Sustained Attention Deficit Along the Psychosis Proneness Continuum

A Study on the Sustained Attention to Response Task (SART)

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Background: Sustained attention deficits have been associated with schizophrenia. However, these findings were limited to patients with schizophrenia and cannot be generalized to a wider nonclinical sample with schizotypal personality features.

Objectives: This study aimed to examine the sensitivity of a theory-driven test, the Sustained Attention Response to Task (SART), in individuals with schizotypal personality features. We also investigated the relationships between different parameters of SART and different dimensions of schizotypal features.

Methods: One hundred and ninety-nine participants (74 individuals with schizophrenia, 69 individuals with psychometrically determined schizotypal features, and 56 healthy controls) took part in this study. Participants scoring in the top 10% of the Schizotypal Personality Questionnaire (SPQ) score were identified as having schizotypal features, and those scoring in the bottom 10% were recruited as healthy controls. All participants were administered the SART in an experimental cubicle.

Results: The findings indicated that: (1) significant differences were found in SART commission error and sensitivity between the 3 experimental groups, with patients with schizophrenia and individuals with schizotypal features performing worse than healthy controls; (2) there was a trend toward statistical significance for SART efficiency score and d', with controls performing better than patients with schizophrenia and individuals with schizotypal features; (3) some associations between some SART indices and schizotypal traits were found; and (4) there was no significant relationship between SART indices and clinical symptoms in patients with schizophrenia in this study.

Conclusions:: This investigation demonstrated the potential value of a relatively new sustained attention paradigm for research in schizophrenia spectrum disorders.

Key Words: sustained attention, schizotypy, schizophrenia spectrum disorder, Chinese

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Neurocognitive impairment is a characteristic of schizophrenia.[1] Sustained attention deficits are consistently found in different stages of the illness[2–8] and nonpsychotic first-degree relatives of patients with schizophrenia.[4] Moreover, recent studies have also indicated that schizotypal personality is linked to schizophrenia through genetic[9,10] and developmental[11] processes. This suggests that schizotypal personality and schizophrenia share a common latent liability,[12–14] which can be inherited and is referred to as schizotaxia.[12,13]

Sustained attention deficit detected by the Continuous Performance Test (CPT) has been considered to be a potential vulnerability marker for schizophrenia.[15] Typically, participants are instructed to respond to a set of relatively infrequent target stimuli over a short period of time. Various versions of the CPT have been successfully applied to patients with schizophrenia, including responses to single stimulus,[16] a sequence of 2 stimuli,[17] or a sequence of any 2 identical paired stimuli.[18] The task difficulty can either be manipulated by degrading the stimuli or increasing the demand on working memory.[19] Despite the consistent findings of sustained attention deficits in patients with schizophrenia on most versions of the CPT and its relationship to clinical symptoms, several issues remain unresolved concerning CPT performance and individuals with schizotypal personality features.

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First, findings on sustained attention deficits using the CPT paradigm in individuals with schizotypal features are less consistent. Although some studies[20–22] reported poorer performance accuracy on a degraded CPT and d' (sensitivity index in the signal detection theory, calculated by hit rate and commission error) in individuals with schizotypal personality, others[23] did not replicate the finding of increased errors using the CPT-IP (Continuous Performance Test-identical pairs) version. Second, the relationship between the disorganization and negative features of schizotypy and sustained attention is less clear.[20,21,24] Finally, sustained attention is not a unitary construct. It can be broken down into at least 2 different aspects, namely vigilance decrement and the overall level of sustained attention performance.[25,26] Using the CPT paradigm as if it is a unitary construct as a sole measure of sustained attention has limitations.[25,26]

Given the significance and sensitivity of reaction time to deficits in information processing as compared with the measurement of accuracy in patients with neuropsychiatric disorders,[27] an index incorporating reaction time into the assessment of sustained attention performance may be warranted. Kurtz et al[28] proposed an "efficiency estimate" to combine both the accuracy and speed of responding into a single measure. As the performance of healthy controls on the CPT and related paradigm is highly accurate, the use of such a measure further differentiates participant scores by including variance attributable to speed of processing in schizophrenia and related disorders.[29,30] It can be calculated as a ratio of number of correct responses per unit time by dividing the number of true positives (hits) by average reaction time on correct responses. In doing so, an angular transformation should be performed according to the procedure described by Snedecor and Cochran[31] that is, arcsin of square root of the ratio of number of correct responses per unit time by dividing the number of hits by average reaction time on correct response.

Robertson et al[32] argued that withholding responses to infrequent nontargets requires controlled processing to combat the tendency to automatize responding to the more frequent targets. Therefore, Robertson and colleagues developed a task, the Sustained Attention to Response Task (SART), to overcome this drawback. As compared with conventional CPT tasks, the SART requires the participant to respond to frequently presented nontarget stimuli (any single digit other than 3) instead of the target stimuli (digit of 3). Therefore, the participant is required to inhibit habitual response to the frequent "foils" by withholding the appropriate responses. In brief, error commission of the SART is thought to be due to impairment of sustained attention. In contrast, as compared with traditional go-no go tasks, SART is characterized with the disproportion of go trials over no-go trials. Moreover, it is developed under the theoretical framework of the supervisory attention framework proposed by Norman and Shallice.[33] According to this framework, the activation level of the target response must be endogenously maintained close to the threshold if it is to compete successfully when appropriate. The SART is therefore, in the supervisory attentional framework, designed to capture the ability to maintain sustained attention, which requires the higher cognitive control function of the supervisory attentional system. Chan et al[34] demonstrated that the correct response and commission error of the SART actually capture sustained attention and action inhibition, respectively. Finally, the neuroanatomy and electrophysiology of the SART has also been examined in both cognitively intact volunteers and brain lesions cases using imaging and evoked potential paradigms.[35–37]

More recently, Chan and colleagues[29,30] demonstrated that the efficiency estimate distinguishes patients with attention deficits, including schizophrenia, from healthy controls. The apparent difference in sensitivity among different parameters of the SART, and the reaction time component in particular, may reflect the trade-off between accuracy and speed of movement in schizophrenia. However, these findings were limited to patients with schizophrenia and cannot be generalized to a wider nonclinical sample with schizotypal personality features.

The purpose of this study was to examine the SART performance in schizophrenia spectrum. It should be emphasized that this study did not attempt to discard conventional CPT paradigms. Instead, it attempted to provide supplementary information on the use of a CPT-like paradigm with inhibition component to examine the use of the efficiency estimate in discriminating sustained attention performance in participants along the continuum of proneness to schizophrenia from healthy volunteers. Given previous findings of the use of this estimate in schizophrenia research, it was hypothesized that individuals with schizotypal features would demonstrate sustained attention deficits on the SART, and their performances would lie intermediate between patients with schizophrenia and healthy controls. Moreover, this study also investigated the relationship between the different parameters of the SART and the different dimensions of schizotypal features. It was further hypothesized that there would be a significant, but small, association between sustained attention performance parameters of the SART and schizotypal personality features.

METHODS

Participants

Seventy-four patients with schizophrenia, 69 psychometrically determined individuals with schizotypal features, and 56 healthy controls took part in this study. Patients with schizophrenia were recruited from the Institute of Mental Health of Peking University and Beijing Anding Hospital. All patients were interviewed by trained psychiatrists using the Structured Clinical Interview for Diagnostic and Statistical Manual of Mental Disorders (DSM)-IV (SCID-II) and diagnoses were made according to DSM-IV based on interview and medical

records.[38] None of the patients had neurologic disease or drug/alcohol abuse. Thirty-three of the patients were of paranoid subtype, 39 were of undifferentiated subtype, and 2 were of hebephrenic subtype. All the patients are taking antipsychotic medication, 13.7% of them are taking typical antipsychotic medication, 82.2% are taking atypical antipsychotic medication, and 4.1% are taking both typical and atypical antipsychotic medication. The schizotypal participants and controls were recruited in the community and from among university students, all of which completed the schizotypal personality questionnaire (SPQ[39]; Chinese version[20,40]). According to the manual of the SPQ,[39] participants scoring in the top 10% of the SPQ were identified as having schizotypal features. In short, a total of 890 participants filled the SPQ, those participants whose score fell into top 10% (cutoff = 35) were defined schizotypal, 85 were identified schizotypal and 69 of whom were contacted and agreed to participate the following study, and 56 of those whose scores below cutoff were contacted and agreed to participate the following > study, they were defined control group. A semistructured interview was conducted to ensure these participants did not have a history of neurologic or psychiatric disorder, or drug/alcohol abuse. None of them had a first degree relative with a psychiatric disorder.

Measures

The Sustained Attention Response to Task

Details of the SART have been described elsewhere.[32] In brief, a total of 225 single digits (25 of each of the 9 digits) were presented visually to participants over a 4.3-minute period. Each digit was presented for 250 ms, followed by a 900-ms mask. Participants were told to respond by pressing a key to each digit, except the digit 3, when they were told to withhold a response. Participants were asked to give equal importance to accuracy and speed in performing the task. The digits were presented in 1 of 5 randomly allocated font sizes to enhance demand for processing the numerical value, rather than simply setting for a search template for some peripheral feature of the noresponse target. Each session was preceded by a practice period consisting of 18 presentations of digits, 2 of which were targets.

Schizotypal Personality Features and Clinical Symptoms

The schizotypal personality features and clinical symptoms were assessed by the SPQ[39,40] and the Positive and Negative Syndrome Scale (PANSS),[41] respectively. The SPQ was designed to detect schizotypal personality features according to the 9 features of the DSM-III-R schizotypal personality disorder (SPD). It is a 74-item questionnaire with a "yes/no" response to each item. It captures specifically the 9 traits of SPD, namely idea of reference, excessive social anxiety, odd belief or magical thinking, unusual perceptual experiences, odd or eccentric behavior, no close friends, odd speech, constricted affect, and suspiciousness/paranoid ideation. The items can be reduced to 3 factors: cognitive-perceptual, interpersonal, and disorganized.[42] Impressive psychometric properties of the original and Chinese version have been described elsewhere.[20,39,40,42] All items in the PANSS were rated from either 1 (absent) to 7 (extreme) according to standardized instructions. Interrater reliability for the PANSS was evaluated. The intraclass correlation coefficients were 0.83 for the global PANSS score; 0.84 for the positive symptoms subscale and 0.73 for the negative symptoms subscale.

Procedures

This study received ethical approval as part of an extensive project examining the prevalence of schizotypy in a healthy population in the Institute of Psychology, the Institute of Mental Health of Peking University and Beijing Anding Hospital ethics committees. Participants gave informed written consent and were assured of anonymity and confidentially of the data being collected. After identifying the SPD and non-SPD cases using the cutoff, participants were approached and invited to take part in the second part of the study. Clinical diagnoses of schizophrenia were made by experienced psychiatrists who were blind to the subgroup status of participants. In addition to the SART assessment, all participants were also administered handedness assessment[43] by a trained research assistant.

Data Analysis

The SART data was analyzed using the methodology of signal detection theory. The d' index (sensitivity) and the ln_β index (response bias) were computed using the hit rate and false alarm (commission error) rate data. The indices provided a measure of overall performance accuracy on the SART. Moreover, an efficiency estimate was also calculated to reflect SART performance. It was calculated as the arcsin of square root of the ratio of number of correct responses per unit time by dividing the number of hits by average reaction time on correct responses. Pearson product-moment correlation coefficients and partial correlation coefficients were used to assess associations. Means were compared by using multiple analysis of covariance. The schizotypal measures (SPQ factors), the clinical symptoms (PANSS scores), and the SART performance indices were examined for evidence of association with the variables age, sex, intelligence quotient (IQ), and education. We further examined the correlations between the SPQ factors and both the d' and efficiency estimate to determine if they differed. The calculation formula can be seen in the study of Meng et al.[44]

RESULTS

Demographics

The demographics for the participants are summarized in Table 1. Significant differences were found between patients and controls in terms of age [$F(2,196) = 42.25$, $P = 0.0005$], education [$F(2,196) = 15.78$, $P = 0.0005$],

TABLE 1. Demographic Variables and Clinical Information

	Schizophrenia (N = 74)	Schizotypal (N = 69)	Control (N = 56)		
	Mean (SD)	Mean (SD)	Mean (SD)	*F*	*P*
Age	30.50 (8.68)	20.30 (1.03)	24.16 (7.66)	42.25	0.0005
Education (y)	12.15 (3.24)	13.90 (0.77)	14.34 (2.43)	15.78	0.0005
IQ	97.27 (19.32)	102.16 (17.55)	113.20 (17.28)	12.53	0.0005
Sex (male:female)	64:10	43:26	19:37	37.96 (χ^2)	0.0005
Handedness (right:left: mixed)	72:1:1	67:2:0	56:0:0	3.46 (χ^2)	0.483
Duration of illness (y)	7.30 (7.74)	—	—	—	—
Medication (Chlorpromazine equivalence mg/d)	326 (251)	—	—	—	—
PANSS					
Positive	14.67 (4.99)	—	—	—	—
Negative	16.49 (4.95)	—	—	—	—
General psychopathology	29.67 (5.62)	—	—	—	—
Total	60.82 (11.49)	—	—	—	—
SPQ					
Cognitive-perceptual factor	—	18.70 (4.06)	8.70 (4.25)	—	—
Interpersonal factor	—	17.37 (5.11)	7.61 (4.59)	—	—
Disorganized factor	—	10.76 (2.64)	4.02 (2.27)	—	—
Total score	—	42.73 (6.99)	18.83 (7.36)	—	—

IQ indicates intelligence quotient; PANSS, positive and negative symptom scale; SPQ, schizotypal personality questionnaire.

and IQ [$F(2,196) = 12.53$, $P = 0.0005$]. Post hoc test revealed that for age, schizophrenia patients were significantly older than schizotypals ($P = 0.0005$) and controls ($P = 0.0005$), schizotypals were significantly younger than controls ($P = 0.002$); for education, schizophrenia patients were significantly less educated than schizotypals ($P = 0.0005$) and controls ($P = 0.0005$), schizotypals and controls did not differ significantly; and for IQ, schizophrenia patients were significantly lower than controls ($P = 0.0005$), schizotypals were also significantly lower than controls ($P = 0.001$). So these variables were controlled in further analysis. There were significant differences in sex proportion [χ^2 (2) = 37.96, $P = 0.0005$]. No differences were found in handedness [χ^2 (2) = 3.46, $P = 0.483$]. However, as sex differences have been found not to affect SART performance in all 3 groups of participants, P ranged from 0.230 to 0.976, this variable was not controlled for in subsequent analyses.

SART Performance

Marginal significant difference was found between the 3 groups in commission error [$F(2,193) = 2.51$, $P = 0.084$], significant differences were found in efficiency score [$F(2,193) = 4.72$, $P = 0.010$], sensitivity [$F(2,193) = 8.99$, $P = 0.0005$], and response bias [$F(2,193) = 5.65$, $P = 0.004$] (Table 2). Post hoc analysis showed that for commission errors, schizophrenia patients made more commission errors than controls ($P = 0.025$); for efficiency scores, controls was higher than schizophrenia patients ($P = 0.002$) and schizotypals ($P = 0.029$); for sensitivity, schizophrenia was significantly lower than controls ($P = 0.0005$) and schizotypals ($P = 0.0005$); and for response bias, schizophrenia patients were more tend to withhold their response than controls ($P = 0.004$) and schizotypals ($P = 0.002$).

Relationship Between SART, SPQ, and PANSS, Clinical Variables

Given the IQ effect in relation to SART performance variables and the SPQ score, partial correlation analysis was performed to assess the associations between the SART indices and SPQ factors controlling for the effect of IQ. Also, relationship between SART performance variables and PANSS scores were evaluated controlled for IQ. However, none of the above relationship was significant. There were trends of significant

TABLE 2. Comparison of SART Measures (Control for Age and IQ)

	Schizophrenia (N = 74)		Schizotypal (N = 69)		Control (N = 56)					SZ vs. HC	SPD vs. HC	SZ vs. SPD
	Mean	SD	Mean	SD	Mean	SD	*F*	*P*	Partial η2	*P*	*P*	*P*
SART commission error	0.45	0.23	0.37	0.21	0.35	0.24	2.85	0.060	0.029	0.025	0.693	0.060
SART efficiency score	0.76	0.14	0.78	0.10	0.84	0.18	5.07	**0.007**	0.050	0.002	0.029	0.322
SART d'	1.95	0.90	2.65	0.94	2.71	0.96	9.80	**0.0005**	0.092	0.0005	0.752	0.0005
SART ln_β	−1.65	1.21	−2.31	1.01	−2.27	0.95	5.98	**0.003**	0.058	0.004	0.813	0.002

P values less than 0.05 are bolded.
The means in this table were corrected means.
HC indicates healthy control; SART, Sustained Attention Response to Task; SPD, schizotypal personality disorder; SZ, schizophrenia.

associations between SART and SPQ, the correlation between SART efficiency score and SPQ cognitive-perceptual factor, $r = -0.162$ ($P = 0.095$), relationship between response bias (ln_β) and interpersonal factor, $r = 0.146$ ($P = 0.131$).

We further examined the correlations between SPQ factors and both the d' and efficiency estimate to determine if they differed. No significant differences were found between the correlations for SPQ factors with d' and efficiency estimates in the schizotypal participants. Also no significant differences were found between the correlations for PANSS subscales with d' and efficiency estimates in the schizotypal participants.

Correlation analysis was performed to explore relationship between SART and clinical variables in patients with schizophrenia. None of the relationships between SART and duration of illness was significant, r ranged from -0.14 to 0.76, P ranged from 0.226 to 0.615; and none of the relationships between SART and medication dosage was significant, r ranged from -0.06 to 0.07, P ranged from 0.644 to 0.930.

DISCUSSION

The present findings are consistent with the a priori hypothesis that individuals with schizotypal features would exhibit deficits in all parameters of a theory-based sustained attention test, the SART, as compared with healthy controls. In particular, the severity of their deficits lies intermediate between patients with schizophrenia and healthy controls. These findings are consistent with the findings of previous studies on sustained attention deficits in patients with SPDs[20,21,24] and those with psychometrically-determined schizotypal personality features.[45] Previous findings were primarily based on the conventional or modified version of the CPT. Our findings support the clinical applicability of an alternate form of sustained attention test, the SART, and demonstrate its ability to capture the underlying deficits in individuals with schizotypal personality features.

More importantly, the present findings were among the very few evidence in demonstrating that there is a linear decrement of sustained attention performance from healthy controls, individuals with schizotypal features to patients with schizophrenia. Deficits in CPT performance have been proposed as an endophenotypic marker of schizophrenia, and have been suggested as a useful quantitative trait marker in genetic studies.[8,10,46] The findings in this study that most parameters of the SART demonstrated differential deficits of sustained attention among the 3 experimental groups suggest that the SART may be considered as an alternative endophenotypic marker for schizophrenia spectrum disorders. Importantly, the efficiency estimate of the SART effectively discriminate individuals with schizotypal features from controls, and also patients with schizophrenia from controls. These findings are consistent with previous studies adopting the SART in chronic schizophrenia.[29]

There were weak and trends of significant associations found between sustained attention performances parameters of the SART and schizotypal personality features. Interestingly, these associations were only limited to the cognitive-perceptual and interpersonal factors of schizotypal features but not the disorganized feature.[24,45] These findings are consistent with the results reported for a Chinese-speaking sample from Chen et al,[20] which also reported associations between schizotypal features and sustained attention performance while controlling for the effects of age, sex, and educational level in a community sample. No significant relationships between the SART indices and clinical symptoms were found in this study in patients with schizophrenia; the differences of the relationships between the SART parameters and different clinical symptoms were non-significant.

There were several limitations in this study. First, we only adopted a self-report questionnaire to identify individuals with schizotypal personality features. Though this type of method is commonly used in research studying schizotypal personality, it may not be as sensitive as using a clinical diagnostic approach in identifying SPD or recruiting nonpsychotic relatives of patients with schizophrenia. The SPQ author Raine[39] reported that only 55% of participants scoring in the top 10% of the SPQ met the clinical diagnosis of SPD. The current sample was only made up of individuals with "proneness to schizophrenia" or "schizotypal personality features" rather than "schizotypy," which may seem to imply diagnostic certainty. Performing a structured diagnostic interview on the schizotypal feature group would address this issue. Second, the sample size of this study was relatively small to detect any potential significant relationships between the various parameters of the SART and schizotypal features. This is particularly crucial for the interpretation of the negative findings in this study. Therefore, future studies should recruit a larger and more representative sample from the community to cross-validate the present findings. Third, the patients in this study are chronic cases and are taking medication, this may influence the results, future studies recruiting first-episode or medication-naive cases may exclude these confoundings.

In summary, we presented results of a CPT-like paradigm involving an inhibition component to quantify the deficits of sustained attention in patients with schizophrenia and individuals with schizotypal features. The results indicate that: (1) significant differences were found in SART commission error and sensitivity between the 3 experimental groups, with patients, with schizophrenia, and individuals with schizotypal features performing worse than healthy controls; (2) there was a trend toward statistical significance for SART efficiency score and d', with controls performing better than patients with schizophrenia and individuals with schizotypal features; (3) some associations between some SART indices and schizotypal traits were found; and (4) there was no significant relationship between SART indices and

clinical symptoms in patients with schizophrenia in this study. This investigation demonstrated the potential value of the SART, as an alternative paradigm to conventional CPT, in schizophrenia research.

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