPRS individual scale correlations with the two CPT d′ levels or span of apprehension P(C) were significant. The correlations with Conceptual Disorganization were consistently in the predicted direction (−.25, −.29, and −.21 for the degraded-stimulus CPT d′, 3-7 CPT d′, and span of apprehension P(C), respectively), but not statistically significant for this sample size.

**Table 5. Correlations of signal detection indices from inpatient CPTs and span of apprehension task with individual scales of the BPRS Anergia factor during inpatient period[1]**

| Task | BPRS subscale | | | |
|---|---|---|---|---|
| | Emotional Withdrawal | Motor Retardation | Blunted Affect | Disorientation |
| **Degraded-stimulus CPT** | | | | |
| d′ level | −.15 | −.38[3] | −.33[3] | −.19 |
| **3-7 CPT** | | | | |
| d′ level | −.30[2] | −.33[2] | −.32[2] | −.26 |
| **Forced-choice span of apprehension** | | | | |
| 10-letter array P(C) | −.08 | −.40[3] | −.38[3] | −.19 |

[1] CPT = continuous performance test; BPRS = Brief Psychiatric Rating Scale; correlations are based on $n = 40$, except for those involving 3-7 CPT, for which $n = 34$.
[2] $p < .10$, 2-tailed.
[3] $p < .05$, 2-tailed.

In summary, these analyses of BPRS data indicate that the signal-discrimination indices from the CPT and span of apprehension were significantly related to clinically assessed, concurrent negative symptoms of schizophrenia, but were not significantly associated with positive psychotic symptoms. The lack of a significant concurrent relationship with positive symptoms is consistent with the general absence of a concurrent inpatient association of the CPT and span of apprehension performance with the key TDI variables, as presented in the last section.

**Relationship of Outpatient CPT and Span of Apprehension Performance to Inpatient BPRS Thought Disturbance and Anergia Factors.** To determine whether the CPT and span of apprehension performance in the stabilized outpatient period showed a similar pattern in relation to the clinically rated negative and positive schizophrenic symptomatology during the inpatient period, a parallel set of analyses was completed. Again, the relationships with the Anxiety-Depression, Activation, and Hostile-Suspiciousness factors were predicted to be nonsignificant due to the lesser relevance of these factors to core positive and negative schizophrenic symptoms.

Table 6 presents the correlations

with the BPRS factor scores. Significant relationships between low outpatient signal discrimination and high inpatient BPRS Anergia factor scores were evident for two of the three hypothesized vulnerability indices from these tasks, in this case for the two CPT d′ level indices but not for the span of apprehension P(C). Correlations of the CPT d′ levels and span of apprehension P(C) with the BPRS Thought Disturbance factor scores were again not significant. As expected, correlations with other BPRS factors were not significant, although it might be noteworthy that the tendency for low outpatient degraded-stimulus CPT d′ levels to be associated with higher inpatient Hostile-Suspiciousness scores is consistent with the parallel significant association of this BPRS factor with the inpatient degraded-stimulus CPT d′ level.

Correlations of the hypothesized vulnerability indicators with component scales of the Anergia factor are shown in table 7. The outpatient CPT d′ levels and span of apprehension P(C) show generalized nonsignificant tendencies to be negatively related to the Anergia component scales. Significant associations are in this case present between low degraded-stimulus CPT d′ level and high inpatient Emotional Withdrawal and Motor Retardation ratings and between low 3-7 CPT d′ level and high inpatient Disorientation ratings.

Examination of the correlations of the three CPT and span of apprehension indices with the component scales of the BPRS Thought Disturbance factor was again used to ensure that specific relationships, particularly with Conceptual Disorganization, were not obscured by the overall factor score results. Correlations of inpatient Conceptual Disorganization ratings with the three outpatient information-processing performance indices were all in the expected direction and were significant ($p < .05$) for the 3-7 CPT d′ level ($r = -.44$) and span of apprehension P(C) ($r = -.38$). On the

**Table 6. Correlations of signal detection indices from outpatient CPTs and span of apprehension task with inpatient BPRS factor scores [1]**

| Task | BPRS factor: Anxiety-Depression | Anergia | Thought Disturbance | Activation | Hostile-Suspiciousness |
|---|---|---|---|---|---|
| **Degraded-stimulus CPT** | | | | | |
| d′ level | −.10 | −.44[3] | −.05 | −.02 | −.32[2] |
| **3-7 CPT** | | | | | |
| d′ level | −.08 | −.36[3] | −.05 | .05 | −.31[2] |
| **Forced-choice span of apprehension** | | | | | |
| 10-letter array P(C) | −.13 | −.19 | −.16 | .24 | −.24 |

[1]CPT = continuous performance test, BPRS = Brief Psychiatric Rating Scale, based on $n = 32$ for correlations involving the degraded-stimulus CPT and $n = 31$ for those involving 3-7 CPT or span of apprehension
[2]$p < .10$, 2-tailed
[3]$p < .05$, 2-tailed

**Table 7. Correlations of signal detection indices from outpatient CPTs and span of apprehension task with individual scales of the BPRS Anergia factor rated during inpatient period [1]**

| Task | BPRS subscale: Emotional Withdrawal | Motor Retardation | Blunted Affect | Disorientation |
|---|---|---|---|---|
| **Degraded-stimulus CPT** | | | | |
| d′ level | −.50[4] | −.45[4] | −.21 | −.20 |
| **3-7 CPT** | | | | |
| d′ level | −30[2] | −.27 | −.13 | −.41[3] |
| **Forced choice span of apprehension** | | | | |
| 10-letter array P(C) | .06 | −.21 | −.18 | −.33[2] |

[1]CPT = continuous performance test, BPRS = Brief Psychiatric Rating Scale, based on $n = 32$ for correlations involving degraded-stimulus CPT and $n = 31$ for those involving the 3-7 CPT or span of apprehension
[2]$p < .10$, 2-tailed
[3]$p < .05$, 2-tailed
[4]$p < .01$, 2-tailed.

other hand, correlations with Unusual Thought Content, Hallucinations, and Grandiosity hovered around zero.

In summary, these results relating the outpatient CPT and span of apprehension signal-discrimination indices to the inpatient BPRS ratings are quite consistent with those that involved the inpatient signal-discrimination levels. The outpatient signal-discrimination vulnerability indicators were more strongly related to the inpatient negative symptoms of schizophrenia than to the positive symptoms. The only significant correlations of the outpatient signal-discrimination indices with inpatient positive symptoms were with Conceptual Disorganization, the Thought Disturbance component scale with which the closest association was expected.

## Discussion

Our results indicate that signal-discrimination deficits on the degraded-stimulus CPT, the 3-7 CPT, and the forced-choice span of apprehension are quite consistently related to the presence of negative symptoms (BPRS Anergia factor scores) among young patients with a recent onset of schizophrenic disorder, as evidenced by significant correlations in five of six evaluated relationships. The relationship of these attentional deficits to formal thought disorder (BPRS Conceptual Disorganization ratings and Rorschach Thought Disorder Index factors) among these recent-onset patients appears to be less consistent, although the hypothesized correlations do achieve statistical significance somewhat more frequently than expected by chance. When significant relationships were observed between the signal-discrimination deficits and the Rorschach TDI factors, they involved, as hypothesized, modes of formal thought disorder that are more typically schizophrenic than manic in nature. Relationships between signal/noise discrimination impairment on the attentional tasks and the presence of delusions and hallucinations were never significant and hovered around zero.

Impaired signal discrimination on the CPT and span of apprehension tasks is associated with schizophrenic negative symptoms in a fashion that is consistent with the hypothesized role of these attentional deficits as vulnerability factors for these clinical symptoms. The relationship of the signal-discrimination deficits on the three attentional tasks to the inpatient negative symptoms (BPRS Anergia factor scores) was present whether the signal discrimination was measured during the inpatient period or during a stabilized outpatient period. Furthermore, the magnitude of the relationship did not change across these two attentional assessment points for two of three measures. Thus, the relationship is not limited to a cross-sectional association within episodes, which would be expected if the signal-discrimination impairment was secondary to clinical symptomatology.

The correlations of the outpatient signal-discrimination deficits with inpatient negative symptoms are, furthermore, not simply due to the continuation of a cross-sectional association between clinical symptomatology and these laboratory-measured deficits. As might be expected, the range of the BPRS Anergia factor score was reduced at the stabilized outpatient point (from 1.00–3.50 at the inpatient point to 1.00–2.50 at the outpatient point, *SD*s = .76 and .46, respectively). The cross-sectional correlations with the three signal-discrimination indices at the outpatient assessment were not significant (*r*'s = − .12, .18, and − .15 for the degraded-stimulus CPT, 3-7 CPT, and span of apprehension, respectively). Yet the signal-discrimination deficits were moderately stable over time in these recent-onset schizophrenic patients, despite the large changes in both clinical state and medication across these two assessment points (*r*'s = .49, .64, and .43 for the degraded-stimulus CPT, 3-7 CPT, and span of apprehension, respectively). Furthermore, as noted earlier, deficits on these attentional tasks also characterize children at risk for schizophrenia who have not experienced a schizophrenic episode (Asarnow et al. 1977; Rutschmann, Cornblatt, and Erlenmeyer-Kimling 1977; Nuechterlein et al. 1982; Nuechterlein 1983) as well as schizophrenic patients in psychotic remission after an episode (Wohlberg and Kornetsky 1973; Asarnow and MacCrimmon 1978). Taken together, this pattern of relationships is consistent with the view that ongoing levels of signal-discrimination impairments on these tasks are associated with schizophrenic negative symptoms during episodes.

An important additional relationship that is being investigated in our current longitudinal study of recent-onset schizophrenic patients is whether ongoing signal-discrimination deficits are predictive of the return of positive symptoms or of the development of later more persistent negative symptoms after the resolution of the index psychotic episode. Schizophrenic negative symptoms have been seen as more strongly associated with poor prognosis than are positive symptoms (Strauss, Carpenter, and

Bartko 1974; Crow 1980), a view supported by early data regarding the prognostic value of restricted affect (Carpenter et al. 1978). Furthermore, negative symptoms appear to be less responsive to neuroleptic treatment than do positive symptoms (Johnstone et al. 1978; Angrist, Rotrosen, and Gershon 1980). The association in the current study between the signal-discrimination deficits and negative symptoms, therefore, serves to bolster the possible utility of these attentional measures as prognostic indicators, a role that has been suggested in studies of simple reaction time (Cancro et al. 1971, Zahn and Carpenter 1978) and the forced-choice span of apprehension (Marder, Asarnow, and Van Putten 1984) among schizophrenic patients and in a study of a composite attentional index among offspring of a schizophrenic parent (Cornblatt and Erlenmeyer-Kimling 1985). Given the current results, it might be fruitful in further evaluations of these prognostic relationships to differentiate the prognostic value of such attentional measures for negative symptoms as opposed to florid positive symptoms of schizophrenia.

The closer association of the CPT and forced-choice span of apprehension deficits with negative, as opposed to positive, symptoms of schizophrenia within this schizophrenic sample might also be meaningfully connected to the recent finding that concordance rates for schizophrenia for monozygotic twins tend to be higher when probands have a larger number of negative symptoms (Dworkin and Lenzenweger 1984). Within schizophrenic samples, poor CPT performance has been found to be associated with a family history of schizophrenia (Walker and Shaye 1982) or severe mental illness (Orzack and Kornetsky 1971). This combination of findings suggests the possibility that poor CPT performance is likely to characterize a subtype of schizophrenia with prominent negative symptoms that has a particularly strong genetic component.

The relationship of the three signal-discrimination measures to negative symptoms seems to cut across the individual BPRS scales of the Anergia factor, with fluctuations in the level of the correlations across scales and occasions possibly being due to chance rather than systematic differences. Blunted Affect and Motor Retardation showed statistically significant relationships with signal-discrimination deficits in concurrent inpatient assessments, whereas inpatient Emotional Withdrawal, Motor Retardation, and Disorientation showed significant associations with an outpatient index of signal-discrimination deficit. The Anergia factor score appears to show more consistent relationships to the signal-discrimination indices than the individual component scales by providing a summary of the individual scale tendencies. Additional examination of the relationship of specific schizophrenic negative symptoms to these signal-discrimination deficits will be undertaken with data from subscales of the Schedule for Assessment of Negative Symptoms (Andreasen 1982) that are currently being collected, because this instrument, unlike the BPRS, was designed specifically for assessment of the full range of such symptoms.

The fact that the relationships with negative symptoms generalized across the signal-discrimination measures from the two CPTs and the forced-choice span of apprehension is consistent with the possibility discussed elsewhere (Nuechterlein and Dawson 1984) that a substantial portion of the schizophrenia-relevant variance in these tasks is associated with a shared high momentary demand on processing capacity. Although the tasks differ as to whether visual target and nontarget stimuli are presented simultaneously or sequentially, accurate signal discrimination in the two versions of the CPT employed here, as well as in the 10-letter array of the forced-choice span of apprehension, demands substantial effortful, capacity-demanding processing (Kahneman 1973; Hasher and Zacks 1979). The stimulus-input loads are high and the conditions of these tasks do not facilitate the development of automatic processing (Schneider and Shiffrin 1977; Treisman and Gelade 1980). Another compatible and related interpretation of these deficits would emphasize that slowed cognitive processing associated with negative symptoms contributes to deficits in these CPT and span of apprehension conditions (Green and Walker 1984).

A logical connection is apparent between deficits in active, effortful processing and the symptoms of affective flattening, emotional withdrawal, and motor retardation. The possible interrelationship of attentional and affective disturbances in schizophrenia was noted early by Bleuler (1911/1950):

> As a partial phenomenon of affectivity, attention is affected with it by deterioration. . . where affect is lacking, there will also be lacking the drive to pursue the external and internal processes, to direct the path of the senses and the thoughts; i.e., active attention will be lacking. [p. 68]

The current evidence supports the interrelationship of these domains. However, the outpatient data suggest that the deficit in active, effortful processing may remain as a vulnerability factor after any anergic symptoms become less apparent. Furthermore, given the data on the existence of such deficits in active, effortful processing in high-risk populations, it appears that these attentional deficits might be present before the clinical symptoms of affective flattening and emotional withdrawal become evident. Thus, the linkage of active, effortful processing to weakened affect, noted clinically by Bleuler, is clearly supported, but the deficit in effortful processing might serve as an enduring vulnerability factor, rather than a secondary reflection of anergic symptoms.

The relationship of these attentional vulnerability indicators to formal thought disorder was less consistent in the current study. To the extent that significant associations were found, the clinically stabilized, outpatient level of signal discrimination, specifically on the degraded-stimulus CPT, was related to TDI factor scores for Fluid Thinking (Holzman, Solovay, and Shenton 1985) and Associative Disorganization during the inpatient period. No significant relationships between concurrent inpatient assessment of these attentional deficits and formal thought disorder were found. This pattern is consistent with the view that the outpatient signal-discrimination deficit is a vulnerability factor for these modes of schizophrenic thinking, rather than a simultaneous acute effect of psychotic disorganization. The relationship of the signal-discrimination deficits to TDI factors that are typically schizophrenic, as opposed to manic, in nature should also be evaluated within a manic sample, to determine the generalizability of this finding. The significant correlations of the outpatient 3-7 CPT and span of apprehension indices with inpatient Conceptual Disorganization ratings are also congruent with the interpretation that outpatient signal-discrimination deficit is a vulnerability factor for certain aspects of formal thought disorder. Thus, the CPT and span of apprehension signal-discrimination deficits do show some potential as vulnerability factors for thought disorder in schizophrenia, although this evidence is less consistent than that for an association with negative symptoms.

Additional investigation will be needed to determine whether the greater consistency of the association of these CPT and forced-choice span of apprehension measures with negative symptoms, as compared to formal thought disorder, generalizes to other forms of information-processing disturbance in schizophrenia. Certain other measures might be more strongly related to formal thought disorder or other positive symptoms than are the ones used in this study, but less clearly related to negative symptoms. Oltmanns, Ohayon, and Neale (1978), for example, found that a measure of auditory distractibility that is a promising vulnerability indicator among children of schizophrenic parents (Harvey et al. 1981) was strongly associated with formal thought disorder in schizophrenic inpatients. Green and Walker (in press) and Cornblatt et al. (1985) have recently found evidence that is also consistent with the connection of distractibility to positive symptoms, while a measure of performance under processing overload conditions in the latter study was associated with negative symptoms. These promising cross-sectional observations will be bolstered if longitudinal predictive relationships between a relatively enduring information-processing deficit and symptom development can be further established. If consistent divergence in the symptomatic correlates of these fundamental attentional and information-processing deficits can be isolated, the role of such potential vulnerability factors in the development of different schizophrenic symptom clusters may be greatly clarified.

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### The Authors

Keith H. Nuechterlein, Ph.D., is Associate Professor in the Department of Psychiatry and Biobehavioral Sciences, University of California, Los Angeles. William S. Edell, Ph.D., is Assistant Professor in the Department of Psychology, University of Massachusetts, Amherst. Margie Norris, M.S., was Senior Psychometrist at the UCLA Neuropsychiatric Institute and is currently a graduate student in clinical psychology at the University of Florida. Michael E. Dawson, Ph.D., is Associate Professor in the Department of Psychology, University of Southern California, Los Angeles, CA.