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Differential sustained attention/vigilance changes over time in schizophrenics and controls during a degraded stimulus Continuous Performance Test

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Abstract The Continuous Performance Test (CPT) is a widely used procedure for sustained attention/vigilance measurement. However, though the key index of vigilance impairment is the decrement of sensitivity over time during the test period, only few studies have examined whether schizophrenics show a larger drop in CPT performance than do healthy controls. 48 schizophrenic inpatients and 48 controls were investigated with the Munich CPT (480 visual stimuli, 25% target stimuli, one stimulus per second). Stimuli were degraded by randomly inverting 40%, 41%, 42%, or 43% of the pixels. Results were calculated separately for three consecutive trial sections. Additionally, PANSS ratings, medication, and other clinical data were documented. Schizophrenics show a vigilance decrement over time, controls show a vigilance increase. Differential vigilance changes were not related to the level of stimulus degradation. Schizophrenics performed worse than controls only at the lowest degradation level. While overall sensitivity correlated negatively with the dose of atypical neuroleptics and benzodiazepines, vigilance shifts over time correlated negatively with the dose of typical neuroleptics. Furthermore, sensitivity was related to the cognitive PANSS syndrome, number of admissions/duration of illness. Differential sensitivity decrements of schizophrenics and controls can be shown if suited CPT procedures are used. The need for basic research on experimental conditions of the CPT as well as examination of the relationship between sustained attention/vigilance decrements and clinical features of schizophrenia is suggested.

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Introduction

Emil Kraepelin (1919) was one of the first researchers who described attentional dysfunction as a characteristic feature of dementia praecox; in his view, difficulties in keeping attention fixed for any length of time were closely related to pathologic discontinuities of thought. The modern human information processing approach enables a more systematic search for the sources of schizophrenic psychopathology. A major concept of information processing is sustained attention or vigilance, refering to the ability to maintain a focus on a stimulus over extended time periods (Kietzman 1991). In a recent review, Green (1996) concluded that sustained attention is among the neurocognitive functions which are crucial for adequate social outcome (especially problem solving and skill acquisition).

The Continuous Performance Test (CPT; Rosvold et al. 1956) is the most widely used procedure for measurement of sustained attention/vigilance in psychopathology research. During a typical CPT trial, the subject is asked to discriminate between rapidly paced target and non-target stimuli. Common parameters of CPT performance are the rates of hits (i.e., correctly detected targets) and false alarms (responses to non-targets). More important are the indices of sensitivity (e.g., d') and response criterion (β) which are available from the signal detection theory (SDT; Green and Swets 1966). Sensitivity refers to the subject´s ability to discriminate target from non-target stimuli, while the response criterion expresses the amount of evidence the subject requires to decide that a given stimulus is a target.

Several studies showed that schizophrenic patients in psychotic states (Binder et al. 1998) and in remission (Wohlberg & Kornetsky 1973) as well as high-risk samples (Nuechterlein 1983; Erlenmeyer-Kimling 1987) have

deficits in CPT performance. Furthermore, CPT measures seem to be related to schizophrenic psychopathology (Nuechterlein et al. 1986; Strauss et al. 1993). Thus, the CPT is considered a putative indicator of cognitive vulnerability to schizophrenia (Nuechterlein et al. 1991).

Unfortunately, the name CPT does not refer to a defined procedure but to a class of tests; test versions can differ in several characteristics that may influence their ability to detect facets of attentional deficits. Some task versions involve the detection of each X in a sequence of single-letter stimuli. In other versions, the target is each X that follows an A, or pairs of successive identical stimuli have to be detected (involving a memory load).

A salient CPT version was introduced by Nuechterlein (1983), involving the presentation of a series of highly blurred single digits. The rationale of this paradigm is partly based on the work of Parasuraman (1979), who demonstrated that in discrimination tasks the capacity to sustain attention at an efficient level deteriorates if target discrimination loads memory (i.e., target and non-target stimuli are not present at the same time) and stimulus events occur rapidly (i.e., about 30 events per minute or more). Nuechterlein et al. (1983) showed that this sensitivity decrement over time in normal subjects is accelerated by degradation of the stimulus images, probably because of the demand for high levels of strenuous processing under time pressure. Hence, using of degraded stimuli can elicit sensitivity decrements within about 8–10 minutes which is a relative short time for sustained attention/vigilance tasks.

As Nuechterlein (1991) emphasized, the key index of a deficit in sustaining attention is the decrement of sensitivity over time during the vigilance period. However, only few studies (Nuechterlein 1983, Cornblatt et al. 1989, Nestor et al. 1990, Buchanan et al. 1997) have examined whether schizophrenics or high-risk subjects show a larger drop in CPT performance during the test period than do healthy controls.

Nuechterlein (1983) compared the vigilance decrement of 24 children born to schizophrenic mothers with that of a control sample during the degraded stimulus CPT task; both groups showed similar sensitivity decrements over time. Moreover, the mean d' values of both groups did not differ significantly (in spite of one-tailed testing). It can be argued that the hypothesized differential sustained attention/vigilance decrement of schizophrenics does not necessarily occur in their children. Weinberger (1987) suggested that schizophrenia is a neurodevelopmental disorder in which fixed brain lesions (especially in the prefrontal cortex) interact with normal brain matural events. The prefrontal cortex does not reach full physiological maturity before late adolescence; hence, abnormalities due to lesions in this brain region may remain relatively unapparent until adolescence or early adulthood. Since there is evidence that activity of the prefrontal cortex contributes to performance in degraded stimulus CPT (Buchsbaum et al. 1990), the offspring of schizophrenic mothers investigated by Nuechterlein (1983) possibly were still too young (mean age 13.1 years) to show marked vigilance decrements. Furthermore, the differential vigilance decrement of schizophrenics generally does not occur before the clinical manifestation of the disorder.

Using a degraded stimulus CPT with a task duration of 8.1 min, Nuechterlein et al. (1986) reported marked sensitivity decrements (-28.9% and -15.2%, respectively) in a group of first-episode schizophrenics during the psychiatric admission and about three months subsequent to discharge. Unfortunately, in this study no control group was included.

Cornblatt et al. (1989) analyzed the sustained attention/vigilance performance using the identical pairs version of the CPT. In this task, consecutive visual stimuli are displayed under several conditions; the subject is asked to respond whenever two identical stimuli are presented in a row. Vigilance decrements were compared between schizophrenics (N = 14), depressives (N = 17), and normal controls (N = 28). No group showed any decrement of sensitivity during the task. However, in this study vigilance decrements were only examined by studying performance changes in test conditions where *non-degraded* stimuli had been employed. Since especially degradation of the stimulus images seems to be a crucial factor for sensitivity decrements (Nuechterlein et al. 1983), it is possible that the application of degraded stimuli would elicit a differential decrement of sensitivity of schizophrenics.

During the CPT procedure developed by Nestor et al. (1990), a total of 486 blurred digit stimuli were presented over a period of 10.5 min with a rate of about one stimulus per second; the digits were presented for 100 ms, the interstimulus interval varied between 1.1 and 1.3 s. Performance was calculated for three 3.5 min blocks separately. Nineteen schizophrenic males were compared to 20 healthy controls; schizophrenics showed a significantly greater rate of vigilance decline over time than did controls.

Buchanan et al. (1997) investigated the CPT performance of 20 deficit schizophrenics, 56 non-deficit schizophrenics, and 27 controls using a degraded stimulus CPT which consisted of 324 rapidly (one per second) presented digits. When comparing the performance of the first and second half of the test, the authors found no significant sensitivity decrease or group X decrease interaction. A disadvantage of the CPT version applied by Buchanan et al. is the relative short task duration (only 5.4 min); therefore, it can not be ruled out that sensitivity decrements would have occured if a longer procedure had been used.

The absence of a differential sustained attention/vigilance decrement in schizophrenic and high risk subjects led Nuechterlein et al. (1986, 1994) to the assumption that the critical deficits tapped by the degraded stimulus CPT may be linked to early perceptual processes rather than to sustained attention; according to the model of Cowan (1988), the initial sensory storage (maintaining the physical properties of a stimulus for a few hundred ms), the activation of codes in long-term storage, or habituation of (non-target) stimuli may be disturbed. If this assumption is true, the extent of differences in the sensitivity of schiz-

ophrenic and normal subjects should be correlated with the level of stimuli degradation, since processing load increases with the random noise that is added to the stimuli.

Since former studies on sustained attention/vigilance decrements of schizophrenics show several methodological problems (e.g., no stimulus degradation, short test period), the main purpose of the present study was to examine the effects of time course and stimulus degradation on the performance of schizophrenics and healthy controls during a degraded stimulus CPT with a sufficient task duration. Additionally, the relationship between CPT results and psychopathological state, course of illness, and psychopharmacologic medication was investigated.

Methods

Subjects

Forty-eight adult inpatients with a diagnosis of schizophrenia (group SCH) were recruited from the Northern Clinic, Hamburg-Ochsenzoll, and from the University Hospital, Hamburg-Eppendorf. Thirty-eight patients (79.2%) fulfilled the ICD-10 (World Health Organization 1992) criteria of paranoid schizophrenia (code F20.0), three patients (6.3%) were of the hebephrenic type (F20.1), and seven patients (14.6%) were of the residual type (F20.5). Diagnostic criteria according to ICD-10 were checked with the International Diagnosis Check Lists (IDCL; Hiller et al. 1995). Seventeen of the schizophrenic patients were on typical neuroleptic (NL) treatment (mean daily dosage equivalent to chlorpromazine: 278 mg); 26 patients took atypical NL (equivalence mean: 236 mg). Three patients received both typical and atypical NL (equivalence mean: 216 mg), and two patients received no NL at all. Additionally, 16 patients received benzodiazepines (median dosage equivalent to lorazepam: 2.2 mg), and 11 patients received other medication (e.g., biperidene, antidepressants). Calculation of NL and benzodiazepine equivalents were based upon algorithms by Jahn and Mussgay (1989) and Poser and Poser (1986). A control group of healthy subjects (group CON) was composed using the *matched-pairs method* with age, gender, and educational level as control variables (see Table 1).

Multiple linear regression analyses (conducted separately for each of the CPT parameters as dependend variables) yielded that age, gender or educational level were not related with CPT performance. All participants were 18 to 59 years old. All were right-handed, free of alcohol or drug consumption, organic brain disorder, severe somatic disorder, and had normal or corrected-to-normal vision (visual acuity was checked before the CPT session). All subjects gave their informed consent for participation; the design of the study was approved by the local ethic committee and was performed in accordance with the ethical standards of the Helsinki declaration.

Continuous Performance Test

In this study the "CPT-M" (Kathmann et al. 1996) was used. This computerized procedure was developed by the Max Planck Institute for Psychiatry (Munich, Germany) and agrees largely with the recommendations of Nuechterlein et al. (1991). During this test, 480 blurred digits are presented successively on the 15-inch monitor of an ordinary IBM compatible PC (2/86 or 3/86 microprocessor). The CPT-M consists of three identical parts with 40 targets and 120 nontargets each.

The visual stimuli are bold black digits (0, 2, 4, 6, or 8) with a width of about 4 cm and a height of about 6 cm which appear on a white rectangular background field (5.5 cm breadth, 7.0 cm height). The remaining part of the monitor display is black. Visual degradation of the stimuli was realized by randomly inverting a certain percentage of the pixels (black to white or white to black) that formed the shape of digits and background field on the monitor. Four levels of degradation were used (randomly distributed): 40%, 41%, 42%, and 43% pixel inversion; 50% inversion would have generated a random pattern. Figure 1 gives examples for the stimuli and degradation levels. The rationale for using different degradation levels was (i) to allow for the experimental analysis of the influence of degradation level on performance and vigilance decrements within a single session, and (ii) to avoid bottom and ceiling effects by the use of tasks of different difficulty.

Each stimulus was presented for 42 ms with an interstimulus interval of 1 second. Between the presentations of the stimuli, an empty background field with 50% inverted pixels was displayed. The task was to detect the digit "0" (25% of all stimuli, randomly distributed) and to respond to it by pressing the space bar of the keybord as fast as possible. The SDT indices of sensitivity (CPT-d') and natural-logarithmic response bias (CPT-β) served as performance measures. Results were calculated separately for the four levels of degradation and three consecutive blocks of the total CPT procedure, respectively, to allow analyses of the effects of stimulus degradation and performance changes over time. The blocks were formed by subdividing the total CPT trial (480 stimuli/8 min) in the initial, middle, and final section, respectively, each of them with 160 stimuli and a duration 2 min 40 s.

During the CPT trial, the subject sat in a comfortable chair in front of the monitor; the distance between monitor and face was approximately 60 cm. Hence, the stimuli subtended about 6° of visual angle vertically and about 4° horizontally. The investigator made sure that no dazzling or reflections interfered with the trial. The duration was 5-10 min for instructions and a practice trial and 8 min for the main test period.

Psychopathological assessment

Psychopathological symptoms of all subjects were documented with the Positive and Negative Syndrome Scale (PANSS; Kay et al. 1987). PANSS ratings were completed by a clinically trained investigator based on a semi-structurized interview of about 30–60 min duration which was carried out immediately after the neu-

Table 1 Background data of the schizophrenic (SCH; N = 48) and control sample (CON; N = 48)

	SCH	CON
Age[a], mean (SD)	34.5 (10.1)	35.0 (10.9)
Gender	31 males, 17 females	31 males, 17 females
Educational level	elementary school, N = 8 middle school, N = 16 high school[b], N = 24	elementary school, N = 8 middle school, N = 16 high school[b], N = 24
Age at first psychiatric admission[a], mean (SD)	30.5 (8.4)	–
Total number of admissions, mean (SD)	4.3 (6.7)	–
Duration of illness[a], mean (SD)	4.0 (6.0)	–

[a] Years
[b] Qualifying for entrance to university

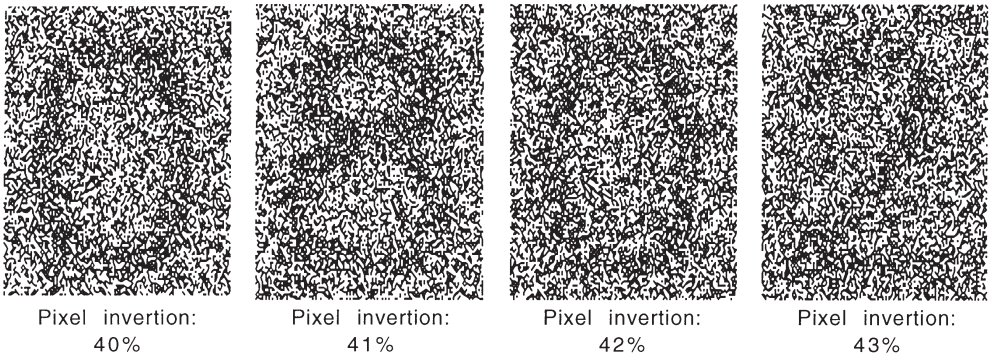

Fig. 1 Examples for the stimuli and degradation degrees of the Continuous Performance Test (CPT-M, Max Planck Institute for Psychiatry, Munich, Germany)

ropsychological testing. According to former factor-analytical results (Mass et al. in press), psychopathology was described with a positive, negative, cognitive, excitement, and depression PANSS syndrome, respectively.

Statistical analyses

All analyses were conducted with the Statistical Package for the Social Sciences (SPSS), Release 6.0.1 for the Macintosh. In cases of skewed distributions or statistical outliers, nonparametric procedures were prefered. Hypothesis testing was always two-tailed.

Results

Group differences, trial course, visual degradation. Repeated measures analyses of variance (ANOVA) were calculated with each of the CPT-M parameters as dependent variables and groups (SCH vs. CON) as a between-subject factor and trial course (first vs. second vs. third block) and degradation level (40% vs. 41% vs. 42% vs. 43% pixel inversion) as within-subject factors. The interaction effects of groups and trial course, and groups and degradation levels, respectively, on the CPT measures are illustrated in Figs. 2 and 3.

For the index of sensitivity (d'), the group effect ($F[1, 94] = 3.85$, n.s.) and the trial block effect ($F[2, 188] = 1.16$, n.s.) failed significance; however, the group effect reached a trend level result ($p = .053$), indicating an overall deficit tendency in the schizophrenic group. The group X block interaction effect was significant ($F[2, 188] = 4.18$, $p < 0.05$) reflecting an improvement of the healthy subjects and a sensitivity decrement of the schizophrenics over time. Visual degradation had a strong effect on CPT-d' ($F[3, 282] = 112.51$, $p < 0.001$); furthermore, the inter-

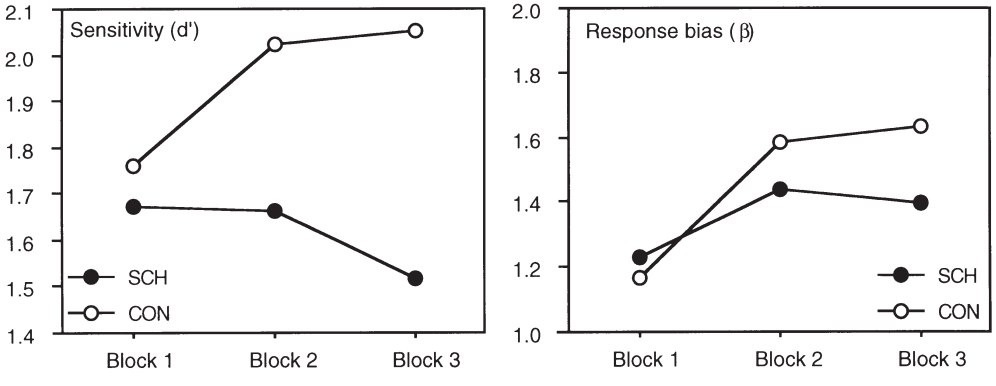

Fig. 2 Within-trial course of the CPT parameters

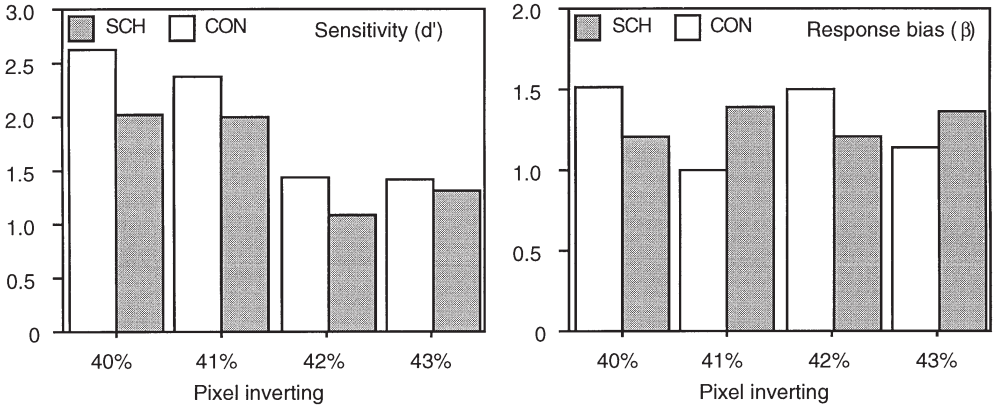

Fig. 3 Effect of the level of visual stimulus degradation (percentage of random pixel inverting) on the CPT parameters

action between group and degradation was significant ($F[3, 282] = 2.70$, $p < 0.05$). Post-hoc t-tests showed that only the stimuli with 40% pixel inverting discriminated between the d' values of schizophrenics and controls ($t = 2.48$, $df = 94$, $p < 0.05$). The block X degradation interaction effect ($F[6, 564] = 1.64$, $p < 0.05$) was significant, the group X block X degradation interaction effect ($F[6, 564] = 0.71$, n.s.) failed significance. To yield an index of *d' change over time* (d'-change), the d' value of block 1 was subtracted from the d' value of block 3; hence, a positive d'-change indicates an increase, a negative d'change a decrease of sensitivity.

For the *response bias index* (β), group ($F[1, 94] = 0.05$, n.s.), block ($F[2, 188] = 2.08$, n.s.), group X block interaction ($F[2, 188] = 1.23$, n.s.), degradation level ($F[3, 282] = 0.99$, n.s.), group X degradation interaction ($F[3, 282] = 1.33$, n.s.), block X degradation interaction ($F[6, 564] = 1.05$, n.s.), and the group X block X degradation interaction ($F[6, 564] = 1.94$, $p = .07$) had no significant effect.

Relationship with psychopathology and course of illness. Within the schizophrenic group, several significant correlations between CPT-M performance and clinical variables were found (Table 2). The cognitive syndrome as documented by the PANSS stood out, correlating with the sensitivity and response bias indices; only the positive syndrome also showed a correlation with CPT-β. Sensitivity and response bias correlated with the duration of illness as well as the number of psychiatric admissions; both of these variables reflect nearly identical aspects of the course of illness (Rho = .88, $p < 0.001$). Sensitivity shifts did not correlate with psychopathology or course of illness.

Psychopharmacological effects. As mentioned above, the neuroleptic (NL) medication was converted into chlorpromazine equivalence units. The subsample (N = 26) receiving atypical NL only (mostly clozapine) showed highly significant correlations between dose and CPT-d' (high dose - poor performance and vice versa) and CPT-β (see Table 3). In contrast to this, sensitivity changes correlated significantly with typical NL dose in those patients receiving typical NL only (mostly haloperidol; N = 17). The inverse correlation (–.54) means that a higher dosage is associated with lower sensitivity increase or higher sensitivity decrease, respectively.

Table 2 Relationship (Rho) between CPT performance and clinical variables (PANSS syndromes, course of illness) within the SCH group

	CPT-d'	d'-change	CPT-β
PANSS-positive	–.16	–.11	–.32*
PANSS-negative	–.21	–.03	–.09
PANSS-cognitive	–.38**	–.16	–.35*
PANSS-excited	–.09	–.06	–.11
PANSS-depressive	.17	–.13	.13
Age at first psychiatric admission	–.05	–.06	.06
Total number of admissions	–.36*	.26	–.53***
Duration of illness	–.42**	.18	–.54***

*** $p < 0.01$; ** $p < 0.01$; * $p < 0.05$

Table 3 Correlations (Rho) between CPT performance and daily neuroleptic (NL) and benzodiazepine doses within the SCH group

	N	CPT-d'	d'-change	CPT-β
$NL_{typical}$	17	–.06	–.54*	.04
$NL_{atypical}$	26	–.55**	.19	–.53**
Benzodiazepine	16	–.32	–.10	–.33

** $p < 0.01$; * $p < 0.05$

Discussion

The absence of any threefold (groups X blocks X degradation levels) interaction indicates that trial course and degradation level interact with the group effect independently from each other and, therefore, will be discussed separately.

Unlike the investigations of Nuechterlein (1983), Cornblatt et al. (1989), and Buchanan et al. (1997), and in accordance with the results of Nestor et al. (1990), the present study yielded a differential within-trial course of sensitivity of schizophrenics and controls: schizophrenics showed a decrement, controls an improvement of sensitivity. This can be traced back to a marked decrease of the number of hits in the schizophrenic group and a marked decrease of the number of false alarms in the control group.

Since the CPT-M task (480 stimuli ⇒ 8 min) lasts about 50% longer than the CPT task used by Buchanan et al. (1997, 324 stimuli ⇒ 5.4 min), the results of the first and the second half of the Buchanan et al. procedure are comparable to the results of block 1 and block 2 of the present study. Indeed, the mean sensitivity decrease from first half (2.49 = 100%) to second half (–0.7%) shown by the schizophrenic subjects of Buchanan et al. (1997) was very similar to the decrease from block 1 (1.67 = 100%) to block 2 (–0.6%) of the present schizophrenic sample. A marked sensitivity decrement in the present study occured not before block 3 (-9.0%), thus, confirming the assumption that the short duration of the CPT used by Buchanan et al. (1997) prevented any sensitivity decrements.

The mask displayed during the interstimulus interval may be an important test condition, though researchers have payed little attention to it. In the CPT-M, between presentation of the stimuli an empty field with a random pattern of pixels is displayed. This field is very similar to the background fields of the stimuli; hence, the subjects in the present study were not distracted by varying backgrounds. If, e.g., a white field would be displayed between stimuli presentation (this is the case in the UCLA CPT version, Nuechterlein and Asarnow 1996), this – like in the backward masking paradigm – could interfere with the detection of the stimuli and increase the load on visual information processing. Interestingly, in the only other

study (Nestor et al. 1990) that also yielded differential vigilance changes of schizophrenics and controls, a CPT procedure was used in which a mask remained on the monitor throughout the interstimulus interval, thus keeping luminance constant like in the CPT-M. However, the healthy control group of Nestor et al. (1990) showed a sustained attention/vigilance decrement over time while the controls in the present study showed an increase. This could be due to a considerable difference of visual angle of the stimuli: $0.6° \times 0.9°$ (Nestor et al. 1990) vs. $4° \times 6°$ (present study), resulting in an greater processing load of the Nestor et al. procedure. Of course, this explanation is speculative as long as no direct comparisons of the CPT versions have been made. Another explanation could be derived from the fact that the control sample in the study of Nestor et al. (1990) was not pairwise matched. Although regression analysis yielded that educational level was not related with CPT performance, the high percentage of probands with high educational levels together with the pairwise matching procedure could contribute to the increase of sustained attention in the control group.

To our knowledge, the effect of different levels of stimulus degradation on differential CPT performance of schizophrenics vs. controls have not been examined in former studies. The present findings show that high levels of visual stimulus degradation in both groups caused a strong decrease of d' and hits. Healthy subjects performed better than schizophrenics only at the lowest degradation level (40% pixel reversal). Therefore, a major result from the present study concerns the level of degradation as an important determinant of group differences. The new conclusion is that group differences seem to vanish above a certain level of perceptual degradation.

Former studies repeatedly have shown correlations between degraded stimulus CPT performance and schizophrenic psychopathology. Nuechterlein et al. (1986) examined N = 40 schizophrenic inpatients and reported significant correlations between the degraded stimulus CPT performance (d') and the anergia and hostile/suspiciousness scales of the Brief Psychiatric Rating Scale (Overall and Gorham 1988). Moreover, the sensitivity measured subsequent to hospital discharge was correlated with an index of thought disorder obtained during inpatient period. Strauss et al. (1993) found no relationship between CPT and BPRS but confirmed the correlation between d' and thought disorder. Hain et al. (1993) applied a CPT similar to that of the present study (CPT-M) to a sample of N = 49 schizophrenic inpatents and found a significant correlation between sensitivity and the attentional impairment rating and the composite score of the SANS (Andreasen 1989). Although psychopathology in the present study was documented with a different method (PANSS), the results are in accordance with former findings: no relationship between CPT-d' and positive symptoms was observed, and the correlation with thought disorder reported by Nuechterlein et al. (1986) and Strauss et al. (1993) was confirmed by the correlation with the cognitive PANSS syndrome (see Table 2). However, in the present sample CPT performance did not correlate with negative symptoms.

Long duration as well as many admissions indicate an unfavorable course of illness; in the present schizophrenic sample, both variables correlate significantly with negative symptoms and total neuroleptic dose. Hence, the relationship between CPT performance and duration of illness/number of admissions (Table 2) indirectly confirms former results (Nuechterlein et al. 1986, Strauss et al. 1993, Hain et al. 1993) suggesting relations between visual attention/information processing impairments and negative or deficit symptoms.

Change of sensitivity over time (d'-change) did not correlate with the initial level of sensitivity (d' value of block 1): SCH, $r_{xy} = -.19$, n.s.; CON, $r_{xy} = -.23$, n.s., thus suggesting that the ability to sustain attention and the ability to detect degraded target stimuli are independent features. Little can be said about the relationship between sensitivity decrements and schizophrenic psychopathology. Nestor et al. (1990) mentioned that the more rapid vigilance decline occured in patients with positive psychotic symptoms; Nuechterlein et al. (1986) reported a counterintuitive correlation between d'-change and the BPRS anergia score. In the present study, no significant correlation between d'-change and psychopathology was found.

With regard to effects of medication on sustained attention, the present results – especially the unexpected differential relationship of d' (negatively correlated with atypical NL dose) and d'-change (negatively correlated with typical NL dose) – should be interpreted cautiously (see Table 3). Since this study was not designed to examine psychopharmacological effects, patients were not randomized to medication groups; e.g., atypical NL were often given to patients which turned out to be refractory to typical NL therapy. Conclusions drawn from the correlational results regarding the NL dose are limited because of an inherent confound between psychopathological status and medication: Patients with atypical NL only (N = 26) had more negative symptoms than patients with typical NL (N = 17; $t = -2.56$, $df = 41$, $p < 0.05$). Furthermore, since atypical NL differ in their receptor binding profiles, the calculation of an atypical NL equivalence dose is problematic. However, when testing the relationship between atypical NL dosage and CPT parameters with the 'Clozapine only' subgroup (N = 16), the resulting coefficients were nearly identical.

Braff (1993) concluded from a literature review that it is unlikely that neuroleptic medication induces information processing deficits in schizophrenia; it seems that NL can at least partially reverse attentional deficits to a normal level (see also Maruff and Currie 1996). However, the development of new atypical neuroleptics (e.g., clozapine) raised the necessity of a more differential consideration of the effects of antipsychotic medication on cognitive functions. Controlled comparative investigations revealed rather beneficial effects for clozapine on a broad range of neuropsychological functions (Buchanan et al. 1994).

The results of the present study indicate the need for a more systematic examination of the determinants of sustained attention/vigilance performance and change over

time. This concerns effects of medication (e.g., the anticholinergic properties of atypical NL, see Nuechterlein 1991) as well as experimental conditions. The present study suggests that differential vigilance changes of schizophrenics (vs. controls) can be shown with degraded stimulus CPT only if several preconditions are fulfilled (e.g., characteristics of the interstimulus mask, test duration). Moreover, further research should be directed to the meaning of vigilance decrements over time for psychopathology or course of illness and to the question of whether differential sustained attention/vigilance decrements are reversible features of schizophrenic episodes or enduring traits and markers of vulnerability.

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