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Is filtering difficulty the basis of attentional deficits in schizophrenia?

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Abstract

The distractibility that schizophrenia patients display may be the result of a deficiency in filtering out irrelevant information. The aim of the current study was to assess whether patients with schizophrenia exhibit greater difficulty when task-irrelevant features change compared to healthy participants. Thirteen medicated outpatients with a diagnosis of schizophrenia and thirteen age- and parental education-matched controls performed a target selection task in which the task-relevant letter or the task-irrelevant features of color, and/or location repeated or switched. Participants were required to respond by pressing the appropriate key associated with the target letter. These patients with schizophrenia were slower when the task-relevant target letter switched than when it repeated. In contrast, schizophrenia patients performed similarly to controls when task-irrelevant information changed. Thus, we found no evidence that patients with schizophrenia were impaired in inhibiting irrelevant perceptual features. In contrast, changes in task-relevant features were problematic for patients relative to control participants. These results suggest that medicated outpatients who are mild to moderately symptomatic do not exhibit global impairments of feature processing. Instead, impairments are restricted to situations when task-relevant features vary. The current findings also suggest that when a course of action is not implied by an irrelevant feature, outpatients' behavior is not modulated by extraneous visual information any more than in healthy controls.

Keywords: Feature processing; Cognitive control; Attentional inhibition

1. Introduction

The ability to focus attention on relevant information in our environment is critical for responding appropriately to any given situation. One can imagine the confusion that would result if attentional selection were unconstrained. Any novelty or change in our environment would demand attentional resources even if it were irrelevant. Impairments in this process of selecting relevant and suppressing irrelevant information may underlie the behavior exhibited by a subset of out patients with schizophrenia. In particular, those patients who have been characterized as distractible and disorganized may be deficient in filtering out irrelevant information (Bleuler, 1919; Nuechterlein and Dawson,

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1984). In the present paper, we examine how potential deficits in the processing of visual features might contribute to larger impairments in goal-driven behavior exhibited by patients with schizophrenia.

Distractibility in schizophrenia patients may be due to problems in ignoring irrelevant features and/or selecting relevant ones, and this study explores both processes. In regard to task-irrelevant feature processing, many experimental paradigms have been employed to detect the intrusion of irrelevant stimuli in patients with schizophrenia, using both auditorially-presented targets (Wishner and Wahl, 1974; Oltmanns et al., 1978) and visually-presented targets (Carter et al., 1992; Elkins et al., 1992; Cohen et al., 1999). However, in these tasks, response competition was present; that is, the irrelevant information afforded a motor response that could be incompatible with the target response (e.g., flanker and Stroop tasks). Other studies examining the effect of irrelevant stimuli in visual search tasks (see Lubow and Kaplan, 2005 for a review) suffer from the same confound, in that distractor stimuli had previously been targets. Patients with schizophrenia may have trouble inhibiting irrelevant information if it is associated with a potential response (especially if that response is prepotent) but have little difficulty with ignoring information that is not linked to a potential action.

In our task, irrelevant information afforded no response, as these features had never been responded to previously. The results of previous research are inconsistent as to whether schizophrenia patients will have trouble processing completely irrelevant stimuli. For example, schizophrenia patients displayed elevated RTs compared to controls in a visual search task that used novel distractors (Lubow et al., 2000). In contrast, highly schizotypal participants displayed normal RTs for this condition compared to those with low schizotypy (Lubow et al., 2001). An important goal of this study is to assess the inhibition of features that remain irrelevant throughout the entire experiment.

Results are also mixed as to whether schizophrenia is associated with problems in selecting task-relevant stimuli. One stream of research assessed whether patients with schizophrenia have difficulty selecting task-relevant features (Mori et al., 1996; Carr et al., 1998a,b; Alain et al., 2002. Using a variety of search and identification tasks, these studies have collectively reported unimpaired performance for patients with schizophrenia when the target is a single feature, such as color or orientation. These findings suggest that automatic attentional processes, such as the "pop-out effect", are undisturbed in schizophrenia. There is also evidence that more attentionally demanding processes are likewise unimpaired. When targets are defined by the conjunction of two features, patients with schizophrenia display normal decreases in speed of response as set size increases, although they are slower overall than controls (Mori et al., 1996; Carr et al., 1998a,b. Moreover, performance on conjunction search tasks does not appear to be associated with symptomatology (Carr et al., 1998a,b). When asked to respond to a target defined by the conjunction of two features in a continuous performance task, patients with schizophrenia showed a modest and non-significant decrement in speed as well as accuracy compared with control subjects (Alain et al., 2002).

Although attention to task-relevant features appears relatively intact for patients with schizophrenia, other research suggests that responding to switches in task-relevant features may be impaired. For example, in a change detection task in which participants are asked to detect whether colored bars have changed in color and/or orientation, patients were less accurate than controls regardless of whether the change was of a single feature or a conjunction of features (Gold et al., 2003), especially at set sizes that are beyond typical working memory capacity. However, this study has the disadvantage of taxing other processes such as working memory and feedback processing in addition to detecting task-relevant feature switches. In the present study, we will determine whether a simple change of target identity is problematic for patients with schizophrenia in the absence of high working memory demands.

We employed a letter identification task in which relevant and irrelevant features could repeat or switch from the previous trial. Color and location of the letter were always irrelevant to the task of identifying the target letter. All participants should be slower in responding when color and location of the target letter switches, despite the fact that color and location had no relevance for the letter identification task. This effect is thought to occur because memory traces, stored in separate feature maps, prime responses to targets sharing that same feature (Treisman, 1996). If undue attention were paid to irrelevant features, memory traces for these features should be stronger and, therefore, prime responses to a greater degree. Thus, if patients have difficulty suppressing irrelevant information, they should show a greater cost to response speed when irrelevant features switch than control participants. Similarly, if attentional problems are due to selecting relevant features, then switches in the identity of the target letter should be more detrimental for patients than control.

Through this study, we can determine whether schizophrenia is associated with a selective deficit in processing

either task-relevant or irrelevant features. However, it is also possible that both inhibition and selection mechanisms will be impaired. In this case, a more fundamental problem in sensory processing may be at fault. Indeed, several event-related potential studies have reported abnormal sensory processing in schizophrenia patients (Freedman et al., 1991; Alain et al., 2002). For example, healthy adults display reduced auditory evoked potentials to the second of two sounds presented sequentially, whereas patients with schizophrenia show little habituation (Nagamoto et al., 1989). Given this result, Freedman and colleagues have proposed that an inability to discriminate relevant information from a flood of sensory input may underlie many of the symptoms of schizophrenia. Thus, evidence for this claim would be obtained if both task-relevant and irrelevant feature switches were abnormal for schizophrenia patients.

2. Methods

2.1. Participants

Thirteen outpatients with schizophrenia (11 males, 2 females) and thirteen control participants (9 males, 4 females) were tested at the University of California Medical Center in Sacramento and received monetary compensation for their participation. All gave informed consent as approved by internal review before the study began. All patients met diagnostic criteria for chronic schizophrenia according to DSM-IV (1987). Both patients and controls were screened by a board-certified psychiatrist (T.E.N.) using a semi-structured psychiatric interview based on the SCID (Spitzer et al., 1990) at the time of their initial entry into the study and again on the day of cognitive testing. All patients were medicated with a fixed dosage for the four weeks prior to participation in the study, and no anticholinergic medications or short-acting benzodiazapenes were taken within 48 h prior to testing. Patients and control participants were screened for head injury and none reported substance abuse within the previous year.

Control participants and patients were equivalent in age (see Table 1, t (24)=0.8, $P>0.1$) and years of parental education (t (24)=0.92, $P>0.1$) as a proxy for socioeconomic status (Resnick, 1992). All participants were right-handed and reported normal or corrected to normal vision as well as normal color vision.

2.2. Stimuli

Stimulus displays consisted of two letters presented vertically, and equally spaced from the center of the display monitor (see Fig. 1). The display subtended 2.6 degrees of visual angle vertically with each letter subtending 1 degree at the participants' viewing distance of 54 cm. On each trial, one letter was green and the other red. On every trial, both a target letter and a distractor letter were present. The stimulus set included two targets (i.e., H and S) and two distractors (i.e., F and P).

Table 1
Demographic and clinical data for patients diagnosed with schizophrenia and control participants

Subject	Age	Parental edu.	Subject edu.	Age of onset	BPRS *	Medications
Patient 1	42	12	16	31	4	Quetiapine
Patient 2	53	10.5	13	41	6	Thioridazine
Patient 3	24	12	12	20	11	Sertindole
Patient 4	36	5	12	9	11	Sertindole
Patient 5	34	12	13	20	0	Sertindole
Patient 6	36	18	16	28	13	Sertindole
Patient 7	28	18	13	15		Sertindole
Patient 8	35	14	15	21		Clozapine
Patient 9	35	15	13	24		Clozapine
Patient 10	40	16	14	25	20	Haloperidol
Patient 11	40	10.5	13	31	29	Haloperidol
Patient 12	41	10	14	22	6	Sertindole
Patient 13	26	18.5	16	17	2	Aripiprazole
Patient mean (S.D.)	36.15 (7.61)	13.19 (3.9)	13.8 (1.46)	23.4 (8.16)	10.2 (8.84)	
Control mean (S.D.)	33.69 (7.89)	14.38 (2.59)	14.77 (1.83)			

* A score of 0 indicated no symptoms.

2.3. Procedure

Participants were seated in a dimly lit room in front of the display monitor with their head position maintained by a chin rest. Each trial began with a 500-ms tone immediately followed by a 100-ms presentation of the letter display. Participants identified which of the two target letters was present by responding with their index finger of their dominant hand using a joystick with two buttons. The letter H was mapped to the left button and the letter S to the right button. After stimulus presentation, a 400-ms interval elapsed before the onset of the next alerting tone resulting in an inter-stimulus interval of one second.

Participants were informed that the color and location of the target and distractor letters could change across trials but that these changes were irrelevant and should be ignored. Their task was solely to determine the identity of the target letter that was present on each trial, and to press the button that corresponded to that target letter as rapidly and accurately as possible. One of the

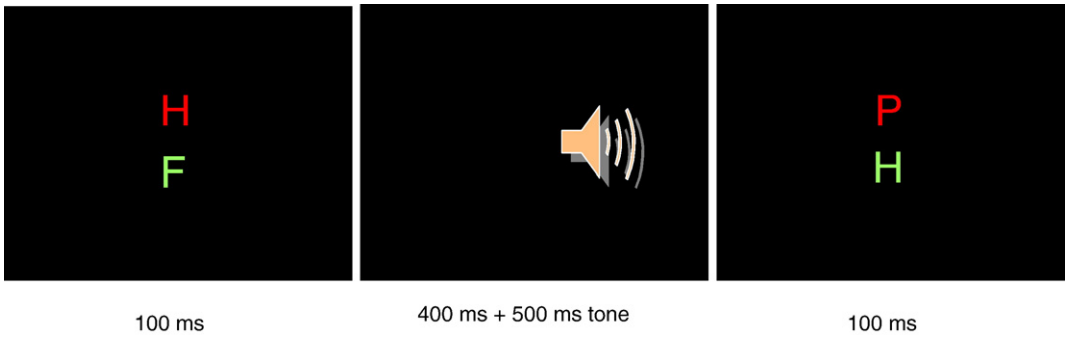

Fig. 1. An example of the stimulus display. See the website for a color version of this figure.

two pre-designated targets was presented on every trial. The experiment consisted of 256 trials presented randomly with the restriction that there be an equal numbers of repetitions and switches of target letter, color, and location. A practice block of 32 trials was performed before the experimental session began.

2.4. Data analyses

In all the analyses using reaction time (RT) as the dependent variable, only correct responses were included in the calculation of the mean. A correct response is defined as responding with the key assigned to the particular target letter. Moreover, trials were discarded when RT was greater than 3 standard deviations above or below a given participants' average speed. In measuring accuracy (correct/[correct+errors]), null responses were discarded so that by "errors", we mean errors of commission (e.g., an error is defined as responding with the wrong key rather than simply not responding). Null response trials constituted between 0 and 3% of the total trials in the experiment and, on average, the number of trials discarded was less than 1% for both patients and control participants. For each type of switch, letter, color, or location, we analyzed only the trials where the feature of interest changed, but the other two did not. For example, to assess the effect of color repetitions, we only examined trials where location and target letter remained constant.

3. Results

3.1. Task-relevant feature switch — target letter

Before examining the effects of task-irrelevant features, we assessed patients' performance when the task-relevant feature – target letter – repeated or switched. A 2×2 mixed factor ANOVA was performed on the reaction time data using group as the between-subject factor and trial repetition as the within-subject factor. Both main effects were significant and indicated that all participants were slower to identify the letter when its identity switched ($F(1, 24)=29.17$, $P<0.001$) and that patients were slower in general than controls ($F(1, 24)=8.56$, $P<0.01$) (see Fig. 2). The interaction effect was also significant ($F(1, 24)=5.18$, $P<0.05$) and indicated that patients were more affected by a change in the target letter than controls.

Both groups were equally accurate overall (controls=94.6%, patients=95.1%). A 2 (group)×2 (switch) mixed factor revealed no main effect of group nor a group×switch interaction effect upon accuracy.

3.2. Task-irrelevant feature switch — color

In order to assess task-irrelevant feature changes in isolation, we used only trials where the target letter repeated from the previous trial. Thus, these analyses

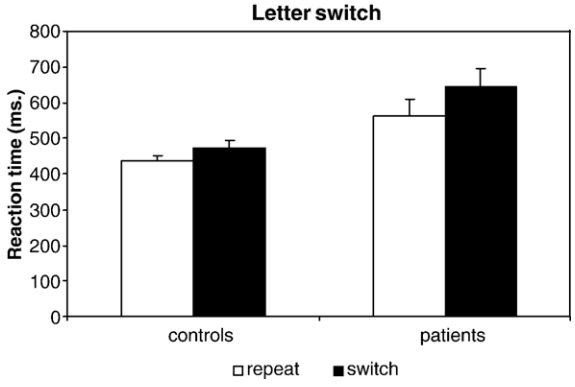

Fig. 2. Mean reaction times (ms.) and variance (SEM) to letter repetitions and switches for patients and controls. Target switching costs (RT switch–RT repeat) is significantly greater for patients that controls.

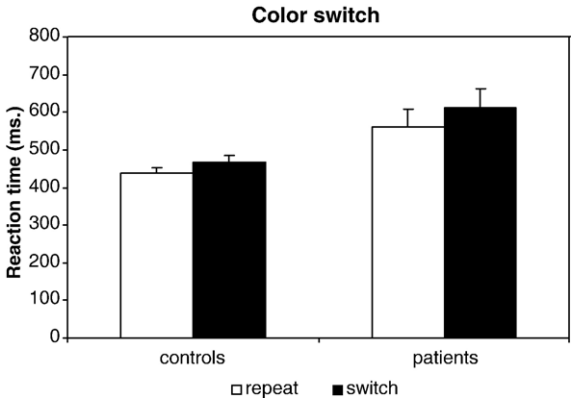

Fig. 3. Mean reaction times (ms.) and variance (SEM) to color repetitions and switches for patients and controls. Color switching costs were equivalent between patients and controls.

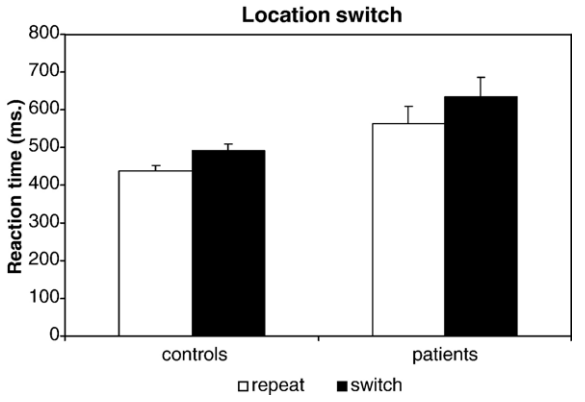

Fig. 4. Mean reaction times (ms.) and variance (SEM) to location repetitions and switches for patients and controls. Location switching costs were equivalent between patients and controls.

focus on the effects of a color switch without a change in the identity of the target letter. A 2 (group) × 2 (color switching) mixed factor ANOVA was performed on the RT data (see Fig. 3). Both main effects (group: F (1, 24) = 7.18, P < 0.05; switching: F (1, 24) = 23.94, P < 0.001) were significant, but a significant interaction effect was not observed (F (1, 24) = 1.92, P > 0.1).

Similar to our findings for accuracy when the target letter switched, there was no main effect of group nor an interaction effect of group and color.

3.3. Task-irrelevant feature switch — location

These analyses also examine location switches only in the context of a target letter repetition (see Fig. 4). A 2 (group) × 2 (location switch) mixed factor ANOVA produced two significant main effects (group: F (1, 24) = 6.54, P < 0.05; switching: F (1, 24) = 52.81, P < 0.001) and no interaction effect (F (1, 24) = 0.98, P > 0.1) (see Table 2).

There was no main effect of group on accuracy nor an interaction effect (P > 0.1) (see Table 2).

3.4. Additive effects of irrelevant feature switches

To assess whether a switch of both task-irrelevant features affected patients more than controls, we examined trials where the target letter stayed the same but both the color and location switched. A switch × group ANOVA with reaction time did not produce a significant interaction effect (F (1, 24) = 2.61, P > 0.1). Moreover, patients were not significantly impaired when all features switched compared to when only the task-relevant feature switched identity (switch × group: (F (1, 24) = 3.02, P = 0.095). Thus, changes in task-irrelevant features did not affect speed over and above switches in the relevant target.

3.5. Clinical ratings

The Brief Psychiatric Rating Scale (BPRS; Overall and Gorham, 1962) was used to measure the severity of clinical symptoms for 10 out of the 13 patients on the day of cognitive testing. These ratings were collected for those patients that were participating in another study that day. When we performed a correlation analysis using the total score on this measure and the costs of target, color, and location switching, we observed a significant positive relationship between symptom severity (total score) and switch cost on the task-relevant dimension (letter: r (10) = 0.73, P = 0.017), but not on the irrelevant dimensions (color = 0.13, location = 0.04, P > 0.1) (see Fig. 5). Note that if we use the Bonferroni procedure to correct for multiple comparisons by dividing the standard P-value of 0.05 by the number of correlations performed (N = 3), the association between symptoms and target switching speed remains significant (e.g., 0.05/3 = 0.017). Response speed, in general, showed only a weak relationship to symptom severity (r (10) = 0.1, P > 0.1) suggesting that the correlation of symptomatology was selective to task-

Table 2
Accuracy for schizophrenia patients and control participants in each switch condition

Switch type	None	Target letter	Color	Location
Patients	0.97	0.94	0.97	0.95
Controls	0.96	0.96	0.95	0.93

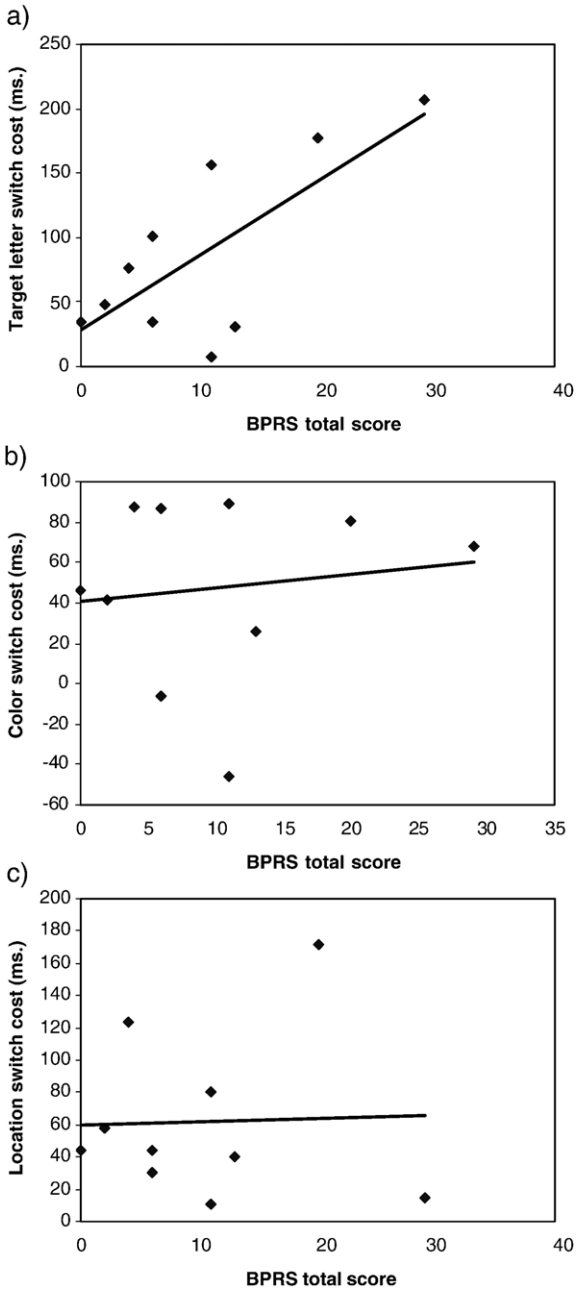

Fig. 5. Association between BPRS total score and a) letter, b) color, and c) location switching costs. Symptom severity was significantly related only to letter switch costs.

relevant feature switching rather than indicative of an overall slowing.

4. Discussion

Patients with schizophrenia often appear to be distracted by tangential thoughts or objects in their environment (Nuechterlein and Dawson, 1984). Our goal was to assess whether a fundamental deficit in attention for stimulus features could be one source of their difficulty. We found that a diagnosis of schizophrenia was associated with relatively greater slowing when the target letter switched identity, whereas task-irrelevant feature changes in color and location were responded to equivalently by those with and without schizophrenia. Moreover, the severity of clinical symptoms was related to switching scores for task-relevant features, but not for irrelevant features. Thus, we found little evidence to suggest that clinical symptoms of schizophrenia are the result of an inability to suppress task-irrelevant features. Instead, symptoms of schizophrenia such as distractibility may be related to deficits in processing changes of task-relevant information.

The diminished performance observed for schizophrenia patients when changes in task-relevant information occurred is unlikely to be due to a generalized deficit. A generalized deficit across all tasks would predict that patients with schizophrenia would show an impairment on the most difficult task which, in our experiment, was identifying the letter when it switched location. For control participants, the task of specifying the identity of the target letter was less affected by switches in the target letter than by changes in the location of the letter. Location switches for controls resulted in a slowing of reaction time by 55 ms compared to a slowing of only 34 ms for letter switches. Despite the greater difficulty of location switches for controls, patients showed comparable switch costs to controls when location switched.

Although it is unlikely that our results are due to a generalized deficit, our claim that irrelevant feature processing is intact in schizophrenia warrants some caution given that it is based on a negative finding. A stronger case for our argument would be a significant interaction between group and the relevancy of the target (Group × Relevancy). If we compare the RT and accuracy for trials when the relevant target letter switches to switches of irrelevant features (collapsed across color and location), the interactions are not significant (RT: F (1, 24)=2.97, P=0.097; accuracy=F (1, 24)=3.49, P=0.074), although there are trends in the predicted direction. For controls, RT is slightly greater when an irrelevant feature switches (478.22 ms) than when the relevant features switches (470.62 ms), but patients showed the opposite pattern of performance (irrelevant=622.75 ms; relevant=644.63). The same pattern holds true for accuracy with control participants being more accurate in the relevant versus irrelevant conditions (96% vs.

94%) and a reversal of this trend for patients (94% vs. 96%). Thus, while we find some support for our claim of intact processing for irrelevant features, caution is warranted given the non-significant interaction effects and the relatively small sample size.

In our experiment, participants always identified the letter rather than its color or location, and it is possible that the impairment exhibited by patients with schizophrenia is selective for this feature rather than the fact this feature was task-relevant. In other words, if the task were to identify the stimulus color rather than the letter, would we find that patients were now impaired when color rather than letter switched? We think the answer to this question would be yes as there is little reason to believe that schizophrenia is associated with selective impairments with letter stimuli. For example, letter stimuli were used in two studies of feature search reporting intact performance for patients with schizophrenia (Mori et al., 1996; Carr et al., 1998a,b).

Interestingly, in our experiment, schizophrenia was not associated with performance differences in responding to irrelevant features. Like healthy controls, switching either color or location produced a cost in response time, and a switch in both color and location produced additive costs. Although others have found that patients with schizophrenia have difficulty ignoring irrelevant information, this information is often associated with a potential response. The current findings suggest that when a course of action is not suggested by an irrelevant feature, patients' behavior is not modulated by extraneous visual information any more than in healthy controls.

The attentional deficits of our sample of outpatients with schizophrenia were not due to poor processing of sensory input (Venables, 1964; Freedman et al., 1991; Alain et al., 2002). In general, research demonstrating sensory processing deficits in schizophrenia has been difficult to interpret. In one study, a reduction of evoked potentials (N2 and P3b) and abnormal scalp distributions were reported for schizophrenia patients when identifying features (Alain et al., 2002). It is unclear, however, whether attentional deficits are associated with these abnormal electrical signals as behavioral performance was relatively good on this task for their sample of schizophrenia patients. In other studies, sensory processing is only abnormal under certain conditions. For example, two studies have found evoked potentials and habituation effects between healthy participants and schizophrenia patients to be equivalent at very short intervals (Baribeau-Braun et al., 1983; Nagamoto et al., 1989. The fact that deficits only occur when the time between sounds is longer suggests that fundamental impairments in sensory processing are undisturbed and, instead, promote the view that higher-level processes are influencing behavior. In the same way, we report some evidence suggesting that schizophrenia patients' attentional abilities are not uniformly impaired.

In contrast, our patients with schizophrenia displayed an abnormal pattern of behavior in response to the task-relevant target feature. In other studies of feature integration, schizophrenia patients have been unimpaired when searching for a target defined by a single feature or a conjunction of features. Although patients are slower in finding targets, they show normal effects of increasing set size and proximity (Carr et al., 1998a,b). These studies differ from ours in that the relevant features always stayed the same throughout a block of trials (e.g., a green "S" was always the target; Mori et al., 1996; Alain et al., 2002) or, if there were two potential targets, switching between feature attributes was not analyzed (Carr et al., 1998a,b). Given that others have reported intact performance for targets defined by a predesignated (and, thus, relevant) feature, our findings suggest that selective attention deficits in schizophrenia are primarily associated with distractions induced by variations in relevant features.

Differences in responding to switches of relevant information between patients and controls may be due to impairments in higher-level control processes or basic impairments of feature integration in very short term memory. In the first case, patients may have trouble maintaining information such as which of the four possible letters are the target letters or remembering the key mappings associated with each letter. Retrieving the appropriate information may be more difficult when the letter switches. In the second case, patients may have abnormal strength of feature binding. For instance, the schizophrenia patients may be slower at conjoining features (color and location) to a new shape (letter) producing increased switching costs. Thus when the task requires that subjects explicitly respond to a change of a target (i.e. letter) they are slower compared to controls. Although the feature maps themselves may be intact in patients with schizophrenia, the process of binding them to objects may take longer.

We cannot disambiguate whether increased response time to a change in the relevant feature is due to potentially greater difficulty in responding to changes of target information or because of greater priming effects of target repetitions. However, we believe that there is more evidence for the former explanation. A meta-analysis of experiments assessing semantic and phonological priming in schizophrenia patients with formal thought disorder report that more studies demonstrate

reduced rather than enhanced priming effects (Kerns and Berenbaum, 2002). This effect is opposite to what we report in this study.

Whatever the explanation for the increased response costs (relative to controls) for relevant targets, the present results suggest that irrelevant color and location changes are no more distracting for schizophrenia outpatients than for healthy participants. These findings imply that the confusion and distractibility experienced by patients diagnosed with schizophrenia in our mildly symptomatic sample are unlikely to be due to difficulty in filtering out irrelevant features.

4.1. Limitations

As we tested relatively high-functioning outpatients, it is possible that more severely affected patients will display filtering impairments. Similarly, all our patients were tested while medicated with antipsychotic drugs, and it is currently unknown how medication status will affect patients' abilities to suppress task-irrelevant features. For example, the patients with the two highest target switch costs in our experiment were also both on haloperidol. Thus, it is unclear whether symptomatology is truly related to deficits in feature processing or whether medication is a contributing factor. These questions need to be answered before we can strongly assert that a diagnosis of schizophrenia is related to impairments in responding to switches of task-relevant features and, conversely, unimpaired in inhibiting task-irrelevant features.

Moreover, future work needs to pinpoint more precisely whether changes in task-relevant features are problematic for schizophrenia patients because of impaired goal-oriented processes such as retrieving key mappings or in more fundamental impairments in feature binding. One way to determine this would be to assess whether neural regions known to be associated with goal-oriented processes such as the dorsolateral prefrontal cortex is recruited when task-relevant features switch. Moreover, hypoactivity in the prefrontal cortex would be expected for schizophrenia patients when responding to relevant feature switch if their difficulty derived from higher-level processing. In contrast, hypoactivity of parietal areas would be predicted if the problem were one with feature binding.

In this study, we have demonstrated that our sample of mild- to moderately-impaired patients with schizophrenia does not display a global deficit in selective attention for features. Instead, their difficulty is restricted to conditions where task-relevant features vary over time.

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