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Neuropsychological correlates of sustained attention in schizophrenia

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Abstract

We employed a simple and relatively undemanding task of monotone counting for the assessment of sustained attention in schizophrenic patients. The monotone counting task has been validated neuropsychologically and is particularly sensitive to right prefrontal lesions. We compared the performance of schizophrenic patients with age- and education-matched controls. We then explored the extent to which a range of commonly employed neuropsychological tasks in schizophrenia research are related to attentional impairment as measured in this way. Monotone counting performance was found to be correlated with digit span (WAIS-R-HK), information (WAIS-R-HK), comprehension (WAIS-R-HK), logical memory (immediate recall) (Weschler Memory Scale, WMS), and visual reproduction (WMS). Multiple regression analysis also identified visual reproduction, digit span and comprehension as significant predictors of attention performance. In contrast, logical memory (delay recall) (WMS), similarity (WAIS-R-HK), semantic fluency, and Wisconsin Card Sorting Test (perseverative errors) were not correlated with attention. In addition, no significant correlation between sustained attention and symptoms was found. These findings are discussed in the context of a weakly modular cognitive system where attentional impairment may contribute selectively to a range of other cognitive deficits.

Keywords: Monotone counting; Neuropsychology; Schizophrenia; Sustained attention

1. Introduction

Cognitive theories of schizophrenia have often suggested that attentional impairment may underlie psychotic symptom formation (Levin et al., 1989; Hirt and Pithers, 1991; Braff, 1993; Gold and Harvey, 1993). Although such impairments are not well captured by conventional symptom scales, subjective complaints of cognitive difficulties are not uncommon among schizophrenic patients (Simhandl et al., 1986). It is now recognized that the construct of 'attention' probably comprises several distinct dimensions (Kremen et al., 1992; Mirsky et al., 1992). Two of the more extensively studied dimensions in schizophrenia are sustained attention (the ability to maintain

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vigilance over time) and selective attention (the ability to focus on relevant information and disregard irrelevant information). While evidence for selective attention involvement in the illness is less clear cut (Green, 1985; Green and Walker, 1986; McKenna, 1994), studies of sustained attention in schizophrenia consistently report impairment (Cornblatt et al., 1985; Green and Walker, 1986; Cornblatt et al., 1988, 1989; Everett et al., 1989; Spring et al., 1989; Grillon et al., 1990; Nestor et al., 1990; Myles-Worsley et al., 1991).

In addition to studies of attention, neuropsychological investigations in schizophrenia have led to the identification of possible abnormalities in other cognitive domains such as executive function (Goldberg et al., 1987; Goldberg and Weinberger, 1988) and memory (Saykin et al., 1991). The exact relationship between attentional impairment on one hand, and executive function and memory performance on the other, remains a contentious issue. For instance, perseverative errors in the Wisconsin Card Sorting Test (WCST) were still found to be increased in schizophrenic patients after attention had been accounted for (Feinberg and McIlvried, 1991). Saykin et al. (1991, 1994) found memory impairment to be disproportionate to impairment of attention, but Kenny and Meltzer (1991) reported that memory deficit could be accounted for by an underlying attentional impairment. There has been few data addressing the relationship between attention and a wider range of neuropsychological performance.

Apart from a theoretical expectation that the ability to focus attention would affect the performance of cognitive tasks, there are empirical reasons to suspect a relationship between attention and neuropsychological impairment in schizophrenia. Like neuropsychological deficits, attentional impairment is found in children genetically at risk for schizophrenia (Rutschmann et al., 1986; Erlenmeyer-Kimling and Cornblatt, 1992) and in first episode medication-naive patients (Saykin et al., 1994). In addition, attention appears to improve with neuroleptic treatment (Strauss et al., 1985; Cohen et al., 1988; Nestor et al., 1991; Serper et al., 1994) but not with cognitive retraining (Benedict and Harris, 1989; Hermanutz and Gestrich, 1991), where any apparent improvement is probably related to the development of a bypassing strategy (Benedict et al., 1994). These characteristics of attentional impairment in schizophrenia coincide strikingly with those reported for neuropsychological deficits and suggest that both might reflect putative developmental vulnerability factor(s). Their potential significance compels a further examination of the relationship between attentional deficit and neuropsychological impairments in schizophrenia.

The way in which attention might be related to neuropsychological performance can be considered within a framework of modularity in the cognitive system (Fodor, 1983; Kosslyn, 1994). In a modular system, cognitive function is conceptualized as consisting of a number of subcomponents (modules). Processing within a module is carried out independently of processing in other modules. In a highly modular system, a disease process can affect one module while sparing others. In contrast, if the system is 'non-modular', interaction between component processes implies that when any part of the system is affected, collateral impairments spread to other areas. It has been suggested that the human cognitive system probably lies somewhere between these two extremes in the sense that there is partial sharing of resources between different modules, but each module also consists of some processes which could be uniquely affected by illness (Kosslyn, 1994). The way in which schizophrenia affects attention, executive function and memory can be considered in this light. If attention, executive function, and memory are considered to be completely modular, they could be independently affected by a disease process, the correlation between performance in these domains is expected to be low. In a non-modular system they are expected to be affected to comparable extents in the same patient, hence impairments in different domains are expected to be highly correlated with one another. In a partially modular system, moderate correlation between impairments in the domains is expected.

Despite a clear need for clarification regarding the relationship between attention and neuropsychological performance, relatively few empirical data are currently available. Most previous studies of sustained attention in schizophrenia have employed various versions of the continuous performance test (CPT), and have tended to focus upon specific issues such as its relationship with symptoms (Cornblatt et al., 1985; Green and Walker, 1986); trait status (Rutschmann et al., 1986; Spring et al., 1989); and medication effects (Strauss et al., 1985; Nestor et al., 1991), etc. Most CPT paradigms involved visual stimulus presentation. In the conventional version of CPT, up to half of the schizophrenic patients may show normal performance (Nuechterlein, 1991). As a result, modified versions with increased cognitive loads, such as the use of identical pair target stimulus (Cornblatt et al., 1989), have been developed. One difficulty with some versions of the CPT is that they are relatively lengthy and demanding, and may as a result limit the amount of concurrent testing that can be carried out for other cognitive domains of interest. In this situation, investigators either have to resort to multi-session assessment or use shorter alternatives in assessment. We have adopted the latter strategy partly because it is possible for neurocognitive performance to fluctuate between sessions (Lezak, 1995), making multi-session assessment less desirable.

From a variety of validated ways of assessing sustained attention, we selected 'monotone counting' as a paradigm of choice because of its relatively short assessment time (around 2 min). This measure of attention (Wilkins et al., 1987) involves the counting of a train of acoustic stimuli presented regularly at a moderate rate (1 Hz). The task is relatively simple and undemanding. In addition, it is efficient because the detection of a lapse of attention does not depend so much upon its coinciding with a stimulus being presented (in contrast to the CPT). Sustained attention deficit as tapped by this task is specifically found in patients with right prefrontal lesions in contrast to left prefrontal or temporal lesions (Wilkins et al., 1987). The monotone counting task is also appealing because it is an auditory task. It is recognized that, although sharing a number of neural resources, sustained attention in the visual and auditory modalities might function independently (Cornblatt et al., 1988), and it has been suggested that sustained attention in the auditory modality is probably of more significance in schizophrenia (Mirsky et al., 1992).

In this study we wished to compare the performance on the monotone counting task between schizophrenic patients and a matched control group, and to identify the way in which monotone counting performance is related to deficits in a wider range of other neuropsychological tasks, including executive and memory tasks.

2. Methods

The study consisted of two parts. In the first part, monotone counting performance in a group of patients was compared with that in a control group matched for age and education. In the second part the relationship between sustained attention and other neuropsychological impairments in schizophrenic patients was explored.

2.1. Subjects

Patients meeting DSM-III-R diagnostic criteria for schizophrenia (American Psychiatric Association, 1987) were recruited from acute and continuing care inpatient facilities covering a defined catchment area in Hong Kong. The age range for inclusion was 16–65 years. Diagnosis was established by information obtained in a clinical interview and review of clinical notes (by one of the first four authors). Patients were carefully screened and those with co-morbidity in substance abuse, organic disorder, mental retardation and a recent history of receiving electro-convulsive therapy (within 2 years) were not included. Patients recruited in this study also took part in a more extensive research programme investigating other aspects of neurocognitive impairments in schizophrenia (Chen et al., 1996a,b).

Control subjects were recruited from healthy volunteers (members of the public as well as colleague) between 16 and 65 years of age. Subjects were screened with a questionnaire (available upon request from authors) and were excluded if they were currently on medication, or if there was a personal history of psychiatric or medical illness, a family history of psychiatric illness, or a history of substance abuse. Ethics committee approval for the project was obtained.

2.2. Assessment of clinical picture

Symptom assessment was carried out with the 18-item Brief Psychiatric Rating Scale (BPRS) (Overall and Gorham, 1962). The BPRS has been successfully used in the Hong Kong Chinese population for assessment of psychopathology (Chan and Lai, 1993). Inter-rater reliability was ascertained by the four investigators rating a further 20 patients. The intraclass correlation (Bartko and Carpenter, 1976) for BPRS items ranges from 0.84 to 0.99. Negative symptoms were assessed using the High Royds Evaluation of Negativity (HEN) (Mortimer et al., 1989). The HEN consists of 18 observer rated items divided into six domains, covering appearance, behavior, speech, thought, affect and functioning. In each of these areas, a global score was also assigned after the rating of individual items. All items were rated along a 5-point scale. The inter-rater reliability for global sum score in the HEN was 0.92. Intraclass correlation for the sub-scales ranged from 0.74 (thought) to 0.85 (speech). Neuroleptic dosages were converted to chlorpromazine equivalent according to Davis (1974). Daily anti-cholinergic dosages were recorded in milligrams (benzhexol was the only anti-cholinergic encountered).

2.3. Assessment of sustained attention

Sustained attention was assessed by asking subjects to silently count regularly paced monotones (adapted from Wilkins et al., 1987). The stimulus consisted of trains of brief pure tones (360 Hz frequency, 250 ms duration) generated at a regular pace of one per second. The stimuli were presented by a loudspeaker adjusted to a comfortable level of loudness for the patient. Subjects were given instruction to silently count the number of tones and report the number at the end of each trial. Twelve trials were conducted in each of which the number of tones varied between 1 and 12 in a randomized order. Accuracy was scored as the number of correct counts out of the 12 trials (maximum 12, minimum 0).

2.4. Assessment of cognitive performance

Semantic fluency was assessed by requesting the patient to name as many exemplars as possible from three categories ('food', 'animal'. and 'furniture') each in 3 min. The responses were tape-recorded and later transcribed for analysis. A total score was calculated by adding up the number of correct items produced for the three categories (repeated items and items clearly outside the category were not counted). Wisconsin Card Sorting test was performed according to standard procedures (Heaton, 1981). Number of perseverative errors was obtained for analysis. Digit Span (forward and backward), Comprehension, Similarity and Information subtests from the Weschler Adult Intelligence Scale WAIS-R-HK (Revised Cantonese Version, Hong Kong Psychological Society, 1989) were carried out according to standard procedures. Scaled scores from these procedures were used in analysis. Logical memory (immediate recall and 30-min delayed recall) and Visual Reproduction (immediate recall) were carried out according to the Weschler Memory Scale-Revised (Weschler, 1987; adapted for Cantonese speaking patients, C.W. Wong, personal communication).

3. Results

3.1. Comparison between patients and controls

Sustained attention performance was compared between the 204 patients (122 male, 82 female; mean age 40.45 years, SD 12.22 years; mean years of education 8.00 years; SD 3.44 years) and 85 controls (38 male, 47 female; mean age 41.96 years, SD 10.99 years; mean years of education 8.31 years, SD 3.46 years) matched for age and the number of years of formal education (unpaired t-tests, non-significant). Overall, the patient group performed significantly worse than the control group (Mann-Whitney U-test; $U=4458$, $W=15\,518$, $Z=-6.45$, $p<0.0001$). The patients exhibited a large range of performance with some performing very poorly, whereas the controls performed at near ceiling level (Fig. 1).

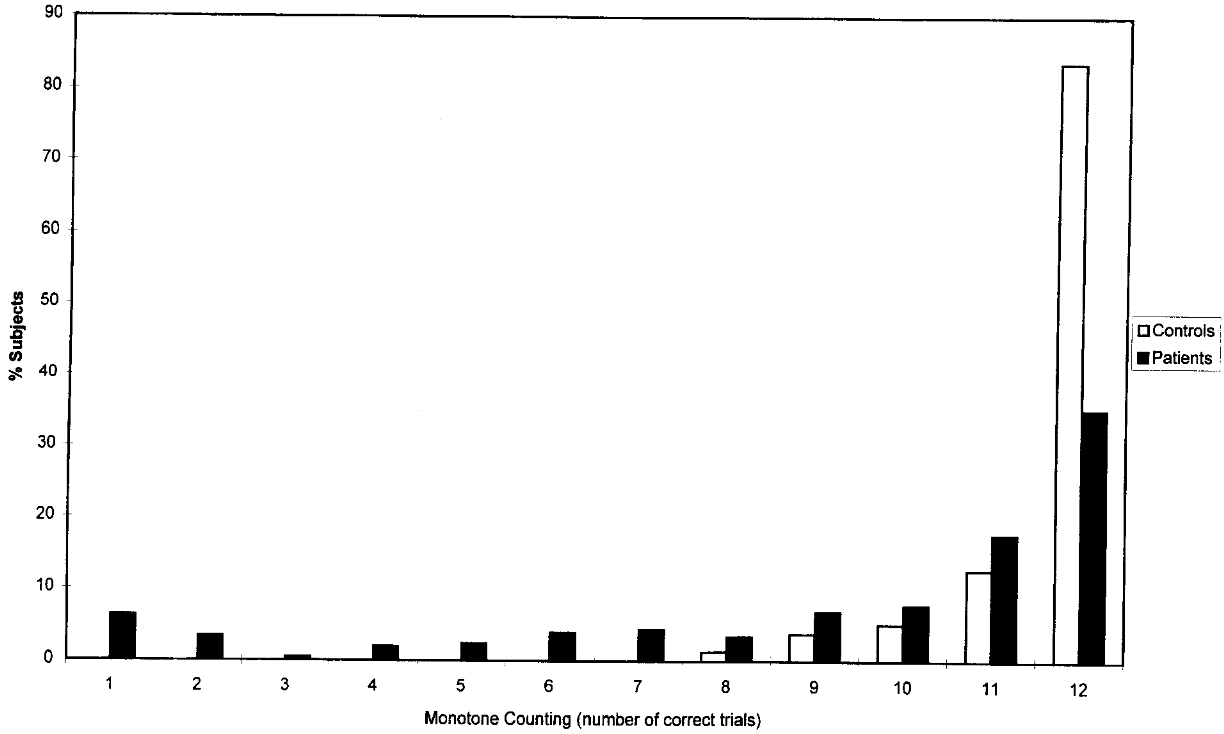

Fig. 1. Monotone counting performance in 204 schizophrenic patients and 85 controls. Frequency histograms showing percentage distribution of subjects over score (number of correct trials out of a maximum of 12).

3.2. *Relationship between sustained attention and neuropsychological deficits*

Correlation between sustained attention performance and other cognitive variables was explored in the patient group. Attention performance was found to be correlated with age (Pearson correlation coefficient −0.31, $p<0.001$), duration of illness (Pearson correlation coefficient −0.27, $p<0.001$), as well as educational level (Pearson correlation coefficient 0.43, $p<0.001$). There was no significant correlation between attention performance and the dosages of anti-psychotic and anti-cholinergic medications.

Further analysis of the relationship between attention, cognitive performance and symptoms was carried out using partial correlation coefficients to control for the effects of age, illness duration and education. Bonferroni correction for multiple comparison was carried out.

Sustained attention impairment was selectively correlated with deficits in a number of cognitive domains (Table 1). These included digit span, information, comprehension, logical memory (immediate recall), and visual reproduction. In contrast, correlation with logical memory (delayed recall), similarity, semantic fluency, and Wisconsin Card Sorting Test errors were not significant.

As a significant proportion of patients did not show abnormality in the sustained attention task, correlation analysis was repeated only for patients who made errors (i.e., scored less than 12) on the task ($n=115$). The results were similar to those reported above for the entire sample, i.e., significant correlations with immediate recall visual memory, digit span, information, comprehension only.

As some of the neuropsychological variables were correlated with one another (Table 2, see below), further analysis was carried out with a multiple linear regression model. A neuropsychological variable was considered in the regression

Table 1
Partial correlation coefficients between monotone counting performance, symptoms and neuropsychological performance in schizophrenic patients, controlling for age, illness duration, and education level

	Correlation coefficient	Significance
Negative BPRS Factor	−0.05	0.49
Positive BPRS Factor	0.16	0.029
Affective BPRS Factor	0.11	0.149
Anxiety BPRS Factor	0.13	0.083
Disorganisation BPRS Factor	0.03	0.711
HEN global	0.02	0.818
Logical memory immediate	**0.24**	**<0.001**
Logical memory delayed	0.18	0.016
WAIS-R-HK Digit span	**0.39**	**<0.001**
WAIS-R-HK Information	**0.29**	**<0.001**
WAIS-R-HK Comprehension	**0.29**	**<0.001**
WAIS-R-HK Similarity	0.04	0.653
Semantic fluency	0.17	0.03
Visual reproduction	**0.37**	**<0.001**
Perseverative errors (WCST)	0.04	0.584

After Bonferroni correction, correlation is significant when $p<0.003$ (significant correlation coefficients shown in bold).

model if its univariate regression on attention performance had a significance level of less than 0.2. This broad inclusion criterion provided a precaution against premature exclusion due to unforeseen interaction among variables (Altman, 1991). Variables were entered into a forward stepwise regression model until further addition produced no significant improvement in the model (at $p=0.05$). The results are shown in Table 3. Variables included in the final regression model were visual reproduction, digit span, and comprehension, respectively.

3.3. *Relationship between attention and symptoms*

Partial correlation coefficients between attention and symptoms were analyzed in several ways. Individual items from the BPRS were first correlated with attention. No significant correlation emerged with any of the items. Secondly, factor scores from the BPRS were correlated with attention. In our sample the BPRS items segregated into five factors (details reported elsewhere). Factor 1 consisted of negative symptoms (Blunted affect, Motor retardation, Emotional withdrawal). Factor two consisted of positive symptoms (Unusual thought content, Suspiciousness, Hallucinatory behavior). Factor three consisted of affective symptoms (Depressive mood, Guilt feelings). Factor four comprised anxiety symptoms (Tension, Anxiety). Factor 5 was a disorganization factor (Conceptual disorganization, Excitement). None of the factors was significantly correlated with sustained attention (Table 1). In order to investigate the relationship with subgroups within negative symptoms, correlation with HEN subgroup scores (appearance, behavior, speech, thought, affect, functioning) were carried out. Before controlling for age, education and illness duration there was a significant correlation between attention and the 'thought' subscale of the HEN (Pearson correlation coefficient: −0.18, $p=0.014$) and not with other subgroups. This correlation however disappeared when partial correlation controlling for age, education and illness duration was carried out.

3.4. *Relationship between neuropsychological variables*

The pattern of inter-correlation amongst neuropsychological variables is presented in Table 2 (partial correlation coefficients controlling for age, illness duration and education). A factor analysis (principal component analysis with varimax rotation) revealed that the variables segregated into two factors, factor one consisted of most of the cognitive variables apart from logical memory performance, factor two consists of immediate and delay recall in logical memory tests (Table 4). The two factors accounted for 63% of the total variance. Perseverative errors in the WCST was not loaded with either factor.

4. Discussion

Monotone counting has been employed in this study as a simple and portable way of assessing sustained attention. With this method, we studied the relationship between sustained attention and other neuropsychological performance in a large

Table 2
Partial correlation coefficients between cognitive variables controlling for age, illness duration, and education level

	Logical memory		WAIS-R-HK				Semantic fluency	Visual reproduction
	immediate	delayed	Digit span	Information	Comprehension	Similarity		
Logical memory delayed	**0.81** $p=0.000$							
Digit span WAIS-R-HK	**0.26** $p=0.001$	0.20 $p=0.11$						
Information WAIS-R-HK	**0.31** $p=0.000$	**0.29** $p=0.000$	**0.46** $p=0.000$					
Comprehension WAIS-R-HK	**0.45** $p=0.000$	**0.40** $p=0.000$	**0.29** $p=0.000$	**0.57** $p=0.000$				
Similarity WAIS-R-HK	**0.37** $p=0.000$	**0.30** $p=0.000$	**0.32** $p=0.000$	**0.54** $p=0.000$	**0.50** $p=0.000$			
Semantic fluency	**0.28** $p=0.000$	0.21 $p=0.000$	**0.26** $p=0.001$	**0.46** $p=0.000$	**0.46** $p=0.000$	**0.45** $p=0.000$		
Visual reproduction	**0.32** $p=0.000$	**0.31** $p=0.000$	**0.28** $p=0.000$	**0.38** $p=0.000$	**0.31** $p=0.000$	**0.28** $p=0.000$	**0.37** $p=0.000$	
Perseverative errors (WCST)	−0.24 $p=0.002$	−0.23 $p=0.003$	−0.21 $p=0.008$	**−0.25** $p=0.001$	**−0.31** $p=0.000$	**−0.28** $p=0.000$	−0.11 $p=0.181$	−0.07 $p=0.407$

After Bonferroni correction, correlation is significant when $p<0.0013$ (significant correlation coefficients shown in bold).

Table 3
Stepwise forward multiple regression analysis using monotone counting performance as dependent variable

Variable	B	SEB	Beta	t	p
Multiple regression of sustained attention (monotone counting)					
Constant	3.8997	0.6867			
Visual reproduction (WMS-R)	0.1049	0.0254	0.3270	4.13	0.0001
Digit span (WAIS-R-HK)	0.2098	0.0802	0.1980	2.62	0.0097
Comprehension (WAIS-R-HK)	0.2156	0.0838	0.2020	2.57	0.011

Source of variation	DF	Sum of squares	Mean squares	F	p
Regression on visual reproduction	1	510.00	510.00		
Addition of digit span	1	598.21	299.10		
Addition of comprehension	1	644.89	214.96	30.45	<0.0000
Residual	161	1136.35	7.05		
Total	164	1781.24			

Adjusted R^2=0.3500; standard error=2.6500.

Table 4
Factor analysis of cognitive variables: principal component analysis with Varimax rotation

	Factor 1	Factor 2	Eigen value	% variance	Cumulative variance
WAIS-R-HK Information	0.796	0.314			
Visual reproduction	0.726	0.299			
WAIS-R-HK Similarity	0.721	0.362			
WAIS-R-HK Digit span	0.720	0.177			
Semantic fluency	0.719	0.174			
WAIS-R-HK Comprehension	0.713	0.452			
Monotone counting	0.641	0.127	5.249	52.5	52.5
Logical memory delayed	0.196	0.925			
Logical memory immediate	0.276	0.898	1.061	10.6	63.1

group of schizophrenic patients. We found that sustained attention performance was not significantly correlated to positive symptoms, negative symptoms, nor to formal thought disorder. In our study any initial correlation between symptoms and attention performance disappeared after taking steps to control for potential confounding variables such as age, illness duration and education level in deriving the correlation coefficient. This finding supports the notions that attention impairment in schizophrenia cannot be considered as merely secondary to distraction from psychotic symptoms (Gold and Harvey, 1993), nor to lack of motivation as a result of negative symptoms (Green and Walker, 1986).

Although sustained attention may be conceived of as being involved in a wide range of cognitive domains, the present results suggest that sustained attention limits performance in a selective subset of the affected areas of cognitive performance in schizophrenia. Some of the cognitive domains that are most closely associated with sustained attention may have features in common. Digit span and visual reproduction both involve the holding of information for a short time span (in the order of seconds). Digit span involves the holding of verbal information for seconds and is an important reflection of the phonological component of working memory (Hitch, 1984; Baddeley, 1986, 1990). Likewise, visual reproduction involves maintaining an image for seconds and is a measure of the function of visuo-spatial working memory (Baddeley, 1990). Neuropsychological evidence suggests that the phonological and the visuo-spatial working memory components are dissociable (Baddeley, 1990). Our data suggest that deficits in both phonological and visuo-spatial working memory domains are significantly correlated with impairment in sustained attention in schizophrenia. This interpretation is compatible with the observation that both auditory and visual vigilance were correlated with performance in another classic working memory task (the delay response task) and suggests the involvement of the dorsolateral prefrontal system in these deficits (Seidman et al., 1995). The close relationship between attention and working memory is further highlighted by the demonstration that working memory consists of modular 'slave' systems which are primarily concerned with temporary information storage; as well as a 'central executive' which is predominantly attentional in nature (Baddeley, 1993). In this context, the observation that *both* phonological and visuo-spatial working memory impairments were correlated with sustained attention impairment suggests that working memory impairment in schizophrenia probably involves deficits in the central executive component.

In contrast, long-term memory performance (logical memory with delay recall), semantic fluency and Wisconsin Card Sorting Test, were not correlated with attention. This suggests that performance of these tests were possibly constrained by factors other than attention and supports the previous finding the WCST performance does not critically depend on attention (Feinberg and McIlvried, 1991). Although there is a significant bivariate correlation between sustained attention and logical memory (immediate recall), the latter did not emerge as a significant predictor variable in multiple regression analysis. This suggests that the initial bivariate correlation was probably mediated by other variables.

In schizophrenia, impaired activation of the prefrontal cortex has been consistently found in functional imaging studies (Berman et al., 1986, 1988; Weinberger et al., 1988). However, the exact neural substrate involved in various prefrontal tasks have not yet been unanimously agreed upon. Neuroimaging studies of sustained attention have identified involvement of the right mid-prefrontal cortex (Guich et al., 1989; Cohen et al., 1992). This is in agreement with the neuropsychological localization of the monotone counting task (Wilkins et al., 1987). Metabolic rate of the right mid-prefrontal cortex also appears to be low in schizophrenic patients who showed sustained attention impairments (Cohen et al., 1987). On the other hand, the fluency test probably preferentially involves the left prefrontal cortex (Cantor-Graae et al., 1993; Warkentin and Passant, 1993; Vilkki and Holst, 1994). Similarly, during the Wisconsin Card Sorting Test the left dorsolateral prefrontal cortex appears to be more involved (Rezai et al., 1993; Seidman et al., 1994), although there have also been reports of bilateral (Haines et al., 1994), and right (Marenco et al., 1993) prefrontal activation. Specific failure in activation of the left prefrontal cortex during the Wisconsin Card Sorting Test has also been reported in functional neuroimaging studies of schizophrenia (Rubin et al., 1991; Kawasaki et al., 1993). Different lateralization pattern between attention and other prefrontal tasks (fluency and Wisconsin Card Sorting Test) might contribute to the lack of correlation between them. This finding further highlights the need to use a broad range of prefrontal probes with different localization patterns in neuropsychological studies of schizophrenia (Seidman et al., 1995).

One limitation of the monotone counting paradigm is the relative low sensitivity. Although the majority of control subjects performed with no error on the task, a significant proportion of patients (>40%) also exhibit little impairment. Although the sensitivity of the task could probably be increased by raising the difficulty of the task (e.g., by presenting longer trains of stimuli), we believe that the current paradigm is useful in identifying a substantial subgroup of schizophrenic patients in whom significant attentional impairment is clearly present.

The finding of modest correlation between sustained attention and several other cognitive tasks could be considered in the context of weakly modular cognitive systems (Kosslyn, 1994). One important mechanism of interaction between cognitive modules is the sharing of basic neural components. Within this framework, the current finding leads to a suggestion that part of the basic neural system involved in sustained attention is also shared (as rate- or resource-limiting processes) by visuo-spatial and verbal working memory, as well as higher verbal processes, leading to a tendency for these systems to be affected together in schizophrenia. In contrast, the neural systems involved in semantic fluency and the Wisconsin Card Sorting Test appear to be affected separately in the illness. The finding of a significant correlation between selective domains of cognitive performance and sustained attention highlights the need to consider the mediating role of attention in future neurocognitive studies of schizophrenia.

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