

# What Determines Continuous Performance Task Performance?

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## Abstract

The Continuous Performance Task (CPT) is widely used as an indicator of cognitive dysfunction in schizophrenia. It is still unclear, however, exactly what this test measures. We examined the contribution of motor speed, reaction time measures, mental effort, and level of psychopathology to the performance on a double-stimulus CPT. This study included schizophrenia patient groups, depressive patient groups, and patient and normal control groups. Subjects were retested twice: once after 1 week and again at 3 months. In patients with schizophrenia or depression, the sensitivity measure ( $d'$ ) was strongly and consistently associated with motor speed and with the standard deviation of reaction times (response variability) to target stimuli. The association with response variability was also found at followup tests in the control groups. We conclude that in patients with schizophrenia or depression, the sensitivity measure of a double-stimulus CPT is associated with cognitive mechanisms that determine motor proficiency and response variability.

*Schizophrenia Bulletin*, 22(4): 643–651, 1996.

Schizophrenia is a complex cognitive disorder that needs to be studied with cognitive and neuropsychological methods. One of the most popular cognitive tests in this area is the Continuous Performance Task (CPT; Rosvold et al. 1956; Nuechterlein and Dawson 1984; Nuechterlein 1991). The CPT is a class of attentional tasks involving a quasi-random presentation of a sequence of target and non-target stimuli, typically for a period of about 10 minutes. As a rule the

stimuli are visual, are presented briefly (40–200 ms), and occur once every 1 or 2 seconds. Subjects respond to targets by pressing a button. In the past, ratings have been based on hit rates (errors of omission) and false alarms (errors of commission). Now, scores are usually based on signal detection theory, providing measures for sensitivity and response criterion.

There are various versions of the CPT. Originally, the task involved the detection of each X in a sequence of single-letter presentations. Later, complexity was increased by defining a target as each X that followed an A. The A-X version differs from the simpler X versions in that it involves a memory load. Other CPT versions with a memory component have been developed (e.g., by Cornblatt et al. 1988) in which targets are defined as stimuli that appear in two successive trials. Another version, the degraded stimulus CPT, is similar to the simple X CPT but is made more difficult by the presentation of highly blurred stimuli (Nuechterlein 1991).

The CPT has been found to offer a reliable index of cognitive performance. A subgroup of schizophrenia patients (40%–50%) has marked difficulty with this task and shows a substantial decrease in sensitivity. Deficits on the task have also been observed in depressive patients (Cornblatt et al. 1989). In schizophrenia subjects, the major symptom correlates seem to consist of negative symptoms, although there also may be an association with formal thought disorder (Nuechterlein et al.

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1986). However, symptom correlates have not been studied extensively, and few data are available on psychopathological correlates in non-schizophrenia patients.

In the search for objective indicators of schizophrenia vulnerability, the CPT has become a virtual landmark task. There is a risk that researchers of the heterogeneous schizophrenia construct will tend to feel content with a simple hit-rate score or a sensitivity measure, as if this would provide an objective and unambiguous window on the basic cognitive pathology. Do we know what is indexed by the CPT? The task is supposed to measure vigilance (Nuechterlein 1991), but is it really a task measuring sustained attention over time? This is a common notion, and indeed Nestor et al. (1990) found a significant decline in sensitivity in normal subjects and a somewhat more rapid decline in schizophrenia patients, which seems in accordance with this interpretation. This decline was small, however, and Cornblatt et al. (1989) did not find a time-on-task effect.

A lower sensitivity level seems to be apparent throughout the vigilance period, and performance does not usually seem to deteriorate significantly in schizophrenia patients. Traditional CPT versions are effortful information-processing tasks, but the maintenance of a high level of mental effort does not seem to be a critical variable. Other factors may influence accuracy on the task. For instance, the correlation with negative symptoms (psychomotor poverty) suggests an association with motor function. Walker and Green (1982) found an association between low hit rate on a CPT and several indices of motor proficiency among patients with schizophrenia or depression. Similar findings have been reported

by Earle-Boyer et al. (1991). Because the CPT requires control by central executive functions, another factor that may be important is the regulation (rather than the maintenance) of attention over time. It seems clear that the determinants of CPT performance may be heterogeneous. This is not a satisfactory situation for researchers interested in objective cognitive measures of pathogenetic mechanisms.

We present a study examining several components of CPT performance, including motor speed and mental effort, but also response time latency and variability of response speed. The study comprised a number of patient groups (schizophrenia patients, depressive patients, and patient controls) and a normal control group. Data were obtained on three test occasions, with intervals of 1 week and 3 months.

## Subjects

Patients in the study had been recently admitted or had recently entered the outpatient department. They were from three diagnostic categories (*DSM-III-R* criteria; American Psychiatric Association 1987). Diagnoses were made using all information available and were based on consensus of at least two clinicians. Included in the study were 21 schizophrenia patients, 16 major depressive patients, 19 nonpsychotic, nondepressive patients (patient controls comprising diagnoses of somatoform disorder, anxiety disorder, adjustment disorder, and personality disorder), and 20 normal controls. Exclusion criteria were evidence of organic brain dysfunction and substance abuse.

Subjects included 38 males and 38 females (schizophrenia patients: 14 males, 7 females; depressive patients:

8 males, 8 females; patient controls: 7 males, 12 females; normal controls: 9 males, 11 females). There were no significant sex differences among groups ( $\chi^2 = 3.80$ ,  $df = 3$ , not significant [NS]). Mean age was 32.2 years (standard deviation [SD] = 10.1). Patients in the depressive group were significantly older than those in the other patient groups (Scheffé test;  $F = 5.10$ ,  $p < 0.001$ ). The mean ages of the groups were as follows: schizophrenia patients, 28.7 years (SD = 8.2); depressive patients, 39.9 years (SD = 12.7); patient controls, 29.5 years (SD = 8.1); and normal controls, 32.2 years (SD = 8.3).

The average daily dosage of antipsychotic drugs in the schizophrenia group was 6.2 mg haloperidol equivalents (range = 0–25 mg). Antipsychotic treatment is known to be associated with a limited normalization on many psychological measures, so that cognitive differences between schizophrenia patients and other patients were probably slightly reduced (Spohn and Strauss 1989). However, it has been suggested that minor motor deficits, induced by neuroleptic drugs, might play a role in reaction time and CPT performance (Medalia et al. 1988). A measure of motor function was included in the present study. Five schizophrenia patients used antiparkinsonian drugs. Multivariate analysis of variance did not reveal significant differences between patients with and those without these drugs for any of the variables in the analyses. None of the subjects used anxiolytic drugs. Subjects were retested after 1 week and again after 11 weeks (77 days, SD = 11).

## Methods

Patients were tested with a comput-

erized CPT, consisting of 600 stimuli with a duration of 100 ms presented with interstimulus intervals of 1 second. Target stimuli consisted of the stimulus combination 3-followed-by-7. There were a total of 90 target stimuli. The single stimuli 3 and 7 were also presented 90 times each. Subjects had to press a response button each time and only when a target stimulus was presented. The program calculated the sensitivity ( $d'$ ) measure of CPT performance and the mean reaction time to target stimuli (correct responses) and its SD (reaction time variability) for each subject. When perfect hit rates or false alarm rates were obtained, corrections needed for calculating  $d'$  were based on the formula given by Davies and Parasuraman (1982).

Motor speed was measured with a computerized finger tapping task, requiring the subjects to press a button with their preferred hand as fast as possible for 10 seconds.

The subjective experience of effort during CPT performance (subjective mental effort) was measured immediately after the test with a visual analog scale constructed according to the magnitude estimation method (Meijman et al. 1986).

All patients were interviewed twice (at the first and third test occasions) with the Present State Examination (PSE; Wing et al. 1974) to obtain ratings for their psychiatric symptoms (1 point for mild and 2 points for severe symptoms). We calculated total PSE symptom scores and included these in the analyses.

## Results

Table 1 shows the psychiatric, cognitive, and motor ratings for all groups at the first session. Patients with schizophrenia or depression had sig-

nificantly more difficulty with the CPT than normal controls did (Scheffé tests,  $p < 0.05$ ). The sensitivity ratings ( $d'$ ) were not significantly different between schizophrenia patients and depressive patients, nor were there significant differences between patient controls and normal controls.

Because severity (PSE symptom score) and age were higher in the depressive group, an analysis was performed for the patient groups at three test occasions, covarying for these variables. Diagnostic groups were significantly different ( $F = 4.82$ ;  $df = 2,51$ ;  $p < 0.01$ ). The adjusted means of  $d'$  (averaged across three occasions) were 3.04 for schizophrenia patients, 3.28 for depressive patients, and 3.94 for patient controls. Scheffé tests showed that only schizophrenia patients were significantly different from patient controls at the first test occasion ( $p < 0.05$ ). Group differences were also highly significant in an analysis including normal subjects, covarying for age ( $F = 9.32$ ;  $df = 3,71$ ;  $p < 0.0001$ ). Adjusted means were 3.07 for schizophrenia patients, 3.22 for depressive patients, 3.97 for patient controls, and 4.20 for normal controls. According to Scheffé tests, schizophrenia patients were significantly different from both control groups at the first occasion, and depressive patients were significantly different from normal controls ( $p < 0.05$ ).

Table 2 shows the test-retest correlations in the total sample for the three measurement sessions. These correlations were fairly high.

Because we aimed at examining the influence of motor function and mental effort on CPT  $d'$ , and had to consider the influence of symptom severity and age, a multivariate repeated measures analysis of covariance (MANCOVA) was conducted.

This analysis was performed for the three patient groups at three test occasions, covarying for finger tapping, subjective mental effort, PSE symptom score, and age. The reaction time measures were not included because the mechanisms determining these measures may not be independent of the mechanisms determining  $d'$ . Both may be manifestations of the same (attentional, motor) processes.

The between-subject analysis revealed a significant main effect for diagnostic group ( $F = 5.20$ ;  $df = 2,49$ ;  $p < 0.01$ ) and a significant main effect for regression ( $F = 11.05$ ;  $df = 4,49$ ;  $p < 0.001$ ) caused by age, finger tapping, and subjective mental effort. The within-subject analysis of variance did not reveal a significant regression effect (Hotellings  $T = 0.13$ ;  $df = 10,92$ ; NS). There was a significant multivariate main effect for repeated measures (Hotellings  $T = 0.16$ ;  $df = 2,47$ ;  $p < 0.05$ ) due to a change between the first two sessions. There was no significant interaction effect on  $d'$  for repeated measures and diagnostic groups (Hotellings  $T = 0.40$ ;  $df = 4,92$ ; NS).

It is interesting, however, that differences between diagnostic groups increased with time (although the divergence with successive occasions was nonsignificant). Differences were nonsignificant at the first test occasion ( $F = 2.40$ ;  $df = 2,53$ ; NS). At the second test occasion, schizophrenia patients were significantly different from patient controls ( $F = 3.59$ ;  $df = 2,53$ ;  $p < 0.05$ ). At the third test occasion, schizophrenia patients as well as depressive patients were significantly different from patient controls ( $F = 8.07$ ;  $df = 2,53$ ;  $p < 0.001$ ) (Scheffé tests,  $p < 0.05$ ).

The Pearson correlations with  $d'$  at the first session are presented in table 3. Half of these correlations were sig-

**Table 1. Cognitive, motor, and symptom measures (first session)**

Measure	Schizophrenia patients		Depressive patients		Patient controls		Normal controls		F (p)
	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	
CPT sensitivity ( $d'$ )	3.13	(1.2)	2.75	(1.1)	3.88	(0.4)	4.06	(0.6)	8.7 (0.001)
Finger tapping (number)	49	(16.0)	45	(11.0)	56	(11.0)	60	(8.0)	5.6 (0.001)
Mean reaction time (ms)	493	(72.0)	470	(79.0)	481	(100.0)	461	(72.0)	NS
Reaction time variability (ms)	140	(64.0)	138	(60.0)	107	(36.0)	101	(23.0)	3.4 (0.05)
Subjective mental effort (self-rating)	72	(31.0)	89	(28.0)	72	(22.0)	74	(17.0)	NS
PSE symptoms (number)	22.6	(16.7)	35.9	(9.4)	20.6	(9.4)	( <sup>1</sup> )	( <sup>1</sup> )	7.4 (0.001)

Note.—CPT = Continuous Performance Task (Rosvold et al. 1956); PSE = Present State Examination (Wing et al. 1974). SD = standard deviation; NS = not significant.

<sup>1</sup>No measures were obtained or no correlations were computed.

**Table 2. Test-retest correlations**

Measure	Sessions		
	1–2	2–3	1–3
All subjects			
CPT $d'$	0.89	0.86	0.85
Mean reaction time	0.79	0.76	0.66
Reaction time variability	0.75	0.81	0.59
Finger tapping	0.90	0.85	0.86
Subjective mental effort	0.74	0.70	0.61
Patients only			
PSE symptom score	( <sup>1</sup> )	( <sup>1</sup> )	0.86

Note.—CPT = Continuous Performance Test (Rosvold et al. 1956); PSE = Present State Examination (Wing et al. 1974)

<sup>1</sup>No correlations were obtained for the second session.

**Table 3. Pearson correlations with CPT  $d'$  (first session)**

Measure	Schizophrenia patients	Depressive patients	Patient controls	Normal controls
Finger tapping	0.61 <sup>1</sup>	0.61 <sup>2</sup>	–0.10	0.40
Mean reaction time	–0.44 <sup>2</sup>	–0.33	–0.13	–0.09
Reaction time variability	–0.83 <sup>3</sup>	–0.86 <sup>3</sup>	–0.08	–0.11
Subjective mental effort	–0.22	–0.44	–0.05	0.20
PSE symptom score	0.10	–0.40	0.17	( <sup>4</sup> )
Age	–0.42	–0.46	–0.19	–0.60 <sup>1</sup>

Note.—CPT = Continuous Performance Task (Rosvold et al. 1956); PSE = Present State Examination (Wing et al. 1974).

<sup>1</sup> $p < 0.01$ .

<sup>2</sup> $p < 0.05$ .

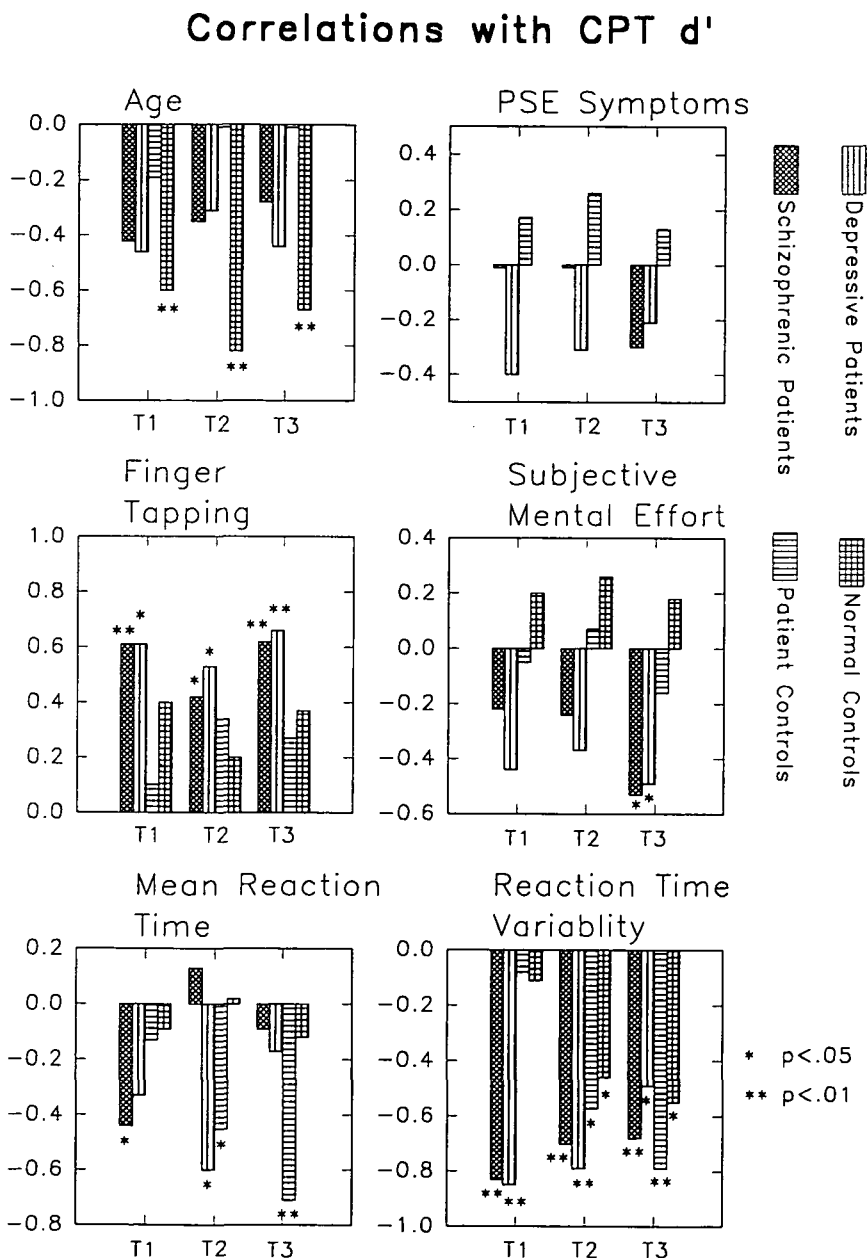
<sup>3</sup> $p < 0.001$ .

<sup>4</sup>No measures were obtained or no correlations were computed.

nificant in the patient groups with schizophrenia or depression, whereas most were nonsignificant in patient and normal control groups. In schizophrenia patients and depressive patients, finger tapping speed was significantly associated with  $d'$ . The correlation between  $d'$  and mean reaction time was significant in schizophrenia patients only. Particularly high correlations ( $> 0.80$ ) were found between reaction time variability and  $d'$  in patients with schizophrenia or depression. Subjective mental effort and PSE symptom score were not significantly associated with  $d'$  in any group. Age correlated significantly with  $d'$  in normal controls only ( $-0.60, p < 0.01$ ).

PSE symptom scores changed over the 11-week period. Scores at the third test occasion were as follows: schizophrenia patients, 15.5 (SD = 13.4); depressive patients, 22.5 (SD = 16.5); and patient controls, 15.6 (SD = 10.1). Group differences on PSE symptom scores on first and third test occasions, covarying for age, were examined by MANCOVA. There were significant main effects for group ( $F = 3.86; df = 2,52; p < 0.05$ ) and time ( $F = 25.94; df = 1,53; p <$

**Figure 1. Graphical representation of correlations with  $d'$  in all groups at three testing occasions**



CPT = Continuous Performance Task (Rosvold et al. 1956); PSE = Present State Examination (Wing et al. 1974).

0.01), but no significant interaction effect was found.

To examine the implications of lower symptom scores for the stability of the findings at the first test occasion, correlations were calculated at both retests as well (see figure 1). The association between  $d'$  and finger tapping as well as reaction time variability in schizophrenia patients and depressive patients appears to be a stable one, since these correlations were also significant at both follow-ups. The association with reaction time variability appears to be diagnostically nonspecific, since at both retest occasions, correlations reached significance levels in both control groups as well. These correlations were highest at the third followup:  $-0.79$  ( $p < 0.001$ ) in patient controls and  $-0.55$  ( $p < 0.05$ ) in normal controls. Correlations with finger tapping were nonsignificant at all test occasions in the control groups.

The correlation with mean reaction time seems unstable and was significant in different groups at different retest occasions, most clearly in patient controls:  $-0.45$  ( $p < 0.05$ ) and  $-0.71$  ( $p < 0.001$ ) at both followups, respectively.

In schizophrenia patients and depressive patients, correlations with subjective mental effort reached significance at the last followup ( $-0.53$  and  $-0.49$ , respectively, both at  $p < 0.05$ ), whereas they were nonsignificant at all occasions in the control groups. PSE symptom scores were not significantly associated with  $d'$  in any group at any testing occasion. The correlation with age is a stable one in normal controls, since correlations were essentially similar at both retests. These correlations continued to be nonsignificant in the other groups.

## Discussion

Performance on a CPT version in which the correct response depends on a prior stimulus is strongly and consistently associated with motor speed and with the variability of response latencies to target stimuli. This is particularly striking in patients with schizophrenia and depression. The association with motor proficiency has been found in previous studies (Walker and Green 1982; Earle-Boyer et al. 1991), but the association with response variability is a new finding. Figure 2 shows the relation between the reaction time distribution and  $d'$  for a typical schizophrenia patient with a poor CPT performance; this figure shows the response latencies to target stimuli as well as the false alarms. Figure 3 shows a typical example of good CPT performance by a normal subject.

In contrast to the results at the first test occasion, the correlation between

reaction time variability and  $d'$  is significant in the patient and normal controls at both followups (as well as in the schizophrenia and depressive groups). It is not clear how this should be explained, since  $d'$  is a stable measure, and clinical state as measured by the PSE symptom score improves in all patient groups. Moreover, the symptom score is not significantly associated with  $d'$  in any diagnostic group.

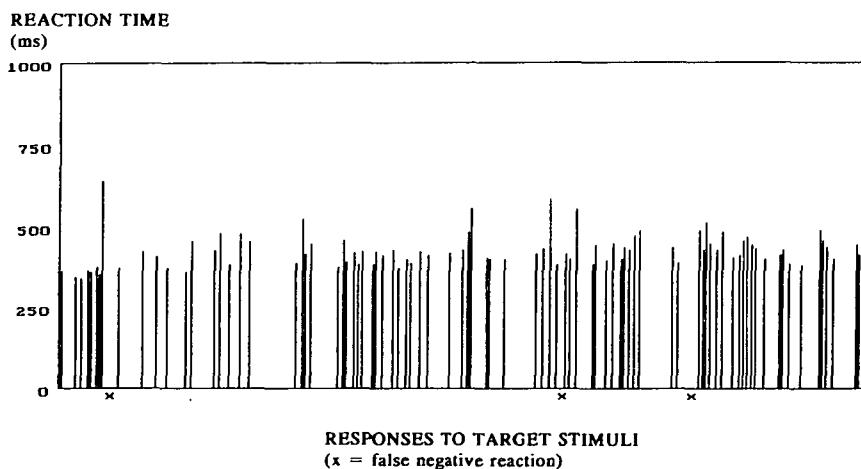
The subjective experience of mental effort during task performance correlates negatively with  $d'$  in patients with schizophrenia or depression and positively with  $d'$  in normal subjects, and it does so consistently. However, these correlations are not usually significant, with the exception of the third followup in schizophrenia patients and depressive patients. The correlations between groups are also not significantly different, with one exception: schizophrenia patients versus normal con-

trols at the third test occasion ( $p < 0.05$ ). Nevertheless, these findings suggest the possibility that mental effort has different meanings in these groups. One might ask whether the patients with schizophrenia or depression misunderstood the nature of the rating and rated perceived difficulty rather than perceived effort. However, instructions to subjects as well as descriptions at anchor points were quite clear, and this explanation does not seem reasonable. Although this is speculative, the experience of a high level of mental effort may represent a failing compensatory attempt in patients with schizophrenia or depression, whereas it serves to increase processing resources and consequently improves performance in other patients.

How do these findings relate to current models of cognitive dysfunction in schizophrenia? The heterogeneity of schizophrenia is well known. Greater intersubject as well as intrasubject variability is the rule in studies of reaction time (Nuechterlein 1977). Although this was already known in the 19th century (Obersteiner 1874), researchers have paid relatively little attention to this phenomenon. It is often treated as "noise" rather than as an interesting feature in its own right.

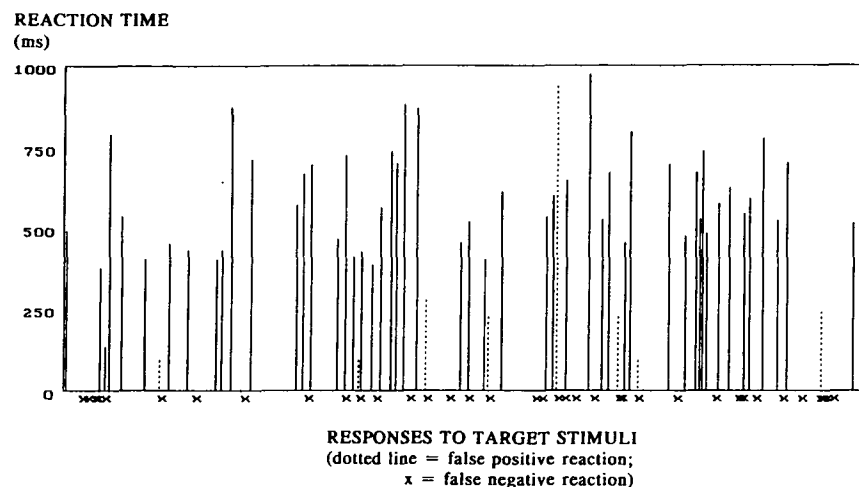
Various mechanisms—attentional as well as motor—may be implicated, and they do not seem to be diagnostically specific. Reaction time variability could be due to transient variations in the level of alertness. Schizophrenia patients also have problems modulating their level of response preparation (e.g., Frith et al. 1988). They do not profit as greatly as normal individuals do from predictability. Hemsley (1987) has described this cognitive deficit as a weakening of the influence of stored memories of regularities of previous input on current perception. As a result, schizo-

**Figure 2. CPT performance: Graphical representation of response latencies to target stimuli in a schizophrenia patient**



CPT = Continuous Performance Task (Rosvold et al. 1956);  $d' = 2.34$ ;  $\ln \beta = 2.33$ ; mean reaction time = 586 ms (standard deviation = 161).

**Figure 3. CPT performance: Graphical representation of response latencies to target stimuli in a normal subject**



CPT = Continuous Performance Task (Rosvold et al. 1956);  $d' = 4.16$ ;  $\ln \beta = 1.01$ ; mean reaction time = 428 ms (standard deviation = 52).

phrenia patients fail to use contextual information in cognitive processing (van den Bosch 1994). It is interesting that this failure allows for superior performance in situations where reliance on rules and schemata is inappropriate to the task requirements (e.g., Schwartz-Place and Gilmore 1980; Brennan and Hemsley 1984; Carter et al. 1993).

All CPT versions demand smoothly integrated perceptual-cognitive-motor functions, but they differ in their load on processing components. In particular, the role of short-term or working memory has been discussed (Nuechterlein and Dawson 1984; Nuechterlein 1991). The present study was based on a double-stimulus CPT version with a working memory component. The results cannot be generalized to other variants of the CPT. Degraded stimulus CPT versions, for instance, may require a higher level of mental effort

but do not have the same memory load. All CPT versions put subjects under time pressure by requiring a continuous preparation for rapid decisionmaking and response preparation. This requires cognitive operations to retain the target schema in working memory while monitoring the stimuli and rapidly comparing these with the schema. CPT variants with targets defined as a stimulus combination differ in that they demand the active maintenance of an internal representation of contextual information. The representation of the previous stimulus has to be used as a context for responding to the current one. As a result, a weak internal representation is likely to affect performance on a double-stimulus CPT.

Cohen and Servan-Schreiber (1992, 1993) have described and tested a neural network simulation model of cognitive deficits in schizophrenia.

Their results suggest that performance deficits on a double-stimulus CPT are indeed due to a degradation in the internal representation required as context for processing the current stimulus. This model suggests that the variability in response latencies during CPT performance may result from a weak internal representation. However, to the extent that this explanation holds for the present data, this mechanism is apparently diagnostically nonspecific.

Although our selection of variables does not exhaust the domain of variables conceivably related to CPT performance, the results indicate that the processes that contribute to the sensitivity measure of a double-stimulus CPT are related to motor speed and mechanisms controlling response variability, particularly in schizophrenia and depressive patients. The results do not point to distinct cognitive dysfunctions, as measured by a double-stimulus CPT, that are different between schizophrenia patients and depressive patients. The role of motor function may be specific to these groups, but mechanisms related to response variability seem to play a part in other patients and normal subjects as well. (However, it is not clear how to explain the lack of a correlation with  $d'$  in these groups at a first test occasion.)

The fact that we obtained significant group differences even after covarying for age, symptom level, motor function, and mental effort suggests that mechanisms determining response variability are important for understanding diagnostic differences. The various mechanisms that may contribute to response time variability during CPT performance—variations in level of alertness, poor modulation of response preparation, weak internal represen-

tation—are not clearly separable, and they are not mutually exclusive. The influence of mental effort may be different for schizophrenia patients and depressive patients than for other patients. This needs further study, preferably including objective measures of mental effort as well.

Because of the rather small number of subjects, our data analyses could not address all relevant aspects and had to rely on within-group correlational comparisons. A replication of this study should be based on a larger number of subjects and should address issues such as the possible mediating influence of age on the relationships of motor speed and reaction time variability to CPT  $d'$ .

## References

- American Psychiatric Association. *DSM-III-R: Diagnostic and Statistical Manual of Mental Disorders*. 3rd ed., revised. Washington, DC: The Association, 1987.
- Brennan, J.H., and Hemsley, D.R. Illusory correlations in paranoid and non-paranoid schizophrenia. *British Journal of Clinical Psychology*, 23:225–226, 1984.
- Carter, C.S.; Robertson, L.C.; Nordahl, T.E.; O'Shara-Celaya, L.J.; and Chaderjian, M.C. Abnormal processing of irrelevant information in schizophrenia: The role of illness subtype. *Psychiatry Research*, 48:17–26, 1993.
- Cohen, J.D., and Servan-Schreiber, D. Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychology Review*, 99:45–77, 1992.
- Cohen, J.D., and Servan-Schreiber, D. A theory of dopamine function and its role in cognitive deficits in schizophrenia. *Schizophrenia Bulletin*, 19(1):85–104, 1993.
- Cornblatt, B.A.; Lenzenweger, M.F.; and Erlenmeyer-Kimling, L. The Continuous Performance Test, Identical Pairs Version: II. Contrasting attentional profiles in schizophrenic and depressed patients. *Psychiatry Research*, 29:65–85, 1989.
- Cornblatt, B.A.; Risch, N.J.; Faris, G.; Friedman, D.; and Erlenmeyer-Kimling, L. The Continuous Performance Test, Identical Pairs Version (CPT-IP): I. New findings about sustained attention in normal families. *Psychiatry Research*, 26:223–238, 1988.
- Davies, D.R., and Parasuraman, R. *The Psychology of Vigilance*. London, England: Academic Press, 1982.
- Earle-Boyer, E.A.; Serper, M.R.; Davidson, M.; and Harvey, P.D. Continuous performance tests in schizophrenic patients: Stimulus and medication effects on performance. *Psychiatry Research*, 37:47–56, 1991.
- Frith, C.D.; Stevens, M.; Johnstone, E.C.; and Crow, T.J. Acute schizophrenic patients fail to modulate their level of attention. *Journal of Psychophysiology*, 2:195–200, 1988.
- Hemsley, D.R. An experimental psychological model for schizophrenia. In: Häfner, H.; Gattaz, W.F.; and Janzarik, W., eds. *Search for the Causes of Schizophrenia*. Berlin, Germany: Springer-Verlag, 1987. pp. 179–188.
- Medalia, A.; Gold, J.; and Merriam, A. The effects of neuroleptics on neuropsychological test results of schizophrenics. *Archives of Clinical Neuropsychology*, 3:249–271, 1988.
- Meijman, T.; Zijlstra, F.; Kompier, M.; Mulders, H.; and Broersen, J. The measurement of perceived effort. In: Osborne, D.J., ed. *Contemporary Ergonomics 1986*. London, England: Taylor and Francis, 1986. pp. 242–246.
- Nestor, P.G.; Faux, S.F.; McCarley, R.W.; Shenton, M.E.; and Sands, S.F. Measurement of visual sustained attention in schizophrenia using signal detection analysis and a newly developed computerized CPT task. *Schizophrenia Research*, 3:329–332, 1990.
- Nuechterlein, K.H. Reaction time and attention in schizophrenia: A critical evaluation of the data and theories. *Schizophrenia Bulletin*, 3(3):373–428, 1977.
- Nuechterlein, K.H. Vigilance in schizophrenia and related disorders. In: Steinhauer, S.R.; Gruzelier, J.H.; and Zubin, J., eds. *Handbook of Schizophrenia. Neuropsychology, Psychophysiology and Information Process*. Vol. 5. Amsterdam, The Netherlands: Elsevier Science Publishers, 1991. pp. 397–433.
- Nuechterlein, K.H., and Dawson, M.E. Information processing and attentional functioning in the developmental course of schizophrenic disorders. *Schizophrenia Bulletin*, 10(2):160–203, 1984.
- Nuechterlein, K.H.; Edell, W.S.; Norris, M.; and Dawson, M.E. Attentional vulnerability indicators, thought disorder, and negative symptoms. *Schizophrenia Bulletin*, 12(3):408–426, 1986.
- Obersteiner, H. Über eine neue einfache Methode zur Bestimmung der psychischen Leistungsfähigkeit des Gehirnes Geisteskranker. *Virchows Archiv*, 59:427–458, 1874.
- Rosvold, H.E.; Mirsky, A.F.; Sarason, I.; Bransome, E.D.; and Beck, L.H. A continuous performance test of brain damage. *Journal of Consulting Psychology*, 20:343–350, 1956.
- Schwartz-Place, E.J., and Gilmore, G.C. Perceptual organization in schizophrenia. *Journal of Abnormal*



*Psychology*, 89:409–418, 1980.

Spohn, H.E., and Strauss, M.E. Relation of neuroleptic and anticholinergic medication to cognitive functions in schizophrenia. *Journal of Abnormal Psychology*, 98:367–380, 1989.

van den Bosch, R.J. Context and cognition in schizophrenia. In: Den Boer, J.A.; Westenberg, H.G.M.; and Van Praag, H.M., eds. *Advances in the Neurobiology of Schizophrenia*. Chichester,

England: John Wiley & Sons, 1994. pp. 343–366.

Walker, E., and Green, M. Motor proficiency and attentional task performance by psychotic patients. *Journal of Abnormal Psychology*, 91:261–268, 1982.

Wing, J.K.; Cooper, J.E.; and Sartorius, N. *Measurement and Classification of Psychiatric Symptoms*. Cambridge, England: Cambridge University Press, 1974.

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## Announcement

The 15th Annual **Therapeutic Activities & Leisure Skills Conference** "Skills for You and Your Clients: The New Millennium" will be held in Philadelphia, Pennsylvania, March 24–26, 1997. The conference is sponsored by the Allegheny University of the Health Sciences. This multidisciplinary conference focuses on the development of activity and leisure skills for various populations in a variety of settings. The presentations

will include program development and experiential workshops.

For further information, please contact:

**Conference Secretary, BHE  
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