Impairment of willed actions and use of advance information for movement preparation in schizophrenia

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Abstract

Objectives—To assess willed actions in patients with schizophrenia using reaction time (RT) tasks that differ in the degree to which they involve volitionally controlled versus stimulus driven responses.

Methods—Ten patients diagnosed with schizophrenia and 13 normal controls of comparable age were tested. Subjects performed a visual simple RT (SRT), an uncued four choice reaction time (CRT), and a fully cued four choice RT task. A stimulus 1(S1)—stimulus 2(S2) paradigm was used. The warning signal/precue (S1) preceded the imperative stimulus (S2) by either 0 (no warning signal or precue) 200, 800, 1600, or 3200 ms.

Results—The patients with schizophrenia had significantly slower RTs and movement times than normal subjects across all RT tasks. The unwarned SRT trials were significantly faster than the uncued CRT trials for both groups. For both groups, fully cued CRTs were significantly faster than the uncued CRTs. However, the S1–S2 interval had a differential effect on CRTs in the two groups. For the normal subjects fully cued CRTs and SRTs were equivalent when S1–S2 intervals were 800 ms or longer. A similar pattern of effects was not seen in the patients with schizophrenia, for whom the fully cued CRT were unexpectedly equivalent to SRT for the 200 ms interval and expectedly for the 1600 ms S1–S2 interval, but not the 3200 or 800 ms intervals.

Conclusions—Patients with schizophrenia were able to use advance information inherent in SRT or provided by the precue in fully cued CRT to speed up RT relative to uncued CRT. However, in the latter task, in which the volitional demands of preprogramming are higher since a different response has to be prepared on each trial, patients showed some unusual and inconsistent interval effects suggesting instability of attentional set. It is possible that future studies using RT tasks with higher volitional demands in patients with predominance of negative signs may disclose greater deficits in willed action in schizophrenia.

Schizophrenia is a psychiatric disorder characterised by various symptoms. Positive symptoms are those that patients experience and by their presence distinguish patients from normal, such as thought disorder or hallucinations. Negative signs exist when the patients lack some element of normal behaviour—for example, flattening of affect, poverty of speech, and social withdrawal. Frith has suggested that the signs and symptoms of schizophrenia such as poverty of action or stereotyped action reflect a dysfunction of “willed” actions, whereas the processes involved in “stimulus driven” actions remain largely intact. This means that patients can perform routine acts elicited by environmental stimuli, but have difficulty in producing spontaneous behaviour in the absence of external cues.

One way of testing the hypothesis of impairment of willed actions in schizophrenia is to examine the speed of response initiation in reaction time (RT) tasks that differ in the extent to which they require volitionally prepared versus stimulus driven responses. In simple RT (SRT) tasks the same stimulus is presented across trials, and requires the same invariable response. The stimulus-response invariance provides the subject with the option of preparing the response before presentation of the stimulus—that is, to preprogramme it. In SRT, this preprogramming is an optional and volitional process, which has been shown to require attention as it is susceptible to interference from the concurrent performance of a secondary task. By contrast, in an uncued choice RT (CRT) task, in which there are several stimuli each indicating a different response, the response is elicited by presentation of the imperative stimulus. In uncued CRT, the response is selected and programmed after presentation of the stimulus, so it is considered to be stimulus driven. Volitional preprogramming is not possible in uncued CRT; but is a requirement in fully precued CRTs. In a fully cued CRT task a precue provides the subject with full advance information about the particular response required on that trial that allows its selection and preprogramming before the presentation of the imperative stimulus. The SRT and the fully cued CRT differ on one important factor: stimulus-response (S-R) variance. In the SRT the stimulus and response are the same on every trial, therefore the subject can preprogramme the same response for every trial. In the fully cued CRT, although full movement information is provided by the
precue, the subject must preprogramme a
different response for each trial.

There have been studies of RTs in schizo-
phrenia since the 1930s.9 The most consistent
finding is that schizophrenic patients have sig-
nificantly slower RTs than normal controls.5,6
Another consistent finding is the “cross over
effect” (COE), reported as far back as the
1940s.7 In normal subjects, in a simple RT
(SRT) task, if the interval between the warning
signal (S1) and imperative stimulus (S2) is short
(<3 seconds), responses are initiated faster on trials where the S1–S2 interval is kept
constant or blocked rather than presented ran-
domly across trials. This improved perform-
ance is thought to be due to the temporal pre-
dictability of the imperative stimulus. However,
with longer S1–S2 intervals, normal subjects
have similar RTs regardless of whether the
S1–S2 intervals are random or blocked.

Patients with schizophrenia generally show the
same RT benefit from temporal predictability
when S1–S2 intervals are short. By contrast,
when the S1–S2 intervals are longer, patients
with schizophrenia have slower RTs for the
blocked S1–S2 intervals than for the random
S1–S2 intervals. This phenomenon is called the
COE.

In the COE the patients with schizophrenia
are failing to use the advance information pro-
vided by the warning signal about the temporal
predictability of the imperative stimulus to
speed up the response. Few studies have exam-
inined the effect of other types of advance infor-
mation on RTs in schizophrenia—for example,
the use of advance movement parameter infor-
mation contained in a precue that allows
volitional preprogramming of the response
before presentation of the imperative stimulus.
Carnahan et al10 measured RTs in leukot-
omised and unleukotomised schizophrenic patients compared with normal controls. Using
a version of Rosenbaum’s RT paradigm,11 the
authors measured RT in uncued, partially
cued, and fully cued four choice RT (CRT)
conditions. The two schizophrenic groups were
slower than the normal subjects across all RT
conditions. The authors concluded that “the
leukotomised and the unleukotomised schizo-
phrenics were able to use this advance informa-
tion to facilitate the speed of their responses in much the same way as did subjects
in a normal control group”.

The type of information provided by a
preparatory signal (S1) presented before an
imperative stimulus (S2) can vary. Any signal
given a short time before an imperative stimu-
lus will serve as a warning to the subject, allow-
ing them to increase their level of alertness and
readiness to respond. This facilitation seems to
be optimal with a preparatory interval of 200
ms.12 Alternatively, the preparatory signal may
provide advance information about the nature
of the response itself—for example, it may
inform the subjects that they have to move to the
upper key with their right hand when the imperative stimulus is presented. In this case it
may be referred to as a movement parameter
precue. This information potentially allows the
subject to preselect and preprogramme a
specific response from a number of alterna-
tives, provided there is adequate time between
the precue and the imperative stimulus to take
action. The amount of reduction of RT by
warning stimulus and movement parameter
precues also depends on when they are
presented relative to the imperative stimulus.
Therefore, the interval between the warning
signal/precue and the go signal is important in
determining the RT facilitation.

The aim of this study was to examine the
effects of different types of advance informa-
tion on RT in schizophrenia: (1) invariance
of the stimulus and response in SRT relative to
uncued CRT, (2) full advance movement
parameter information in a precued CRT task.
We were also interested in determining if the
interval between the warning stimulus/precue
(S1) and the imperative stimulus (S2) had
similar or differential effects on motor prepara-
tion in schizophrenic patients and normal sub-
jects.

Methods

DESIGN

A mixed between group and within subject
design was used. The two groups of subjects,
patients with schizophrenia or healthy normal
controls, performed a series of reaction time
(RT) conditions: simple reaction time (SRT),
uncued four choice RT (CRT), fully cued
CRT, and retest of SRT. In each RT condition,
an S1–S2 paradigm was used. For each condi-
tion, trials were either unwarned (S1–S2 inter-
val of 0 ms) or the imperative stimulus followed
the warning signal/precue, with S1–S2 inter-
vals of 200, 800, 1600, or 3200 ms.

SUBJECTS

The characteristics of the two samples are pre-
presented in the table. Ten subjects clinically diag-
nosed with schizophrenia according to the
DSM III R were tested. Each was seen as an
outpatient at the National Hospital for Neuro-
logy and Neurosurgery. Each patient was rated
on a four point standardised psychiatric assess-
ment scale13 for current positive and negative
symptoms. Overall, the patients were chroni-
cally ill and their symptoms were not very
severe. Thirteen healthy normal subjects with
no history of psychiatric or neurological illness,
head injury, or drug misuse were tested. The
mini mental state examination14 was adminis-
tered to all subjects and no one scored below
the cut off indicative of cognitive deficit.

PROCEDURE-REACTION TIME TASKS

A full description of the procedure is available
in Jahanshahi et al.15 Responses were made on a
response box with six buttons. The two centre
black buttons acted as the home keys. Four
inches above and 4 inches below each black
button were the response buttons. Stimuli
were presented on a 14 inch computer screen. A
variation of Rosenbaum’s16 movement precue-
ing RT was used. The subject pressed down the
two home keys to begin the trial and a fixation
point appeared. The warning stimulus ap-
peared after a variable delay of 1–4 seconds.

The imperative stimulus (S2) appeared after
Details of subject groups

<table>
<thead>
<tr>
<th>Sex</th>
<th>Patients with schizophrenia</th>
<th>Controls</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Female</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Hand</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Left</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mean age (y)</td>
<td>37.9 (8.0)</td>
<td>38.9 (10.1)</td>
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<tr>
<td>Mean mini mental state scores</td>
<td>28.0 (2.5)</td>
<td>29.9 (6.0)</td>
</tr>
<tr>
<td>Mean duration of illness (y)</td>
<td>13.1 (7.0)</td>
<td></td>
</tr>
</tbody>
</table>

Values in parentheses are SD.

The S1–S2 interval (200, 800, 1600, or 3200 ms). On unwarned trials (S1–S2 interval of 0 ms) there was no warning stimulus.

Three types of error trials were recorded: anticipations (RT<100 ms), long responses (RT>3 s), decision errors (incorrect responses in CRT). RT and movement time (MT) from these trials were omitted, and the trials were repeated—that is, trials on which errors occurred were omitted from calculation of mean RTs, but to ensure equal number of trials across subjects any trials with errors were replaced by administering an additional trial.

RT was measured (in ms) as the time between the presentation of the imperative stimulus and the release of the home key. MT was measured (in ms) as the time between releasing the home key and pressing the response key. The mean RT for each condition for each subject were used in the analyses.

**Simple reaction time (SRT)**

The stimulus and the response were constant across trials within a block. The subject moved from one home key to one response key, and all other keys were covered. Each subject performed two blocks of 50 trials (10 trials per interval), one block with each hand. The order of testing the left or right hand was counterbalanced across subjects in each group—that is, in the groups of patients with schizophrenia half of the subjects performed the test with their right hand first and half used their left hand first. Similarly, within the group of normal subjects the order of left and right hands was counterbalanced. At the end of the experiment, the SRT condition was presented again to counterbalance. At the end of the experiment, subjects the order of left and right hands was randomized—either uncued or fully cued. This average was used in all subsequent analyses.

**Four choice reaction time (CRT)**

There were two movement parameters, hand (right or left) and direction (up or down). The two conditions were either uncued or fully cued. In each condition there were 75 trials with 15 trials of each of the five S1–S2 intervals randomly mixed in a block. A similar and randomly mixed number of right and left hand responses were incorporated.

**Uncued CRT**

The warning stimulus consisted of four empty squares appearing to the left and right and above and below the fixation cross. After the S1–S2 interval one square filled which became the imperative stimulus.

**Fully cued CRT**

One empty square appeared in one of the four possible locations above or below, to the left or right of the fixation point. After the S1–S2 interval the square filled to become the imperative stimulus. Thus the subject knew the precise nature of the required response before the presentation of the imperative stimulus.

**Order of testing**

The SRT condition was performed first followed by the CRT conditions. The order of performance of the CRT conditions was counterbalanced across subjects in each group. We considered counterbalancing more appropriate than randomising because for theoretical reasons we wanted subjects to perform SRT before the CRT tasks so as not to influence the S-R invariance of SRT by prior exposure to CRT with multiple stimuli and responses. Subsequently, we counterbalanced the order of testing of the CRT tasks.

**Statistical analysis**

Mean RTs were used for further analysis. The data were analysed using the Statistical Program for Social Sciences (SPSS), version 8.0. Differences between RTs for the left versus right hand were examined using repeated measures analysis of variance (ANOVA) with group as the between subjects factor and hand (left, right), condition (SRT, uncued CRT, fully cued CRT), and S1–S2 Interval (0, 200, 800, 1600, 3200 ms) as the within subject factors. For both groups, although RTs for the right hand were (non-significantly) faster than those for the left hand, there were no interaction effects of hand with any other variable (group, condition, S1-S2 interval). The data for the left and right hands were averaged for each condition. This average was used in all subsequent analyses.

$t$ Tests were used to further investigate significant interactions in the ANOVAs. When $t$ tests were used equal variances were not assumed. Paired $t$ tests were used to examine within subject measures and independent $t$ tests were used for between group measures.

To compare the difference between the true SRT and CRT conditions, data from the trials with an S1–S2 interval of 0 ms—that is, without a warning signal, were analysed using a repeated measures ANOVA. The between subject factor was group (patients, controls) and the within subject factors were condition (SRT of 0 ms S1–S2 interval) and uncued CRT (0 ms S1–S2 interval).

To examine the effects of advance movement parameter information on CRT, the differences between the uncued and fully cued CRT were
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The effects of using two types of advance information on RT were examined by directly comparing SRTs which can involve volitional and optional use of advance knowledge about S-R invariance for preprogramming of the response before stimulus presentation, and the fully cued CRT in which the cue provides full information about the specific response required on that trial which allows its selection and preparation before presentation of the imperative stimulus. A repeated measures ANOVA was used with group (patients, controls) as the between subject factor and condition (SRT, fully cued CRT) and interval (200, 800, 1600, 3200 ms) as the within subject factors.

Movement time was analysed using a repeated measures ANOVA. The between subject factor was group (patients, controls) and the within subject factors were condition (SRT, uncued CRT, fully cued CRT) and interval (0, 200, 800, 1600, 3200 ms).

Error data were analysed using Mann-Whitney U tests for the between groups comparisons and Wilcoxon matched pairs test for the within subject analyses.

Results

The two groups did not differ in age ($t(21) = 0.80$, $p > 0.05$) or male to female ratio ($x^2(1) = 0.62, p = 0.42$). Although the groups differed on scores on the mini mental examination ($t(21) = 2.1, p = 0.05$), no subject scored below the cutoff of 23.

Very few errors of any type were made by the patients or normal subjects. In the SRT for the schizophrenic group, the median number of anticipation errors was 0.10 (range 0.00–0.20) and the median number of long responses was 0.00 (range 0.00–0.10). For the controls, the median number of anticipation errors was 0.10 (range 0.00–0.40) and the median number of long responses was 0.00 (range 0.00–0.20). Across the CRT conditions, the schizophrenic group had a median of 0.10 (range 0.00–3.50) anticipation errors, 0.00 (range 0.00–3.00) long responses, and 0.10 (range 0.00–0.10) decision errors. Across the CRT conditions, the controls had a median of 0.00 (range 0.00–0.20) anticipation errors, 0.00 (range 0.00–0.15) long responses, and 0.00 (range 0.00–0.20) decision errors.

A series of Mann-Whitney U tests showed that there were no significant differences between the patients and controls in the number of anticipations, decision errors, or long responses in the various RT conditions ($p > 0.05$). Similarly, Wilcoxon matched pairs tests showed that there were no differences in errors between the various RT conditions for the patients with schizophrenia ($p > 0.05$). For the controls, there were more anticipation errors in the SRT compared with the uncued CRT ($Z = 2.5, p = 0.01$) but not in the fully cued CRT ($Z = 1.21, p = 0.22$) conditions. Also, for the controls there were more anticipation errors in the fully cued CRT than in the uncued CRT ($Z = 2.6, p = 0.01$).

**Figure 1** Mean reaction time for the normal subjects and the patients with schizophrenia in the unwarned simple reaction time (SRT) (black bar) and the uncued and unwarned choice reaction time (CRT) (open bar) tasks.

**UNCUED CRT VERSUS UNWARNED AND UNCUED CRT**

The mean RTs for the two groups in unwarned CRT and unwarned and uncued CRT conditions are presented in figure 1. The group effect was significant ($F(1, 20) = 7.94, p = 0.01$) with patients with schizophrenia having slower reaction times than the controls. The condition effect was significant ($F(1, 20) = 18.16, p = 0.001$) with CRTs being faster than SRTs; however the group $\times$ condition interaction was not significant ($p > 0.1$). To determine if the speeding up of CRT relative to SRT is an index of preprogramming was equivalent in the two groups, the differences in RT between the two conditions were examined using paired $t$ tests for each group. The mean differences between the CRT and SRT conditions was 60.3 (SD 50.6) ms for the controls and 69.1 (SD 91.8) ms for the patients with schizophrenia. The unwarned SRT was significantly faster than the uncued and unwarned CRT for both the controls ($t(12) = 4.30, p = 0.01$) and the patients with schizophrenia ($t(20) = 2.30, p = 0.05$).

**UNCUED CRT VERSUS FULLY CUED CRT**

The mean RTs for the two groups for the uncued and fully cued CRT are presented in figure 2. The main effects of group ($F(1, 21) = 8.32, p = 0.01$), condition ($F(1, 63) = 69.02, p = 0.001$), and interval ($F(3, 63) = 13.23, p = 0.001$) were significant. The group $\times$ condition interaction was not significant ($p < 0.05$). By
contrast, the condition × interval (F(3, 63) = 5.18, p = 0.003), the group × interval (F(3, 63) = 4.84, p = 0.004) and the group × condition × interval (F(3, 63) = 4.29, p = 0.01) interactions were significant.

Further analysis of the condition effect showed that across the two groups and the various intervals, the uncued CRT was significantly slower than the fully cued condition (p = 0.001). The significant main effect of interval was also examined in more detail. Across the two groups, RTs for the 800 ms S1−S2 interval were slower than those for the 200 ms (p = 0.01), the 1600 ms (p = 0.001) and the 3200 ms (p = 0.001) intervals. No other intervals differed significantly.

Further analysis of the group × interval interaction showed that for the control subjects RTs for the 3200 ms intervals were faster than those for the 200 ms (p = 0.04) and the 800 ms interval (p = 0.002). By contrast, for the patients with schizophrenia RTs for the 800 ms interval were slower than those for the 200, 1600, and 3200 ms intervals (p < 0.01) and no other intervals differed significantly.

Further analysis of the group × condition × interval interaction disclosed that across the two CRT tasks for the controls subjects fully cued CRT were significantly faster than the uncued CRT at each interval (200, 800, 1600, and 3200 ms) (p < 0.02). On average for the normal subjects, the fully cued CRT was faster than the uncued CRT by 19.9, 83.1, 68.7, and 73.4 ms respectively with the 200, 800, 1600, and 3200 ms S1−S2 intervals. Thus the differences between the two CRT conditions at the 200 ms interval, though small (mean 19.9 (SD 24.3) ms), reached significance. For the patients with schizophrenia the RTs for the fully cued CRT were significantly faster than the CRTs for the uncued CRT for the 1600 ms (faster on average by 86 ms) and 3200 ms (faster on average by 77.4 ms) intervals (p < 0.01) only.

SRT VERSUS FULLY CUED CRT

The mean RTs for the two groups for the SRT and fully cued CRT are shown in figure 3. The main effects of group (F(1, 20) = 7.60, p = 0.01), condition (F(1, 20) = 12.19, p = 0.002), and interval (F(3, 60) = 11.89, p = 0.001) were significant. The group × condition interaction (F(1, 20) = 2.35, p = 0.14) was not significant. The condition × interval (F(3, 60) = 2.80, p = 0.05), group × interval (F(3, 60) = 3.43, p = 0.02), and the group × condition × interval (F(3, 60) = 9.52, p = 0.01) interactions were significant.

The significant three way interaction was examined further by investigating differences between SRT and fully cued CRT for each of the four intervals within each group. For the normal subjects, fully cued CRTs were significantly slower than SRTs at the 200 ms interval (p = 0.001) but not at the 800, 1600, or 3200 ms intervals (p > 0.1). By contrast, for the patients with schizophrenia, CRTs were significantly

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**Figure 2** Mean reaction times for the normal subjects and the patients with schizophrenia in uncued (circle), and fully cued (square) CRT conditions.

**Figure 3** Mean reaction times for the normal subjects and the patients with schizophrenia in SRT (triangle) and fully cued CRT (square) conditions.
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Vect of neuroleptic medication have found no earected by the medication that eight of the patients with schizophrenia not taking medication, there is confounding factors on the RT results. As it will consider and exclude the possible effects of and controls.

Discussion

Overall, the RTs and MTs of patients with schizophrenia were significantly slower and more variable than those of age matched normal subjects across all conditions. Unwarned SRT were significantly faster than the uncued CRT in both groups. For both groups the fully cued CRTs were significantly faster than the uncued CRTs. There was a curious interval effect for the patients with schizophrenia which resulted from the fact that in the fully cued CRT condition, the patients with schizophrenia had CRTs which were significantly faster at the 200 ms than the 800 ms interval. Besides significant slowness in movement initiation and execution, significant differences in interval effects were the main factors that distinguished the various RTs of the patients and controls.

Before we discuss the main results further we will consider and exclude the possible effects of confounding factors on the RT results. As it was not possible to test the patients with schizophrenia not taking medication, there is always the possibility that the results obtained are affected by the medication that eight of the 10 patients were taking. Most existing studies have found no effect of neuroleptic medication on RTs. Nevertheless, in an RT paradigm with auditory stimuli, RTs were significantly lower for schizophrenic patients on medication than in those not taking medication.

Whereas the first results suggest that medication status may not affect RTs, the second study suggests that the slowing of RTs in schizophrenia may be partly attributable to the neuroleptic medication that is taken by most patients. If this is the case, then RTs should be assessed in drug-free patients, a procedure which is not feasible in most studies for clinical reasons. In the present study, there was some indication that the RTs of the two patients who were not taking any medication at the time of the study were in fact somewhat slower than those of the remaining eight patients taking medication.

For both groups, RTs slowed slightly during the experiment as seen by the increased RT in the final SRT task compared with the initial SRT. As there was no significant difference between the two groups on the amount of slowing, the results are not confounded by different patterns of fatigue effects in the two groups.

Precueing produced no differential effect on MT, as MTs for uncued and fully cued conditions did not differ significantly. By contrast, precueing or provision of advance movement parameter information, produced a significant effect on RTs. The RTs were significantly faster for the fully cued than for the uncued CRT. The differential effects of precueing on MTs and RTs suggest that the use of advance information for motor preparation is complete by the end of the RT period when the subject lifts his or her index finger from the home key and that there is no evidence of “on line” preparation during movement execution.

The two groups did not differ in the number of anticipations, decision errors, or long responses. Therefore, the differences in RT between the patients with schizophrenia and normal subjects do not seem to be associated with different speed-accuracy trade offs across the two groups.

USE OF STIMULUS RESPONSE INVARIANCE FOR PREPROGRAMMING IN CRT: SRT VERSUS UNCUED CRT

The patients with schizophrenia were significantly slower than the controls on both the SRT and uncued CRT tasks. However, for both groups the patients showed significantly faster than CRT. These results suggest that in the SRT condition, which involves optional and volitional preprogramming, the patients with schizophrenia preprogramme the response before presentation of the stimulus. As a result this condition was significantly faster than the uncued and unwarned CRT, which is a purely stimulus driven task in which no preprogramming is possible and the correct response is selected, prepared, and initiated only after presentation of the imperative stimulus. The significant slowness of SRT in schizophrenia relative to normal subjects agrees with the results of previous studies. Nuechterlein has reviewed the few studies which have directly compared SRT and uncued CRT in schizophrenia. As with the present results, all previous studies have found that CRT is slower than SRT for patients with schizophrenia, similar to normal subjects. However, the present results also showed that the CRT–SRT difference was similar in the two groups.

USE OF ADVANCE MOVEMENT PARAMETER INFORMATION FOR PREPROGRAMMING IN CRT: FULLY PRECUED VERSUS UNCUED CRT OR SRT

The fully cued CRTs were significantly faster than the uncued CRTs for the patients with schizophrenia, similar to the normal subjects. This is in agreement with previous studies suggesting that valid cues are used by patients with schizophrenia to speed up RT. However, the significant group×interval and group ×condition×interval interactions when comparing the fully cued CRT with the uncued CRT or SRT, disclosed that the patients with schizophrenia showed anomalies in the use of advance information. Confirming our previous finding for the normal subjects with the RT tasks used, an S1–S2 interval of 200 ms is not long enough for subjects to use advance information to speed
up fully cued CRTs to the level of SRTs. But with S1–S2 intervals of 800 ms or longer, the advance information provided by the precue is fully used by normal subjects to speed up precued CRTs and make these equivalent to the corresponding SRTs. For the patients with schizophrenia an unusual S1–S2 interval effect was present, mainly due to slower fully cued CRTs for the 800 ms and faster fully precued CRTs for the 200 ms S1–S2 interval. As a result, by contrast with the normal subjects, fully precued CRTs were equivalent to SRT even for the 200 ms interval, but not for the longer 800 ms S1–S2 interval or the 3200 ms interval. Examination of the raw data shows that the interval effect found was not caused by a single outlier. Nine of the 10 patients had slower fully cued CRTs for the 800 ms S1–S2 interval relative to the 200 ms S1–S2 interval. This abnormal S1–S2 interval effect may reflect inconsistencies of set in patients with schizophrenia similar to that seen in the cross over effect.27

There are some similarities between the current results for patients with schizophrenia and results from patients with Parkinson’s disease in our previous study.15 Both patient groups had significantly slower RTs and MTs than age matched normal subjects, both were able to use the S–R invariance to preprogramme the response in SRT and use advance information in precued CRT tasks to speed up their RT’s relative to uncued CRT. However, both groups showed abnormal interval effects. Patients with Parkinson’s disease required a longer S1–S2 interval (3200 ms) to speed up fully cued CRTs to the level of SRT whereas elderly normal subjects did so with an S1–S2 interval of 800 ms.15 In the present study, instability of attentional set in schizophrenia was associated with equivalent RTs for the fully cued CRT and SRT for the 200 ms and 1600 ms S1–S2 interval but not the 800 or 3200 ms S1–S2 intervals.28–32

**DEFICITS IN VOLITIONAL PROCESSES IN SCHIZOPHREНИA**

The extent to which actions are volitional or reflexive differ on a continuum from the completely automatic and reflexive such as the knee jerk, to the fully internally driven such as spontaneous actions. Most of our daily actions rest somewhere in between. This is also true of the various RT tasks used in the present study, which differed in the degree of volitional control required for selection, preparation, and initiation of a response. The uncued CRT task was probably the least demanding of volitional control. For this reason, the patients with schizophrenia showed no significant differences in uncued CRTs relative to the normal subjects. The SRT task would probably be placed next on a continuum of degree of volitional control required. The optional but internally driven preprogramming in the SRT task is dependent on an act of “will”, but as the stimulus–response pairing never varies, the subject preprogrammes the same response on each trial. There was evidence that the patients with schizophrenia were engaging in this. Finally, in the fully precued CRT, as the imperative stimulus repeated the information held in the precue, preprogramming was also optional and volitional and the subject could simply wait for the imperative stimulus before programming the response similar to uncued CRT. However, in the fully cued CRT although the exact response is known before presentation of the imperative stimulus, the subject must preprogramme a different response for each trial. Thus a higher degree of volitional control is required relative to SRT, where given the S–R invariance, the same response is preprogrammed across trials in a block.

Performance of SRT tasks concurrently with a second attention demanding task under dual task conditions, which introduces a capacity load and requires greater volitional control, has been shown to be particularly detrimental to the performance of patients with schizophrenia.31 In general, evidence suggests that patients with schizophrenia are particularly slowed by increases in task complexity in CRT tasks.30–32 For example, in a review of the literature on information processing in schizophrenia, Hemsley (D R Hemsley, unpublished PhD thesis 1976) concluded that CRT tasks involving low S–R compatibility are more sensitive to deficits in schizophrenia.28–30 There is some suggestion from the present results that in schizophrenia RT deficits become more evident as tasks require greater volitional control. As noted above, compared with SRT where the same response is preprogrammed across all trials, in fully cued CRT, a different response has to be preprogrammed on each trial, hence requiring greater allocation of attention and volitional control. It was precisely on the fully cued CRT condition that the patients with schizophrenia showed unusual and inconsistent interval effects suggesting instability of attentional set. These unusual interval effects are reminiscent of the cross over effect, which has been replicated in schizophrenia in numerous studies. The cross over effect has also been interpreted as reflecting an impaired ability to maintain attentional set.27 Such instability of attentional set may contribute to other deficits found in schizophrenia such as increased perseveration on the Wisconsin card sorting test34 or the modality shift effect.35

Therefore, the present results suggest that ordinarily, the patients with schizophrenia do not have any major deficits in preprogramming of responses in an SRT or a fully cued CRT task. However, in the second task, in which the volitional demands of preprogramming are higher as a different response has to be prepared on each trial, patients show some unusual and inconsistent interval effects suggesting instability of attentional set. In the present study, it was not possible to differentiate subgroups of patients with predominance of negative signs or positive symptoms. It is possible that future studies using RT tasks requiring greater volitional control (for example, with high stimulus–response incompatibility requiring volitional S–R decoding before response selection) and a sample of patients...
with schizophrenia and predominance of negative signs may show greater deficits in willed action.

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Impairment of willed actions and use of advance information for movement preparation in schizophrenia

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