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Psychiatry Research 110 (2002) 137–149

PSYCHIATRY RESEARCH

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Attentional control and word inhibition in schizophrenia

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Received 19 July 2000; received in revised form 11 March 2002; accepted 20 March 2002

Abstract

Previous studies have suggested that schizophrenia patients do not utilize contextual information efficiently to modulate attentional performance. The goal of the current study was to compare the utilization of context in modulating responses to irrelevant information on the Stroop task between a group of schizophrenia outpatients and matched controls. A single-trial version of the Stroop task was used to investigate performance on the Stroop task under three expectancy conditions. Eleven schizophrenia outpatients (on and off antipsychotic medication) and sixteen matched controls were tested. The schizophrenia patients showed: (1) augmented facilitation; (2) interference comparable to normals; and (3) normal ability to reduce interference under certain experimental circumstances. Schizophrenia patients were able to utilize contextual information under certain conditions and could modulate the magnitude of irrelevant word interference, although they were not able to overcome the prepotent tendency to read the word during the Stroop task as effectively as normals, which was reflected in greater Stroop facilitation. This suggests that the integrity or impairment of cognitive control functions in schizophrenia is related to the complexity of the context representation required to support that function.

Keywords: Schizophrenia; Stroop task; Expectancy

1. Introduction

Cognitive deficiencies have long been reported in schizophrenia with deficits appearing in multiple domains including memory, attention and language (Bleuler, 1911/1950; Kraepelin, 1919/1971). Inadequate performance, such as associative intrusions in schizophrenia speech, has been attributed mainly to attentional deficits (Cornblatt and Erlenmeyer-Kimling, 1985; Gjerde, 1983; Nuechterlein and Dawson, 1984) and in particular to the patients' inability to inhibit irrelevant words or phrases (Maher, 1983; Manschreck et al., 1988). The study of language processes in schizophrenia has yielded valuable insight into the processes that

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0165-1781/02/$ - see front matter
PII: S0165-1781(02)00100-2

underlie cognitive abnormalities in this psychiatric disorder (Andreasen et al., 1982; Salzinger et al., 1970). In addition, many studies have examined the breakdown of attentional processes in schizophrenia patients using lexical stimuli (Nuechterlein and Dawson, 1984, for review). Although many studies of memory and attention in schizophrenia employ lexical stimuli, only a few have measured the impact of context and expectancy in guiding these processes (Cohen et al., 1999; Cohen and Servan-Schreiber, 1992; Salzinger et al., 1970).

The Stroop task is one test that has employed lexical stimuli to examine attentional inhibition. In the Stroop task, reaction time deficits on color naming are often interpreted as an inability to inhibit the irrelevant lexical stimulus (i.e. color-word). The Stroop task is especially relevant for investigating the ability of schizophrenia patients to utilize context to guide attentional inhibition because healthy subjects show attentional modulation of words in the Stroop task under different expectancy conditions (Tzelgov et al., 1992). The present study investigated the ability of schizophrenia patients to suppress irrelevant word processing under various expectancy conditions of the Stroop task.

1.1. The Stroop effect

The Stroop task (Stroop, 1935) has been employed extensively in studies of word processing (MacLeod, 1991, for a recent review). In this task, subjects are asked to name the ink color of a word and ignore the meaning of the word (e.g. when presented with the word GREEN in red ink, they are supposed to say 'red'). Ink-color-naming is slower on incongruent trials (e.g. GREEN in red ink) than on congruent trials (e.g. RED in red ink) or on neutral trials (e.g. XXX or a non-color word in red ink). That is, the to-be-ignored word interferes with reporting the ink color. With young normals (e.g. college undergraduates) it is usually the case that the interference effect (the reaction time, RT, difference between the neutral and the incongruent conditions) is relatively large and stable, whereas the facilitatory effect (RT difference between the congruent and the neutral conditions) is small and may not reach significance. Although other conventions are sometimes used to measure Stroop effects, they can be problematic to interpret as no baseline or neutral stimulus is employed (Henik, 1996). Some researchers have suggested that the Stroop effect measures the automaticity of word processing (Logan, 1980, 1985; Posner, 1978; Stroop, 1935). Namely, word reading is initiated without intention and occurs in spite of the subject's effort to suppress it.

1.2. Stroop and expectancy effects

Recent work has shown that subjects may reduce the influence of the irrelevant word. Such reductions are dependent upon language proficiency (Tzelgov et al., 1990) and expectations (Tzelgov et al., 1992). In order to study the effect of expectancy, Tzelgov and his colleagues (Tzelgov et al., 1992) manipulated the proportion of neutral trials in order to induce different expectations as to the forthcoming stimulus. They reasoned that if subjects could suppress reading the irrelevant words, they should be in a better position to do so when a large proportion of words required application of such suppression. Tzelgov and his colleagues found that the greater the proportion of color words (relative to neutral words) in a block of trials, the smaller the interference effect. Interestingly, this manipulation affected interference but did not affect facilitation. It is important to note that the neutral proportion effect does not influence performance in the Stroop task through supplying different opportunities to practice the suppression of the irrelevant word. Instead, modulation of the Stroop effect is achieved by creating expectations, which in turn induce subjects to modulate their attentional resources (Tzelgov et al., 1992). In addition, these findings demonstrated that performance on the Stroop task could be dissociated into two distinct components with only one component (i.e. interference) being affected by strategies. The other component producing facilitation was not affected by expectancy and appears to be automatic or reflexive.

1.3. Stroop effect and schizophrenia

Attentional deficits in schizophrenia patients are thought to be reflected in a decreased ability to

select the appropriate dimension of a stimulus and to inhibit the irrelevant dimension. Since the suppression of the content of the irrelevant word is essential for efficient performance on the Stroop task, this task has been employed in many studies that examine attentional processing in schizophrenia patients. Most researchers have measured the interference component and predicted that it would be larger for schizophrenia patients compared to controls. The results, however, as discussed in greater detail below, were not always consistent.

Several investigators have used the serial version of the Stroop task (Abramczyk et al., 1983; Buchanan et al., 1994; Everett et al., 1989; Golden, 1976; Mirsky et al., 1984; Schwartz and Shagass, 1960; Wapner and Krus, 1960; Wysocki and Sweet, 1985). Most studies reported that schizophrenia patients exhibited slower color naming both on incongruent and neutral cards compared to controls, but did not test directly the interference effect (i.e. the difference between incongruent and neutral cards). However, two studies (Abramczyk et al., 1983; Buchanan et al., 1994) tested the interference effect directly and reported a significant difference in the predicted direction (i.e. increased interference in the schizophrenia patients).

Carter and colleagues (Carter et al., 1992) employed the single-trial version of the Stroop task with unmedicated patients and found a different pattern of results. Schizophrenia patients showed augmented facilitation but no difference in interference compared to control subjects. Later Carter and his colleagues (Carter et al., 1993), also with unmedicated patients, found that the augmented facilitation characterized an undifferentiated subtype of the disorder whereas interference characterized a paranoid subtype. In a number of recent studies that used the single-trial version (Salo et al., 1996, 1997; Taylor et al., 1996), no difference in Stroop interference between schizophrenia patients and normal controls was found.

The various studies mentioned above differed in methods, instructions, and general design so that various aspects of the task and experimental design may be responsible for differences among these studies. In most of the single-trial studies cited above, equal proportions of the Stroop wordtypes were employed. This balanced design eliminated the possibility that the subjects had any expectancy about which word type would appear on the next trial.

When such a balanced design was employed, equivalent RT interference was found between schizophrenia patients and matched controls. Other studies have manipulated expectancy or contextual situations in non-Stroop tasks by changing the inter-stimulus interval (ISI) between trials. On a visual continuous performance task, Cohen and Servan-Schreiber (1992) found that at longer ISIs, the performance of the schizophrenia patients suffered compared to matched controls. Their interpretation of this finding was that the context that guided performance on the subsequent trial was no longer available to the schizophrenia patient. This finding of a performance deficit at longer delays has also been reported using an auditory continuous performance task (Cohen et al., 1988) and a lexical disambiguation task (Cohen and Servan-Schreiber, 1992; Salzinger et al., 1970). Because the ability to use expectancy in schizophrenia patients has been studied in large part by manipulating temporal distance between trials, we were interested in examining whether or not patients with schizophrenia could take advantage of other contextual information such as the proportion of neutral or control conditions (Tzelgov et al., 1992).

1.4. Rationale

The goals of the present study are (1) to investigate the effects of expectancy and attentional control on Stroop facilitation and interference; (2) to compare the utilization of context to modulate attention between schizophrenia patients and matched controls; and (3) to test the effects of neuroleptic medication on attentional modulation. Previous studies with healthy college aged subjects (Tzelgov et al., 1992, 1990) have shown that expectancy, generated by manipulation of proportions of neutral trials, could help subjects reduce the Stroop effect. Accordingly, we manipulated the proportion of neutral trials relative to the proportion of congruent and incongruent trials (the number of congruent and incongruent trials was always

Table 1
Demographic characteristics of subjects

	Patients	Controls
N	11	16
Age, mean (S.D.)	32.09 (±4.0)	31.69 (±4.45)
Gender		
Male	9	13
Female	2	3
Chronicity (years since onset)	11 (±5.62)	
Parental level of education (in years)	15.2 (±3.5)	13.2 (±2.4)

equal). We hypothesized that control subjects would show greater interference under larger proportions of neutral trials in conjunction with no change in facilitation. A similar effect for the schizophrenia patients would document their ability to utilize contextual information (% of neutrals) and to control inhibition of word processing in a normal way. As mentioned previously, there is evidence that the facilitatory and the interference components of the Stroop effect are dissociable (MacLeod, 1991; Tzelgov et al., 1992). Thus, we expected the effect of neutral proportion manipulations to be limited to the interference component of the Stroop effect in both the schizophrenia patients and the matched controls.

2. Experiment 1A (session 1)

2.1. Subjects

The schizophrenia group consisted of 11 outpatients (9 men, 2 women) from the Department of Psychiatry at the University of California at Davis. Diagnoses were made using the Structured Clinical Interview for DSM-III-R (Spitzer and Williams, 1987). Five patients met criteria for the paranoid subtype of the disorder, and six patients met the criteria for the undifferentiated subtype. Patients had been ill for a mean period of 11 (S.D.=5.62) years. Patients were tested on two occasions. In the first session (Exp 1A), the patients were all receiving doses of antipsychotic medication (Table 1). In the second session (Exp 1B), all 11 patients had been withdrawn from antipsychotic medication for at least two weeks as part of a clinical drug study. They continued to use anticholinergic medication during the washout period.

The control group consisted of 16 subjects recruited by advertisement. The control subjects had no lifetime history of neurological or mental disorder or first-degree family history of psychotic disorder, as determined by a semistructured interview (UCD Department of Psychiatry Control Screening Questionnaire). The control subjects were matched to patients on age (patients: mean=32.09 years, S.D.=4.0 years; control subjects: mean=31.69 years, S.D.=4.45 years) and years of parents' education (patients: mean=15.18 years, S.D.=3.54 years; control subjects: mean=13.19 years, S.D.=2.4 years).

2.2. Stimuli

Four colors and their associated color names were presented: blue, green, red and yellow. Each letter within the stimulus words was upper case and subtended 1° vertically and approximately 0.7° horizontally. The width of the stimulus display varied as a function of the word presented (range three to six letters). There were three types of Stroop stimuli: congruent (e.g. RED in red ink), neutral (e.g. TIGER in red ink), and incongruent (e.g. BLUE in red ink). The number of letters in the neutral stimuli varied between three and six to match the number of letters in the color words. There were four different congruent stimuli, four different neutral stimuli (TIGER, BEAR, DOG, MONKEY) and 12 different incongruent stimuli. Each type of stimulus was repeated several times in a given block.

There were three blocks of randomly ordered trials, each one composed of 192 stimuli. One block had 25% neutral trials (48 neutral, 72 congruent, and 72 incongruent trials), a second block had 50% neutral trials (96 neutral, 48 congruent, and 48 incongruent trials), and a third block had 75% neutral trials (144 neutral, 24 congruent, and 24 incongruent trials). Three additional blocks of 32 trials each, consisting of the same proportions of the three conditions, served for practice. For all subjects, the 50% neutral block was run first with the 25% neutral, or 75% neutral blocks counterbalanced across subjects to come either second or third.

2.3. Apparatus

Stimuli were presented on a 14-inch HP color monitor. Stimulus presentation and data collection were controlled by an HP 286 Vectra computer. Vocal responses were recorded via a Gerbrand voice-operated relay (Model G1341T) interfaced to the computer.

2.4. Design

The independent variables were: congruency (congruent, neutral, or incongruent), neutral proportion (25, 50, or 75%), and group (patients or controls). These first two variables were manipulated within subjects. Reaction time was measured in milliseconds (ms) from target onset to the onset of the subject's vocal response. Errors were also recorded.

2.5. Procedure

Each trial began with the appearance of the stimulus, which remained in view until the subject's vocal response. The subject's response terminated the stimulus presentation. The experimenter keyed in the subject's response using four keys on the computer keyboard, and this keypress initiated presentation of the next stimulus. The next stimulus was presented 1500 ms after the response. Subjects were run individually in a 35–40 min session. Each experimental block (with a given neutral proportion) was preceded by an appropriate practice block of trials and there was a short break in the middle of the experimental block of trials. Subjects were asked to respond as quickly as possible and to refrain from making too many errors.

2.6. Statistical analysis

For every subject in every condition, percent errors and median reaction times (RT) in milliseconds (ms) were computed for correct responses in each condition. A mixed model analysis of variance (ANOVA) was applied to these data. Interactions between variables were further analyzed. In Section 2.2 we present the F value, mean square error (MSe), and P value for every significant effect.

2.7. Results

Median RTs were subjected to a $2\times3\times3$ mixed model ANOVA, group (schizophrenia, control), congruency (congruent, neutral, incongruent), and neutral proportion (25, 50, and 75%). The schizophrenia patients responded more slowly than the control subjects [$F(1,25)=6.97$, MSe = 188, 375, $P<0.025$] and there was a significant difference among the three congruency conditions [$F(2,50)=77.4$, MSe = 5945, $P<0.001$]. The interaction between neutral proportion and congruency was also significant [$F(4,100)=2.47$, MSe = 1258, $P<0.05$]. In addition, the interaction of group and congruency approached significance [$F(2,50)=2.77$, MSe = 5945, $P=0.07$]. Moreover, the triple interaction between neutral proportion, congruency, and group was also significant [$F(4,100)=3.03$, MSe = 1258, $P<0.025$]. Median RTs as a function of experimental condition and subject group are presented in Table 2.

Interference and facilitation relevant to the triple interaction are depicted in Fig. 1. As can be seen, the medicated schizophrenia patients showed larger facilitation than the control group, while there was no significant difference in interference between the two groups. We performed separate analyses for the interference and the facilitation components of the task. These two analyses were similar to the previous analysis except that the congruency var-

Table 2
Median reaction times in milliseconds (first line) and percent errors (second line) as a a function of congruency, neutral proportion, and group in Experiment 1A

Congruency	Congruent	Neutral	Incongruent	Interference	Facilitation
Controls					
25% Neutrals	609	638	702	64	29
	0.81	1.25	6.44	5.19	0.44
50% Neutrals	628	655	775	120	27
	1.13	2.0	6.25	4.25	0.87
75% Neutrals	615	635	762	127	20
	1.5	1.56	8.94	7.38	0.06
Mean	617	643	746	103	26
Medicated schizophrenia patients					
25% Neutrals	746	805	917	112	59
	2.18	4.09	10.91	7.5	3.14
50% Neutrals	743	827	945	118	84
	1.82	3.18	13.64	8.41	2.51
75% Neutrals	709	790	872	82	81
	1.45	3.91	13.36	8.64	2.68
Mean	733	807	911	104	75

iable was now composed of two levels: incongruent and neutral for interference and congruent and neutral for facilitation. We are aware of the fact that tests of Stroop facilitation and interference are not statistically independent. Nevertheless, we performed these tests because of their theoretical importance.

The two-way interaction between neutral proportion and congruency (neutral vs. incongruent) failed to reach significance [$F(2,50) = 2.30$, MSe =

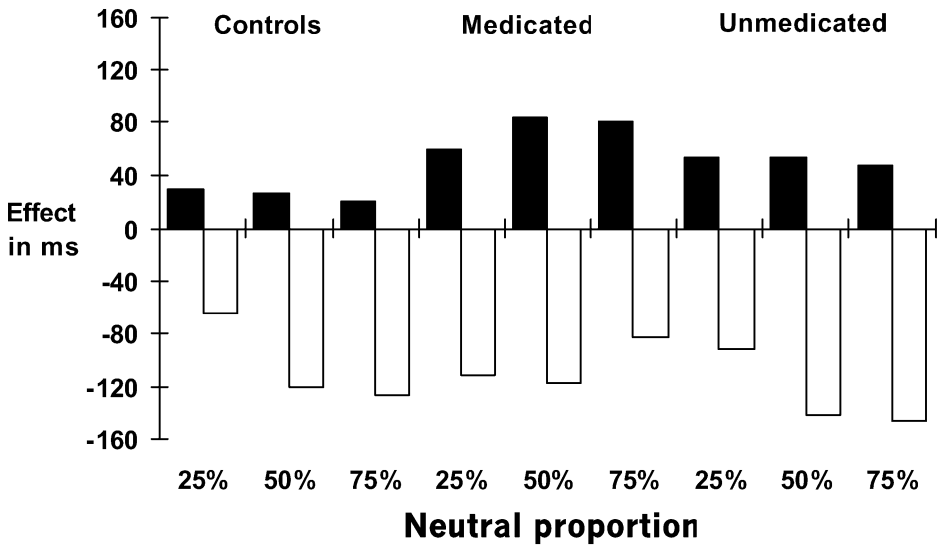

Fig. 1. Facilitation (dark bars) and interference (white bars) in milliseconds as a function of group and neutral proportion. Facilitation is calculated as the difference between the median RT on congruent trials and the median RT on neutral trials. Interference is calculated as the difference between the median RT on incongruent trials and the median RT on neutral trials.

1506, $P=0.109$], the triple interaction of congruency, neutral proportion, and group did [$F(2,50)=4.71$, MSe = 1506, $P=0.01$]. To reveal the source of this interaction, we examined the difference in interference between the patients and controls under each of the three neutral proportions separately. The two groups showed similar interference effects in all three neutral conditions: (1) 25% neutrals [$F(1,25)=2.75$, MSe = 2692, $P=0.11$]; (2) 50% neutrals ($F<1$); and (3) 75% neutral condition [$F(1,25)=1.98$, MSe = 3353, $P=0.17$]. Although the planned comparisons of interference effects in the schizophrenia and control groups did not differ statistically between the three neutral conditions, we carried out a post hoc analysis to examine further the source of the significant triple interaction. Although the 11 medicated schizophrenia patients showed a smaller interference under the 75% neutrals condition (82 ms) than under the 50% neutrals condition (118 ms), the difference did not reach statistical levels [$F(1,10)=1.49$, MSe = 2398, $P>0.05$]. For the 75% neutral condition the control subjects showed no significant increase in interference relative to 50% neutrals (interference effects were 127 and 120 ms for the 75% neutrals and 50% neutrals, respectively, $F<1$).

The two-way interaction between congruency (congruent vs. neutral) and group was significant [$F(1,25)=10.6$, MSe = 2135, $P<0.01$]. The schizophrenia patients showed an enlarged facilitation effect of 75 ms compared with a facilitation effect of 26 ms in the control subjects. No other interaction was significant.

2.7.1. Error rates

For every subject in every condition, the error percentage was computed. A mixed model ANOVA revealed that the medicated schizophrenia patients made more errors (6.06%) than the control subjects (3.32%) [$F(1,25)=4.49$, MSe = 96, $P<0.05$]. There was a significant congruency effect [$F(2,50)=46.66$, MSe = 33, $P<0.001$] as well as a significant interaction between group and congruency [$F(2,50)=3.64$, MSe = 33, $P<0.05$]. For the control subjects the error rates were 1.15, 1.60, and 7.21% for the congruent, neutral, and incongruent conditions, respectively. For the schizophrenia patients the error rates were 1.82, 3.73, and 12.64% for the congruent, neutral, and incongruent conditions, respectively. Additional analyses revealed that error rate facilitation (congruent vs. neutral) was significant in the medicated schizophrenia group [$F(1,10)=7.30$, MSe = 8.24, $P<0.02$] but not in the control group [$F(1,15)=1.63$, MSe = 3.09, $P>0.20$]. In contrast, the error rate interference was significant in both groups [control: $F(1,15)=23.17$, MSe = 32.54, $P<0.001$; schizophrenia: $F(1,10)=26.49$, MSe = 49.44, $P<0.001$]. The difference in error-rate interference between the two groups of subjects was not significant [$F(1,25)=2.72$, MSe = 39.30, $P>0.05$].

2.8. Discussion

The lack of enlarged interference in the medicated patients is consistent with the findings reported by Carter et al. (1992) and others (Salo et al., 1996, 1997; Taylor et al., 1996). The results of this experiment revealed that RT interference in both the control subjects and the medicated schizophrenia patients was influenced by neutral proportion, but in different ways. Interference in the control subjects was significantly larger in the 75 and 50% neutral conditions than in the 25% neutral condition. The schizophrenia patients showed a similar pattern for the 50% neutral condition, but exhibited less interference under the 75% neutral condition, although this difference did not reach statistical significance. The pattern of reduced interference effect presented by the medicated patients under the 75% neutral condition is not statistically significant and problematic to interpret. One hypothesis for the pattern of results in the 75% neutral condition is that the medicated schizophrenia patients are not taking advantage of the probability introduced by the different neutral proportions to modulate their attention in the same way as the controls.

Although, compared to control subjects, the schizophrenia patients showed an increased facilitation for both RT and errors, there was no interaction between neutral proportion and facilitation in either group for either RT or errors. It could be argued that the augmented facilitation shown by the patients in the medicated condition

Table 3
Median reaction times in ms (first line) and percent errors (second line) as a function of congruency and neutral proportion in Experiment 1B

Congruency	Congruent	Neutral	Incongruent	Interference	Facilitation
Unmedicated schizophrenia patients					
25% Neutrals	747	801	893	92	54
	4.73	4.55	11.36	6.81	−0.18
50% Neutrals	739	792	933	141	53
	1.27	2.82	11.09	8.27	1.55
75% Neutrals	746	794	941	147	48
	3.64	3.73	12.82	9.09	0.09
Mean	744	796	922	126	52

was related to their general slowness. That is, the patients were slower than the control subjects and the facilitation effects were proportional to the general RT level so that the difference in facilitation reflected nothing more than a difference in general RT. If this were true, one would expect not only augmented facilitation, but also enlarged interference, and this did not occur.

3. Experiment 1B

The stimuli, design and data analysis of Experiment 1B were the same as in Experiment 1A except for the order of the three neutral proportion conditions. There were three neutral proportion orders, created by a Latin square design: 75, 25 and 50%; 25, 50 and 75%; 50, 75 and 25%. The first order was administered to three subjects and the other two to four subjects each. In this session the schizophrenia patients were tested in an unmedicated state. The 11 patients had been withdrawn from antipsychotic medication for at least two weeks as part of a clinical drug study.

3.1. Results

The antipsychotic-withdrawn schizophrenia patients responded more slowly than the control group [$F(1,25)=11.65$, MSe$=116313$, $P<0.005$] and there was a significant difference among the three congruency conditions [$F(2,50)=84.72$, MSe$=5896$, $P<0.001$]. The triple interaction between neutral proportion, congruency and group was not significant ($F<1$). However, the two-way interaction between neutral proportion and congruency was significant [$F(4,100)=6.12$, MSe$=$ 1361, $P<0.001$]. Additional analyses showed that neutral proportion still did not influence facilitation ($F<1$) but did influence interference [$F(2,50)=$ 8.17, MSe$=1650$, $P<0.001$]. The interference effects (incongruent minus neutral) were 79, 130 and 147 ms, for 25, 50 and 75% neutral conditions, respectively.

The interaction between group and congruency was not significant [$F(2,50)=2.05$, MSe$=5896$, $P<0.14$]. However, because previously the groups did differ in congruency (in Experiment 1 and results reported in other studies), we analyzed the differences in facilitation and interference between the control and the patient groups (Fig. 1). We found that although the two groups did not differ in interference ($F<1$), they differed significantly in facilitation [$F(1,25)=5.32$, MSe$=1263$, $P<$ 0.05]. The facilitation effects (neutral minus congruent) were 26 and 52 ms for the control and the schizophrenia groups, respectively. Fig. 1 also suggests that the facilitation for the antipsychotic-withdrawn patients was smaller than the facilitation for the medicated group. However, a separate analysis, which analyzed medication as a within-subjects variable, showed that this difference was only marginally significant ($P<0.10$) (Table 3).

3.1.1. Error rates

For every subject in every condition, error percentage was computed. These error rates were subjected to a three-way analysis of variance with group (schizophrenia patients vs. control subjects), neutral proportion, and congruency as the independent variables. The schizophrenia patients

made more errors (6.22%) than the control subjects (3.32%) [$F(1,25)=5.84$, MSe = 84.67, $P<0.025$], and there was a significant congruency effect [$F(2,50)=45.47$, MSe = 28.75, $P<0.001$]. No other main effects or interactions were significant.

3.2. Discussion

The RT analysis showed that augmented facilitation occurred in the schizophrenia patients both with medication and without medication. Although augmented facilitation was observed in both medication states, there was no difference in its magnitude across the different neutral proportion conditions. The antipsychotic-withdrawn patients were able to exploit information on list composition (i.e. proportion of neutral trials) to help them reduce interference, similar to the control subjects. When inhibition of the word was more frequent in a block of trials (25% neutrals), both the antipsychotic-withdrawn patients and the control subjects showed an ability to reduce interference. When inhibition was less frequent (75% neutrals), both groups showed increased interference.

3.2.1. Medicated vs. unmedicated schizophrenia patients

3.2.1.1. RT analyses. Additional analyses were carried out to examine the effects of antipsychotic medication on attentional modulation. To do this, a repeated measures ANOVA was carried out with the 11 schizophrenia subjects who were tested both on neuroleptic medication and then a second time after they had been discontinued from their neuroleptic medication for a two-week period. The results revealed a main effect of congruency (congruent, neutral, and incongruent). No other main effects or interactions were significant.

3.2.1.2. Symptomatology. Additional analyses were carried out to determine if there was a significant relationship between clinical symptomatology (as measured by the Brief Psychiatric Rating Scale (BPRS) and the amount of Stroop interference generated. Analyses revealed that although higher total BPRS symptoms were reported in the schizophrenia patients when they were unmedicated [$t(10)=2.85$; $P=0.02$], there was no evidence of any correlation between Stroop interference and clinical symptomatology as rated by the BPRS ($r=0.09$). The same pattern was observed for the sub-cluster of positive BPRS items [$t(10)=2.18$; $P=0.05$], with patients exhibiting more positive symptomatology in the antipsychotic-withdrawn state compared to the medicated state (Tables 4 and 5).

Table 4
Brief Psychiatric Rating Scale ratings for 11 schizophrenia patients

	Medicated	Unmedicated
BPRS ratings (total)	13 ($\pm$10.6)	24 ($\pm$12.1)
BPRS ratings (positive)	6 ($\pm$4.4)	10 ($\pm$4.7)

3.2.1.3. Error analyses. For every subject in every condition, error percentage was computed. These error rates were subjected to an analysis of variance with medication (on vs. off), neutral proportion, and congruency as the independent variables. There was a significant congruency effect [$F(2,20)=25.23$, MSe = 70.65, $P<0.001$]. No other main effects or interactions were significant.

4. General discussion

This work examined components of the Stroop effect (interference and facilitation) under different expectancy conditions. Compared to control subjects, schizophrenia patients exhibited augmented facilitation whether medicated or unmedicated. Increased facilitation has now been reported a number of times in the literature for the single-trial version of the Stroop task (Carter et al., 1992; Taylor et al., 1996). Several groups have reported a similar effect in priming paradigms for medicated schizophrenia patients. When a target word (e.g. DOG) follows a related prime word (e.g. CAT), responding to the target is faster than when the prime is unrelated (e.g. TABLE). The difference in RT between the related and the unrelated conditions is termed the priming effect. Several investigators (Henik et al., 1995; Kwapil et al., 1990; Manschreck et al., 1988; Spitzer et al., 1993) have

Table 5
Medication and clinical symptomatology for individual patients

Subject ID	Medication	Medicated	Unmedicated
1	Navane	BPRS total = 3 BPRS positive = CGI = 2	BPRS total = 20 BPRS positive = CGI = 4
2	Haldol	BPRS total = 34 BPRS positive = 14 CGI = 4	BPRS total = 47 BPRS positive = 15 CGI = 4
3	Haldol	BPRS total = 2 BPRS positive = 1 CGI = 2	BPRS total = 39 BPRS positive = 15 CGI = 4
4	Prolixin	BPRS total = 29 BPRS positive = 12 CGI = 3	BPRS total = 21 BPRS positive = 13 CGI = 4
6	Remoxipride	BPRS total = 8 BPRS positive = 5 CGI = 3	BPRS total = 40 BPRS positive = 18 CGI = 4
8	Remoxipride	BPRS total = 8 BPRS positive = 4 CGI = 3	BPRS total = 20 BPRS positive = 8 CGI = 3
9	Remoxipride	BPRS total = 20 BPRS positive = 11 CGI = 3	BPRS total = 19 BPRS positive = 8 CGI = 4
11	Haldol	BPRS total = 15 BPRS positive = 9 CGI = 3	BPRS total = 18 BPRS positive = 6 CGI = 4
13	Haldol	BPRS total = 8 BPRS positive = 3 CGI = 3	BPRS total = 12 BPRS positive = 4 CGI = 4
14	Haldol	BPRS total = 7 BPRS positive = 4 CGI = 2	BPRS total = 20 BPRS positive = 10 CGI = 4
16	Haldol	BPRS total = 4 BPRS positive = 3 CGI = 2	BPRS total = 10 BPRS positive = 4 CGI = 3

reported hyper-priming for schizophrenia patients. Spitzer and his colleagues (Spitzer et al., 1994) have suggested that one mechanism that may underlie this effect is increased activation of word representations in the semantic system of schizophrenia patients. The large Stroop facilitation exhibited by schizophrenia patients may also involve abnormal activation in semantic memory. Note, however, that Carter and his colleagues (Carter et al., 1995) have recently reported no association between Stroop facilitation and automatic priming effects. These investigators have proposed that the increased facilitation effect shown by patients and the increased error rates for incongruent trials often seen in schizophrenia patients both reflect a failure of top-down control and an increased influence of the irrelevant dimension of the Stroop stimulus on color-naming performance (Barch et al., 1999). These two theories reflect competing ideas regarding the neural underpinnings of impaired selective attention in schizophrenia, with proponents of the increased spreading activation hypothesis proposing that this reflects a disturbance in posterior and superior temporal cortical function, whereas the 'top-down control' hypothesis suggests a disturbance in a prefrontally based context-processing function.

In contrast with increased facilitation effects in the schizophrenia patients, we found RT interference comparable to that in normal controls, con-

sistent with other studies (Carter et al., 1992; Salo et al., 1996, 1997; Taylor et al., 1996). Note that Perlstein and colleagues (Perlstein et al., 1998), Cohen et al. (1999) and (Barch et al., 1999) also found RT interference comparable to control values, but reported an enlarged error interference in the patients. The current study only found a marginal effect of errors and only in the medicated condition.

4.1. Medication effects and attentional modulation

The present results suggest that antipsychotic medication does not modulate overall levels of interference or facilitation, but it may have an effect on the way in which schizophrenia patients use probabilities or expectancies in an experimental situation. When inhibition of the word was more frequent in a block of trials (25% neutrals), both the unmedicated patients and the control subjects showed an ability to reduce interference. In contrast, when inhibition was less frequent (75% neutrals), the medicated patients showed a pattern of reduced interference. We can only speculate on what this might mean. One possibility is that practice can modulate Stroop effects. Previous studies, however, have systematically examined the effect of practice on reducing Stroop interference and found that it does not account for the effects observed in healthy controls (Tzelgov et al., 1992). In addition, the analysis that directly examined medication as a within-subjects variable did not find any significant group differences. For this reason, we are not advocating this possibility and it should be pointed out that the group differences in interference effects in the 75% neutral condition were only a pattern and did not reach statistical significance. More experiments are needed to resolve this issue.

It has been proposed that schizophrenia patients exhibit generic strategic deficits, or some generic inhibitory deficits. Our results suggest that the former might not be true as the antipsychotic-withdrawn schizophrenia patients were able to exploit the neutral proportion effect to the same degree as controls. Expectations influenced the interference but not the facilitatory component of the Stroop effect.

5. Conclusion

Although many studies have suggested that schizophrenia patients have impaired context processing, the present results suggest that this may be a function of the complexity of the context representation involved. The schizophrenia patients tested in this study were able to reduce Stroop interference as a result of different proportions of neutral trials, suggesting that when the task representation involved merely adjusting the degree to which attention was allocated to word reading or color naming in order to produce a speeded response, they are able to do so. On the other hand, their ability to use context to overcome the prepotent tendency to read the word during the Stroop task was quite impaired, as reflected by their increased facilitation effects. In a previously published semantic priming study (Henik et al., 1995); Henik et al. reported that although schizophrenia patients showed augmented priming effects, they were still able to anticipate and prepare for the upcoming stimuli. Similar to finding in control subjects, the patients' responses were speeded up when the prime to target interval [stimulus onset asynchrony (SOA)] was relatively long. Moreover, under the long SOAs the patients coped better with certain aspects of cognitive load. The SOA effect is similar to the foreperiod effect found in reaction time studies in schizophrenia (Bohannon and Strauss, 1983; Greiffenstein et al., 1981). Thus, at least under certain circumstances, schizophrenia patients are able to maintain task-oriented set and utilize context to prepare for responding. On the other hand Meiran et al. (2000) investigated task switching in schizophrenia patients and concluded that while schizophrenia patients were able to use a preparatory interval in order to update a task set and reduce the magnitude of task-switching RT costs, their overall pattern of performance suggested that they were impaired in representing the task context. In a follow-up experiment these investigators were able to show that increasing the complexity of the task context in normal subjects produced a pattern of performance comparable to that seen in the schizophrenia patients. These results and those of the present study suggest that many control processes that

depend upon relatively simple context representations are intact in schizophrenia but that the ability to represent and maintain more complex task contexts, such as those required to overcome a prepotent response tendency or those that involve a highly complex or unconstrained set of stimulus response mappings, is impaired in this illness.

The present results have implications not only for research on cognitive processes in schizophrenia but possibly also for work on word processing and the Stroop effect in normal cognition. These results may be interpreted as supporting the hypothesis that the facilitatory and interference components are dissociable parts of the task (Henik et al., 1993; Lindsay and Jacoby, 1994; Tzelgov et al., 1992). The data suggest that the facilitatory component of the Stroop task involves early processes, those that are more automatic, operate prior to or at the point of lexical entry and thus are less subject to strategic control. If facilitation were due to processes operating post-lexically (after the word was recognized), it should have been influenced by neutral proportion in the same way that the interference component was. In contrast, interference may be due to post-lexical processes that operate after the word has been recognized.

Finally, we would like to comment on the subtype issue. The current study was not designed to examine the paranoid and the undifferentiated subtypes separately. The number of patients in each subtype was relatively small, limiting the statistical power needed to investigate this issue.

Acknowledgments

This work was carried out while the first author was on sabbatical leave at UC Davis Department of Neurology and the Center for Neuroscience. This work was supported by a Research Scientist Award to L. Robertson by the Veterans Administration and NIMH grant MH46990 to Thomas Nordahl.

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