Impairments of response conflict monitoring and resolution in schizophrenia

M. YÜCEL,[1] C. VOLKER, A. COLLIE, P. MARUFF, J. DANCKERT, D. VELAKOULIS
AND C. PANTELIS

From the Cognitive Neuropsychiatry Research and Academic Unit, Department of Psychiatry, University of Melbourne, Sunshine Hospital, St Albans and Applied Schizophrenia Division and Neuropsychology Laboratory, Mental Health Research Institute of Victoria, Parkville, Victoria, Australia; Department of Neuro- and Rehabilitation Psychology, Catholic University of Nijmegen, Nijmegen, The Netherlands; and Vision and Motor Research Laboratory, University of Western Ontario, London, Ontario, Canada

ABSTRACT

Background. It has been argued recently that the attentional dysfunction in schizophrenia occurs as a result of an inability to inhibit automatic attentional shifts to compelling external stimuli. However, this hypothesis is based on performance on paradigms that require overt or covert shifts of spatial attention.

Method. We investigated responses to foveally presented stimuli in patients with schizophrenia and healthy controls as they performed unidimensional and bidimensional versions of the flanker task. In both tasks, centrally presented target stimuli were flanked by peripheral stimuli that were either congruent or incongruent with the behavioural goal of the subject. In the bidimensional task, the flanking stimuli could be congruent and incongruent on multiple stimulus characteristics.

Results. On the unidimensional flanker task, the behavioural goal modulated the responses of the schizophrenia group such that response times (RTs) to target stimuli that were flanked by congruent stimuli were faster than RTs to target stimuli flanked by incongruent stimuli. However, on the bidimensional flanker task, the responses of schizophrenia patients were no longer constrained by the behavioural goal and RTs to both congruent and incongruent stimuli were equivalent.

Conclusions. It appears that the attentional dysfunction in schizophrenia may reflect difficulty in resolving multiple and simultaneous response conflicts. These findings suggest a possible role for the anterior cingulate cortex in the attentional impairments associated with schizophrenia.

INTRODUCTION

While it is generally argued that visual attentional processes are impaired in patients with schizophrenia, no unified theories of attentional dysfunction in schizophrenia are currently available. However, one reason for this is the paradigmatic approach of many studies of attention in schizophrenia and because few studies seek to relate their operational definition of attention to that used in other studies (Maruff & Currie, 1996; Maruff & Pantelis, 1999). Therefore, one approach to the development of unified theories of attentional dysfunction in schizophrenia is to generate hypotheses based on results obtained within one attentional paradigm, and then to determine the validity of those hypotheses using a different attentional paradigm. On the basis of our own studies of spatial attention we have hypothesized that the attentional impairment in schizophrenia can be characterized as an inability to use goal-directed behaviour (i.e. generation and execution of a volitional response) to inhibit prepotent or

[1] Address for correspondence: Dr Murat Yücel, Cognitive Neuropsychiatry Unit, C/o Mental Health Research Institute, Locked Bag 11, Parkville, VIC 3052, Australia.

automatic attentional shifts to compelling external stimuli (Maruff *et al.* 1995, 1998). This impairment is most obvious when the behavioural goals of the voluntary and automatic attentional processes are opposite (Maruff *et al.* 1998). Thus, in schizophrenia, information that is not consistent with the individuals' behavioural goal (i.e. information that is irrelevant but compelling) is allowed into the act of making a conscious decision. There are several potential explanations for why this may be the case including impaired conflict monitoring/ resolution, reduced selective attention, failure to sustain attention on the relevant stimuli and/or increased susceptibility to interference from irrelevant stimuli. In any case, the attentional disruption interferes with decision-making behaviour as evidenced by slower and/or more erroneous decisions. To date, our studies of attentional function in schizophrenia have employed ocular motor paradigms in which attention is allocated in space either covertly (i.e. without eye movements) or overtly (i.e. with eye movements). The current study seeks to determine whether the impairments observed on these tasks exist when behavioural goals constrain the selection of information represented in a task without spatial constraints.

In a series of studies of healthy adults we have investigated the relationship between voluntary and automatic attentional processes in the selection of responses based on internal representations of non-spatial stimuli. More specifically, the ability to select pre-specified stimulus response associations was studied using different variants of the flanker task (Danckert *et al.* 1999; Maruff *et al.* 1999). In its simplest form, the flanker task requires that a central target be identified with a specific manual response. When the target appears, it is flanked by distractors that are either congruent (e.g. E E E) or incongruent (e.g. O E O) with the target. As with previous studies (Erikson & Hoffman, 1973; Erikson & Shultz, 1979), we found that despite being instructed to ignore flankers, subject's response times (RTs) to identify the target are slower when the flanker and target are incongruent than when the flanker and target are congruent. It is thought that the presentation of an incongruent flanker adjacent to a target stimulus creates interference because the two stimuli are associated with conflicting responses

(flanker congruency effect). This flanker congruency effect (FCE) is so reliable that studies attempting to isolate conditions under which flankers do not interfere with target identification find it difficult to eliminate the FCE completely (Erikson & Hoffman, 1973; Erikson & Shultz, 1979; Miller, 1991; Cohen & Shoup, 1997; Lavie & Cox, 1997).

In another study, we modified the flanker task to include a conventional and reverse condition (Danckert *et al.* 2000). In both conditions, subjects were presented with a central target that could be either red or green. In the conventional condition, subjects were required to identify the target colour as presented (i.e. see red, say red). In the reverse condition, subjects were required to name the opposite colour to that of the target (i.e. see red, say green). Thus, subjects must both inhibit a response to the target colour and select an alternative response, of which there is only one. Accordingly, correct responses in the reverse condition were considerably slower than those in the conventional flanker task condition. This finding in the reverse flanker condition is similar to the findings in the eye-movement literature. For example, in contrast to the prosaccade task, in which the eye is directed towards the target, the antisaccade task requires an eye movement towards an imaginary location in the opposite visual hemifield. Many studies including our own have shown that saccadic latencies are longer in the antisaccade task compared to the more reflexive prosaccade task (Maruff *et al.* 1998).

The effect of varying the subject's behavioural goal on the ability to inhibit prepotent responses in the face of distraction from flankers was also investigated. On the conventional flanker task, the identification of targets surrounded by flankers congruent with the behavioural goal was faster than the identification of targets surrounded by flankers that were incongruent with the behavioural goal. Interestingly, when the subject's goal was reversed so that they had to identify the colour opposite to that of the target, reaction times slowed systematically and the distracting effect of flankers also changed. In the reverse condition, vocal reaction times (VRT) to targets were faster when flankers were perceptually congruent with the target (i.e. same colour), even though they are behaviourally incongruent. This pattern of results suggested

that the successful inhibition of the prepotent response to the target was also extended to the flankers (Danckert *et al.* 2000).

In a second modification of the flanker task, we presented subjects with targets and flankers that varied on two dimensions simultaneously (e.g. colour and letter, see Fig. 2) (Danckert *et al.* 1999; Maruff *et al.* 1999). In separate conditions, the subjects' goal was to identify one dimension of the target while ignoring the second dimension and ignoring the distracting flankers. We found that flankers interfered with target selection only when targets and flankers differed on the goal-relevant dimension. For example, when required to identify target letters, RTs were unaffected by the congruence of the goal-irrelevant dimension (i.e. colour) but showed the normal FCE when flankers were altered along the goal-relevant dimension (i.e. faster RTs for target-flanker displays with congruent letters when compared with target-flanker displays with incongruent letters). Importantly, when the behavioural goal was changed, the pattern of interference from perceptually identical stimuli was reversed so that flankers now affected target selection only according to the new goal-relevant dimension. That is, when subjects were now required to identify target colours, the congruence of the letter dimension did not affect the RT pattern. These results suggest that behavioural goals constrain the selection of visual information to a greater extent than the physical characteristics of the visual information (i.e. as the perceptual characteristics remained identical across the two tasks of identifying letters or colours). These data also suggest that in healthy adults the selection of previously learned, and internally generated, stimulus response associations can be constrained by behavioural goals.

The aim of the current study was to use our previously described unidimensional (e.g. the conventional and reverse flanker tasks) and bidimensional (e.g. with coloured letters as targets and flankers) modifications of the flanker task to investigate the nature of attentional dysfunction in schizophrenia. More specifically, to investigate the ability of patients with schizophrenia to use goal-directed behaviour to inhibit prepotent responses to non-spatial stimuli, and to constrain the processing of internally represented information. For the unidimensional

flanker task we hypothesized that the flanker congruency effect was due to perceptually incongruent flankers interfering (slowing responses) with identification of the target, rather than congruent flankers facilitating target identification. Furthermore, we hypothesized that patients with schizophrenia would show increased interference in the reverse flanker paradigm, indicating impairment in inhibiting responses to prepotent stimuli. For the bidimensional flanker task we hypothesized that the time for target identification by patients would be related to the perceptual similarity between both dimensions of targets and flankers such that selection would not be constrained by behavioural goals, as it is in healthy controls.

EXPERIMENT 1: UNIDIMENSIONAL FLANKER TASK

Method

Subjects

Twelve patients with chronic schizophrenia (11 male; mean age $= 35 \cdot 7$ years; s.D. $= 11 \cdot 0$ years) and 12 normal control subjects (12 male; mean age $= 37 \cdot 2$ years; s.D. $= 8 \cdot 9$ years) participated in this study. All patients were classified as having chronic schizophrenia according to DSM-IV criteria and were maintained on anti-psychotic medication. The majority were medicated with clozapine (nine subjects; mean dosage $= 480$ mg; s.D. $= 233$ mg). The average number of admissions for patients was 13 (s.D. $= 12$) and months since first admission was 171 (s.D. $= 127$). Patients were recruited from out-patient clinics. Exclusion criteria for the control subjects included a history of neurological or psychiatric disease or brain trauma. All subjects had normal or corrected to normal visual acuity and normal colour vision as determined by Ishihara plates. The institutional ethics committee approved the research protocol and informed consent was obtained from all participants prior to testing.

Materials and procedure

The stimuli for this experiment consisted of targets and flankers that were red and green filled squares. Targets were presented centrally and subtended approximately 2° of visual angle, while flankers subtended approximately 4° of visual angle and were presented 6° to the left or
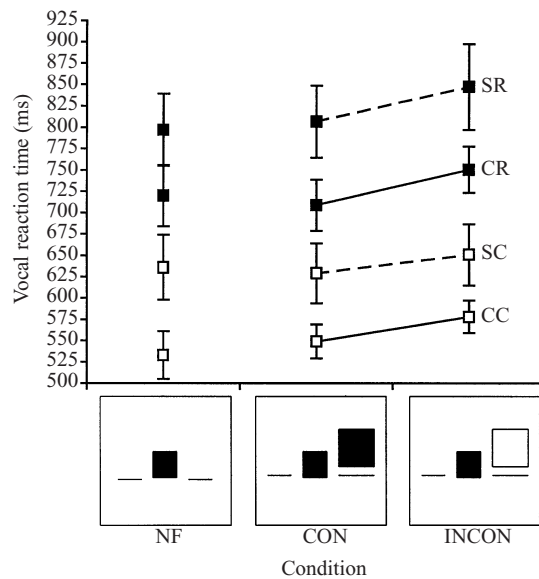
FIG. 1. Mean vocal reaction times on the unidimensional flanker task for the control and schizophrenia groups. Fig. 1 also includes a schematic representation of the target-flanker relationships. (CC, Control group-conventional flanker task; SC, schizophrenia group-conventional flanker task; CR, control group-reverse flanker task; SR, schizophrenia group-reverse flanker task; NF, no flanker condition; CON, congruent flanker condition; INCON, incongruent flanker condition; error bars, standard error of the mean.)

right of central fixation. An example of the two possible permutations of flanker and target appearing with a red target for both the conventional and reverse flanker tasks are shown in Fig. 1. The flanker could be congruent or incongruent with the target. In a third condition, the central target was presented in the absence of a flanker. For both the conventional and reverse flanker tasks, target and flanker dimensions were presented randomly. In the conventional flanker task, subjects were required to name the colour of the central target (i.e. see red, say red). In the reverse flanker task, subjects were required to name the colour that was not presented centrally (i.e. see red, say green). All subjects completed 12 blocks of trials over four sessions, six blocks for each of the conventional and reverse tasks. Four of these blocks (two conventional, two reverse) consisted of 15 practice trials, while the remaining eight (four conventional, four reverse) were test blocks, which consisted of 60 test trials. A single session of testing consisted of three blocks (one practice, two test), and session order was randomized.

Rest periods were given between each block and longer rests were given between sessions. Further methodological details can be found in two previous publications (Danckert *et al.* 1999, 2000).

Data analysis

For each task, subjects' vocal reaction times (VRT) were defined as anticipatory or abnormally slow responses if they were faster than 100 ms or slower than 1500 ms, respectively. Errors were defined as the incorrect identification of the target. For each task, the number of misidentification errors made by each subject was expressed as a percentage of the total number of trials. The number of anticipatory and abnormally slow responses as well as errors was investigated across the different groups, tasks and congruency conditions using independent samples t tests. Data from the trials on which misidentification errors, anticipatory or abnormally slow responses occurred were excluded from further analysis. The remaining data was then submitted to a group (two; schizophrenia v. control) by task (two; conventional v. reverse) by congruence (two; perceptually congruent v. perceptually incongruent) repeated measures analysis of variance (ANOVA) with task and congruence the repeated measures. For each subject group in the conventional and reverse flanker tasks, flanker congruence effects (FCE) were calculated by subtracting the mean VRT to congruent trials from the mean VRT to incongruent trials. As VRTs in the no flanker condition could not be classified according to congruence, these data were not included in these analyses and were separately analysed using simple planned comparisons.

Results

Both anticipatory/abnormally slow responses and error rates for all conditions were low for both groups ($< 2\%$ and $< 8\%$ of trials, respectively) with no differences between the different congruency conditions. However, patients made significantly more errors in the reverse flanker task (8%) compared with the conventional flanker task (2%; $t(22) = -4\cdot36$; $P < 0\cdot01$) and the same task in controls (1%; $t(22) = -3\cdot52$; $P < 0\cdot01$). Mean VRTs to each

condition in the conventional and reverse flanker tasks, including the no flanker condition, are shown in Fig. 1. While the mean VRT of the schizophrenia group (mean = 734 ms, S.E. = 32 ms) was slower than the mean VRT for controls (mean = 647 ms, S.E. = 32 ms), this group difference failed to reach significance ($F(1, 22) = 3 \cdot 65$, $P < 0 \cdot 07$). There was a significant main effect of task ($F(1, 22) = 171 \cdot 25$, $P < 0 \cdot 001$) with mean VRT in the conventional task (mean = 602 ms, S.E. = 20 ms) faster than mean VRT in the reverse task (mean = 779 ms, S.E. = 27 ms). There was also a significant main effect of congruency ($F(1, 22) = 30 \cdot 20$, $P < 0 \cdot 001$) with mean VRT for congruent trials (mean = 674 ms, S.E. = 22 ms) being faster than mean VRT to incongruent trials (mean = 707 ms, S.E. = 24 ms). No significant interactions were observed. Accordingly, there were no differences in the magnitude of the FCEs between the control and schizophrenia group for either the conventional (control FCE = 29 ms, schizophrenia FCE = 22 ms) or reverse flanker condition (control FCE = 42 ms, schizophrenia FCE = 41 ms). Finally, planned comparisons revealed a significant difference between the no-flanker and incongruent flanker conditions ($F(1, 22) = 19 \cdot 56$, $P < 0 \cdot 01$) as well as between the congruent and incongruent flanker conditions ($F(1, 22) = 30 \cdot 20$, $P < 0 \cdot 01$). There was no significant difference between the no-flanker and congruent flanker conditions. These results indicate that when compared to the no-flanker and congruent flanker conditions, VRTs are slowed to incongruent condition.

EXPERIMENT 2: BIDIMENSIONAL FLANKER TASK

Experiment 1 showed that, despite a general slowing of VRTs (trend level significance) as well as increased errors in the reverse flanker condition, patients with schizophrenia were able to inhibit prepotent responses to targets as effectively as healthy adult control subjects. Experiment 1 also showed patients with schizophrenia and healthy control subjects were affected equally by distracting stimuli. In order to examine the performance of patients with schizophrenia under conditions where flanker stimuli can be consistent or inconsistent with the target and behavioural goals on multiple dimensions, we administered a bidimensional flanker task to both patients and control groups in Experiment 2.

Method

Subjects

The same group of healthy control and schizophrenia subjects as participated in Experiment 1 also completed Experiment 2.

Materials and procedure

For the bidimensional task, targets and flankers were red and green Es and Os with the letter and colour dimensions of the stimuli varied randomly. Targets and flankers subtended 2° of visual angle with flankers presented 4° to the left and right of fixation. An example of the four possible permutations of flankers and targets occurring with a red E target are shown in Fig. 2. Identical stimuli were presented under two different behavioural goals. One goal was to identify the colour of the target while ignoring its form (the letter), and the other goal was to identify the form of the target while ignoring its colour. For each behavioural goal, the different combination of targets and flankers led to four different congruency conditions (see Fig. 2). Specifically, targets and flankers could be congruent on both the goal-relevant and goal-irrelevant dimensions (CR/CI), congruent on the goal-relevant dimension and incongruent on the goal-irrelevant dimension (CR/II), incongruent on the goal-relevant dimension and congruent on the goal-relevant dimension (IR/CI), or incongruent on both the goal-relevant and goal-irrelevant dimensions (IR/II; see Fig. 2). In a fifth condition, the target was presented in the absence of flankers (no flanker condition).

All subjects completed a single session in which four blocks (two for each behavioural goal) of 40 trials were administered. A block of 15 practice trials was administered to each subject prior to commencement of the test trials. The order of block presentation was randomized and rest periods (~ 1 h) were given between each block. The bidimensional flanker task was administered to subjects on the same day as the unidimensional flanker tasks described in Experiment 1. The order of presentation of these
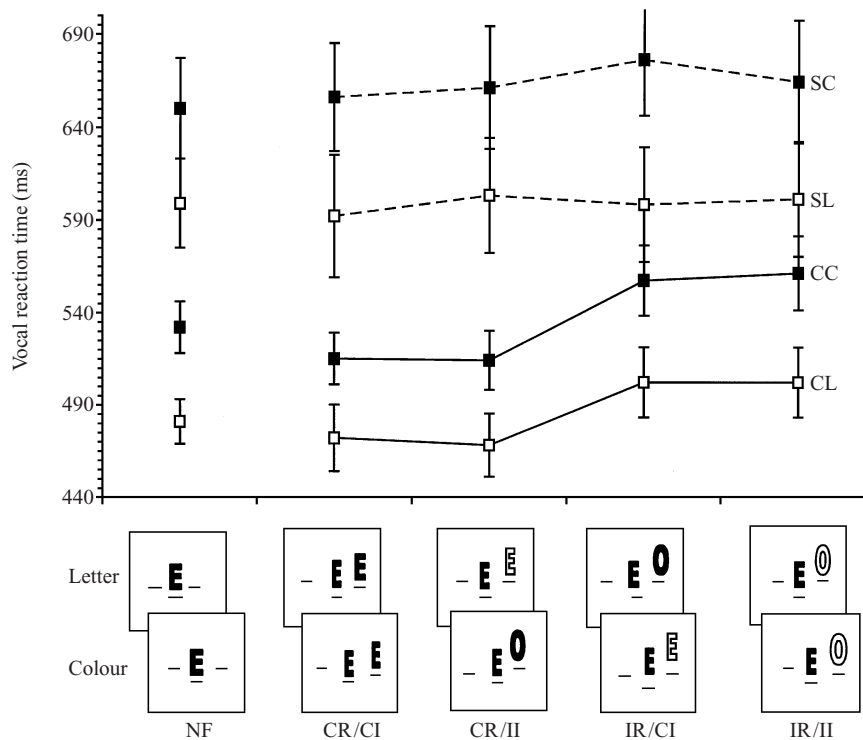
FIG. 2. Mean vocal reaction times on the bidimensional flanker task for the control and schizophrenia groups. Fig. 2 also includes a schematic representation of possible target-flanker relationships. (CC, Control group-identify colour task; SC, schizophrenia group-identify colour task; CL, control group-identify letter task; SL, schizophrenia group-identify letter task; NF, no flanker condition; CR/CI, congruent on the goal relevant and goal irrelevant dimensions; CR/II, congruent on the goal relevant dimension, but incongruent on the goal irrelevant dimension; IR/CI, incongruent on the goal relevant dimension, but congruent on the goal irrelevant dimension; IR/II, incongruent on the goal relevant and goal irrelevant dimensions. error bars, standard error of the mean.)

tasks was randomized and long rest periods were given between the completion of one task and the beginning of another.

Data analysis

Vocal RTs and misidentification errors were treated in an identical fashion to Experiment 1. Group mean VRTs were then submitted to a group (two; schizophrenia *v.* control) by task (two; identify colour *v.* identify letter) by congruence (four; CR/CI, CR/II, IR/CR, IR/II) repeated measures ANOVA with task and congruence as the repeated measures. Significant interactions were further investigated using repeated measures ANOVA with simple planned contrasts. In Experiment 2, the FCE were calculated by subtracting the mean VRT to trials where the target and flanker were congruent on the goal-relevant dimension (i.e. the average of the CR/CI and CR/II conditions) from the mean VRT to trials where the target

and flanker were incongruent on the goal-relevant dimension (i.e. the average of the IR/CI and IR/II conditions; see Fig. 2). The FCE was directly compared between patients and controls using univariate ANOVA. The effect sizes and statistical power associated with the FCE analyses were also calculated. As with Experiment 1, VRTs to no-flanker trials were separately analysed using simple planned comparisons.

Results

Both anticipatory/abnormally slow responses and error rates for all conditions were very low for both groups ($< 2\%$ and $< 4\%$ of trials, respectively) with no significant differences between the subjects groups, flanker tasks or congruency conditions. Mean VRTs under each behavioural goal (identify letter and identify colour) for both groups are shown in Fig. 2. Comparison of the healthy controls and patients with schizophrenia revealed a significant main

effect of group $(F(1, 22) = 11.79, P < 0.005)$, indicating that the mean VRT of the schizophrenia group (mean = 631 ms, S.E. = 25 ms) was slower than the mean VRT for controls (mean = 511 ms, S.E. = 25 ms). A significant main effect of task was also found $(F(1, 22) = 68.93, P < 0.001)$ with mean VRT to identify the target letter (mean = 542 ms, S.E. = 18 ms) faster than mean VRT to identify target colour (mean = 600 ms, S.E. = 18 ms). The absence of any group by task interaction indicated that the magnitude of the difference in mean VRT between the identify colour and the identify letter condition was equal in the two groups. ANOVA also indicated a significant main effect of congruency $(F(3, 20) = 13.77, P < 0.001)$ and a significant group × congruency interaction $(F(3, 20) = 7.53, P < 0.001)$. Consequently, the congruency effect was analysed separately for each subject group using a task (two; identify colour *v*. identify letter) by congruence (four; CR/CI, CR/II, IR/CR, IR/II) repeated measures ANOVA design with simple planned contrasts. For the control group, ANOVA indicated a significant main effect of task $(F(1, 11) = 26.32, P < 0.001)$ and a significant main effect of congruence $(F(3, 9) = 24.36, P < 0.001)$. There was no significant congruency × task interaction. For the schizophrenia group, ANOVA indicated a significant main effect of task $(F(1, 11) = 43.69, P < 0.001)$ but no main effect of congruency, and no significant congruency × task interaction. Simple planned contrasts comparing the four congruency conditions in the controls revealed that while there were no significant differences in VRTs between the CR/CI and the CR/II conditions, VRTs to both of these conditions were significantly faster than the IR/CI $(F(1, 11) = 78.91, P < 0.001$ and $F(1, 11) = 62.53, P < 0.001$, respectively) and the IR/II conditions $(F(1, 11) = 71.52, P < 0.001$ and $F(1, 11) = 67.99, P < 0.001$, respectively). There were no significant differences between the IR/II and IR/CI conditions. Planned comparisons for the no-flanker task indicated no significant difference between the no-flanker condition and either the congruent or incongruent flanker conditions.

Finally, the data were investigated by calculating and directly comparing the FCEs for both the controls and patients for both task conditions. For each task, FCEs were calculated by subtracting the average VRTs to perceptually congruent conditions (CR/CI; CR/II) from the average VRTs to perceptually incongruent conditions (IR/CI; IR/II). Univariate ANOVA revealed that for the letter condition, the FCE of the control group (32 ms) was greater than that of the schizophrenia group (2 ms; $F(1, 23) = 15.57; P < 0.01$). The effect size associated with this group difference was moderate ($\eta^2 = 0.41$) and the observed statistical power was high ($\alpha = 0.97$). Similarly, for the colour condition the FCE of the control group (44 ms) was significantly greater than that observed for the schizophrenia group (11 ms; $F(1, 23) = 10.38; P < 0.01$). Again, the effect size associated with this group difference was moderate ($\eta^2 = 0.32$) and the statistical power high ($\alpha = 0.87$).

DISCUSSION

In Experiment 1 when subjects were required to identify the colour of a unidimensional target, the congruency of flankers affected the speed of target identification in both groups. The time to identify the colour of targets was slower when the flanker was incongruent (i.e. the opposite colour) than when it was congruent (i.e. the same colour). The magnitude of the difference between congruent and incongruent trials (i.e. the flanker congruency effect) was equal in the schizophrenia and control groups. When the behavioural goal was changed so that subjects were required to identify the colour of the target and to simultaneously name the opposite colour the time to identify targets slowed considerably. The magnitude of this increase was again the same in the schizophrenia and control groups. In addition, flanker congruency effects were also equivalent in the two groups and were due to perceptually incongruent flankers slowing responses to the target, rather than congruent flankers facilitating target identification. Overall, these results indicate that patients with schizophrenia were able to inhibit their prepotent response to targets in favour of the alternative response, and this inhibition extended to flanker stimuli in the same manner as it did in healthy for controls. However, it should be noted that patients were generally slower and made significantly more errors than controls in the reverse flanker condition suggesting that while they were able to successfully inhibit a prepotent

response, it took relatively greater effort than for controls to do so. Nevertheless, patients were able to inhibit prepotent responses to non-spatial stimuli even in the face of distracting information. This result is somewhat surprising given that previous studies using the antisaccade task and the COVAT have shown that schizophrenia patients have great difficulty inhibiting reflexive shifts of attention toward salient stimuli in the periphery (Maruff *et al.* 1998, 1999). With respect to these studies, the current finding suggests that impairment in inhibiting reflexive attentional shifts may be specific to spatial attentional systems.

In contrast to their ostensibly normal performance in Experiment 1, patients with schizophrenia were unable to effectively attend to information according to different behavioural goals in the bidimensional flanker task. Patients with schizophrenia failed to show FCEs from flankers under either the identify letter or identify colour conditions (Fig. 2). In contrast, the performance of controls was equivalent to that of healthy subjects in our previous studies. When the behavioural goal was to identify the colour of the target, FCEs were dependent only on the colour of flankers. Conversely, when the behavioural goal was to identify the target letter, FCEs were dependent only on the form of the flankers. As in Experiment 1, the speed with which the schizophrenia group was able to identify the target was generally slower than that observed in controls. This general slowing of responses is found consistently in studies of attentional functions in schizophrenia (Maruff & Currie, 1996; Maruff & Pantelis, 1999). In addition, the speed of target identification for the name letter condition was faster than the name colour condition in the schizophrenia group, and the magnitude of the difference in general response times between the two conditions was equivalent to that found in controls. Given that the stimuli were identical in both tasks (i.e. identify letter *versus* identify colour), the colour naming condition in this paradigm is equivalent to the colour naming condition of a Stroop task. As such the increased VRTs in the colour naming condition probably reflects the fact that the tendency to read the letter must be inhibited. The normal advantage for identifying letters observed in schizophrenia suggests that patients were able to inhibit letter

reading by keeping the relevant behavioural goal on-line during blocks of trials, but that they were unable to use it to constrain processing of the flankers. It is possible that the effects of attentional dysfunction in schizophrenia might be evident relatively late in the information processing stream during which controlled, voluntary and more effortful attentional processes need to be engaged. To this end, it may be that the nature of the attentional dysfunction seen in patients reflects increased task difficulty rather than the processes of interest. This may explain the relatively normal performance of patients in the unidimensional flanker paradigm of Experiment 1, which contrasts with their abnormal performance in the more difficult bidimensional flanker paradigm of Experiment 2. On the other hand, abnormal performances observed with increased difficulty may be a proxy for deficits in other attentional mechanisms such as conflict resolution (discussed below).

The lack of FCEs (lack of interference) from flanker stimuli in patients with schizophrenia found in Experiment 2 of the current study is in accordance with a previous study that utilized a modified version of the conventional flanker task (Elkins & Cromwell, 1994), which demonstrated that flankers incompatible with targets produced significantly less interference for schizophrenia patients than for normal controls and depressed patients. Together, the findings suggest that patients with schizophrenia are unable to use behavioural goals to constrain the selection of visual information. That is, patients are less efficient in using attentional resources to inhibit responses to irrelevant but compelling stimuli in order to facilitate responses to relevant stimuli. There are a number of potential explanations for why this may be the case, including an increased susceptibility to interference from irrelevant stimuli and/or failure to sustain attention on the relevant stimuli. Alternatively, deficits in selective attention or conflict monitoring may be more relevant explanations of the current data. Selective attention or 'selection for action' suggests that the attentional system can be selectively biased to a subset of relevant stimuli (see Allport, 1987). Thus, it is possible that under increased task loads, schizophrenia patients pay too much attention to concrete stimulus characteristics. The result is a lack of

control in the selective processing of information, whereby it is more difficult to select between relevant and irrelevant items, especially when there is time pressure.

Conflict monitoring, suggests that the role of certain neural systems within the attentional network is to detect and signal the occurrence of conflicts in information processing (Carter *et al.* 1999, 2000). In this regard the flanker task involves both conflict and selection-for-action, in particular on incompatible trials. That is, during incongruent trials the combined influence of the target and flankers leads to conflict in the form of competition between correct and incorrect responses, an effect that is reflected in prolonged reaction times. At the same time, attending to the target but not the flanker calls for selection-for-action. To this end, a couple of recent studies (Botvinick *et al.* 1999; Casey *et al.* 2000) have used functional MRI and the flanker task to dissociate attentional subsystems both behaviourally and neuroanatomically. These studies found that activity in both the anterior cingulate cortex (ACC) and dorsolateral prefrontal cortex (DLPFC), were correlated with behavioural performance on the flanker task. However, Botvinick and colleagues (1999) found that activity within the ACC was greater during trials featuring high levels of conflict (and weak selection-for-action) than during trials with low levels of conflict (and strong selection-for-action), providing evidence in favour of the conflict-monitoring account of ACC function (Carter *et al.* 1999, 2000). These findings have been replicated in other companion studies in which the ACC showed comparable behaviour in different behavioural tasks. For example, in a series of neuroimaging studies using the Stroop task and a continuous performance task, Carter *et al.* observed that the ACC was not only activated during erroneous responses, but also during correct responses under conditions of increased response competition (Carter *et al.* 1999, 2000). This model also proposes that other frontal brain regions, such as the DLPFC regulate the control of conflict resolution. The model proposed by Carter and colleagues may also account for current data (Carter *et al.* 1995, 1997, 1998, 1999, 2000) in that patients with schizophrenia may have an impaired sensitivity to conflict elicited by the goal irrelevant flanker, which leads to a failure to adjust attentional

mechanisms based upon the behavioural goal, especially under increased task load. Thus, patients with schizophrenia do not show RT costs when flankers are incongruent.

In a recent study, we investigated the performance of a patient with an ACC (patient G.M.) lesion on the same unidimensional and bidimensional flanker tasks that were used in the current study (Danckert *et al.* 2000). Importantly, the performance of patient G.M. and the performance of the current patients with schizophrenia are very similar. When performing the unidimensional flanker tasks, patient G.M. showed faster VRTs for congruent trials compared to incongruent trials, although the magnitude of the difference between the two conditions (i.e. the FCE) was larger when flankers appeared in the ipsilesional field compared to the contralesional visual field. In addition, VRTs were slowed to the same extent as controls when G.M. performed the reverse flanker task. Like the current group of patients with schizophrenia, G.M. showed no flanker effects when she performed the bidimensional flanker task. The model of ACC proposed by Carter and colleagues would suggest that this absence might have been a result of the bidimensional flanker task yielding multiple and overlapping stimulus response conflicts that were difficult for the patients to resolve and/or detect. Thus, the abnormal performance in the current patient group seems to reflect a specific impairment in effective response monitoring during complex/concurrent tasks with downstream implications for resolving response conflict. This suggestion is supported by our data, which show performance on the unidimensional flanker task is preserved, and behavioural goals were used effectively to alter the selection of visual information. However, in the absence of conflict detection and/or resolution, it is unclear why error rates were not significantly increased in patients. Another possibility is that under conditions of high perceptual load, flanking stimuli have less effect on performance (see Lavie & Fox, 1995). In this context it may be that the task in Experiment 2 placed a higher perceptual load on the patients than it did on the controls. In any case, the net effect is a disruption in decision-making processes, which takes the form of slower and/or more erroneous decisions.

In summary, it can be stated that on the basis

of the current results, patients with schizophrenia are able to use internally generated behavioural goals to select previously learned stimulus response associations. In conditions where a unidimensional target stimulus was displayed, patients with schizophrenia displayed normal interference effects from distracting stimuli. However, when a more complex, bidimensional stimulus was displayed, there was no evidence of interference from the distracting stimulus, even when that distracting stimulus was behaviourally relevant. This deficit may be attributed to a specific impairment in monitoring and resolving of response conflict, which has recently been hypothesized to be the role of the ACC and DLPFC, respectively.

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