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# Visual search irregularities in schizophrenia depend on display size switching

Todd S. Woodward
*Simon Fraser University, Burnaby* and *Riverview Hospital, Coquitlam, Canada*

Jennifer C. Whitman
*Simon Fraser University, Burnaby, Canada*

Katherine Arbuthnott
*University of Regina, Canada*

Tonya L. Kragelj
*Riverview Hospital, Coquitlam, Canada*

Jessica Lyons
*University of British Columbia, Vancouver, Canada*

Emmanuel Stip
*Hôpital L. H. Lafontaine, Montréal* and *Université de Montréal, Canada*

*Introduction*. In past research it has been demonstrated that when performing a visual search task with either one or multiple (4, 7 or 10) stimuli displayed, patients with schizophrenia demonstrate slow response times (RTs) in the display size of one, target-absent (one-absent) condition. The goals of the present investigation were to replicate this effect, and to gain an understanding of the underlying cognitive operations by comparing display-size switch to display-size repeat trials.

Correspondence should be addressed to Dr Todd S. Woodward, Department of Medicine and Research, Room 302, 3rd Floor, Henry Esson Young Building, Riverview Hospital, 2601 Lougheed Highway, Coquitlam, British Columbia, Canada, V3C 4J2; e-mail: twoodward@psych.ubc.ca

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*Methods*. In two experiments, patients and controls performed a visual search task with either one or four stimuli displayed. In Experiment 1 (one block with mixed switch and repeat trials), RT for display-size switch trials was compared to RT from display-size repeat trials. In Experiment 2, the display-size one and display-size four conditions were run in separate, homogeneous blocks.
*Results*. The results demonstrate that the one-absent slowing effect was eliminated on repeat trials, regardless of whether the switch and repeat trials were mixed or presented in separate blocks.
*Conclusions*. This set of results suggests that a combination of cueing and switching effects may underlie the one-absent slowing observed in patients, such that switching to the one-absent condition is difficult due to insufficient cueing of the relevant cognitive operations. This visual search paradigm is an excellent candidate for inclusion in the development of a neurocognitive profile specific to schizophrenia.

Kraepelin (1919) was among the first to highlight the importance of cognitive deficits in schizophrenia. Since then, cognitive deficits have been recognised as an integral aspect of the illness, with impairment being evident on most tests of higher mental abilities (Green, 1998; Heinrichs, 2001). Although meta-analyses have provided a good understanding of the pattern of relative impairment on standardised neuropsychological tests (Aleman, Hijman, de Haan, & Kahn, 1999; Heinrichs & Zakzanis, 1998; Rund & Borg, 1999), a neurocognitive profile that is uniquely characteristic of schizophrenia has proven elusive. This may be because traditional neuropsychological measures were designed with neurological patients in mind, and focal brain damage as seen in classical neurology may be a poor model for a disorder like schizophrenia (Heinrichs, 2001, pp. 31–33). The first step towards constructing a neurocognitive profile specific to schizophrenia is to identify cognitive paradigms that are sensitive to the specific cognitive impairments underlying this mental illness.

Evidence is now mounting that one such measure may be derived from the study of visual search speed. Research into visual search speed has clearly established that when two features of an object must be considered to find a target item within a field of distracters, search speed increases with the number of distracter items. Consider a situation in which a participant is required to find a black X within a field of white Xs and black Os. To detect the target, distinctions must be made on the dimensions of contrast polarity (black vs. white) and shape (X vs. O). In such a task, response (RT) increases with the number of stimuli presented (Treisman & Gelade, 1980; Wolfe, 1998). In healthy subjects, RT is fastest in the display size of one condition, regardless of target presence or absence. Moreover, keeping display size constant, target-absent responses are typically slower than target-present responses. The RT/number-of-stimuli slope is typically steeper in the target absent than in the target present condition, because when the target is present, the search is self-terminating (Corbetta, Shulman, Miezin, & Petersen, 1995; Navon, 1990).

Within the schizophrenia literature, Stip, Lussier, and colleagues (Lussier & Stip, 1998, 1999, 2001; Stip & Lussier, 1996; Stip, Lussier, Lalonde, Luyet, & Fabian, 1999) developed a paradigm similar to that described above, where the task was to search for a black X as a target among distracter stimuli consisting of black Os, white Xs, and white Os. They demonstrated that when the target was present, the pattern of responding in schizophrenia was similar to that in healthy individuals (although slowed). In contrast, when the target was absent, the pattern of performance for the schizophrenia group was abnormal. Namely, when the display size was one (i.e., the display consisted of only one stimulus) and the target was absent (hereafter referred to as the *one-absent* condition), the RT was notably slow compared to when the display size was four, seven, or ten and the target was absent. (We use the terms *one-present*, *four-present*, etc., and *one-absent*, *four-absent*, etc., to refer to the various combinations of target present/absent, and display size.)

A theoretical explanation regarding the cognitive underpinnings of this result has not been put forward. In the present investigation, we have taken the first step in formulating such a theoretical account. Specifically, we tested whether the one-absent slowing effect depends on switching between display sizes of one and four. The motivation of this approach is based on the assumption that different cognitive operations underlie performance in the one- and multiple-stimulus display conditions. If this were the case, switching display sizes would necessitate switching tasks. Task switching performance is known to decrease when stimuli provide poor or ambiguous cues for the relevant task, due to the additional cognitive operations required to select the appropriate task set from those currently held on line (Arbuthnott & Woodward, 2002; Jersild, 1927; Shallice, 1994; Woodward, Meier, Tipper, & Graf, 2003a). Moreover, people with schizophrenia are impaired at switching tasks (Meiran, Levine, Meiran, & Henil, 2000), and at effectively allocating attentional resources (Hutton, Joyce, Barnes, & Kennard, 2002; Strandburg et al., 1994; Strauss, Buchanan, & Hale, 1993). If the one-absent condition provides poor task cues, and task switching underlies display-size switching, one-absent slowing would be expected under display-size switching conditions (due to the associated poverty of task cues), but not under display-size repetition conditions.

In addition to the importance of display-size switching, the impact of the nature of the one-absent stimulus is also of theoretical significance to this ''task cueing'' interpretation of the one-absent slowing effect. For example, if one-absent slowing is increased when the one-absent stimulus shares features with the target (e.g., a white X and a black O), this would suggest a deficit in managing overlapping stimulus-response mappings. In contrast, if one-absent slowing is *decreased* under the same conditions, this would suggest impairment at the level of cueing. That is to say, this would suggest that the necessary cognitive operations that are elicited by the target stimulus (i.e., black X) are at least partially elicited by the one-absent stimuli that share features with the

target (e.g., white X and a black O), but not by the one-absent stimuli that share no features with the target (e.g., white O). If this result emerges, it should follow that the one-absent slowing will decrease when one-absent trials are immediately preceded by one-present trials. In this case, the necessary cognitive operations would have been elicited on the immediately preceding trial, rendering them more accessible on the present trial.

In the present work, we attempted to replicate the one-absent slowing effect using a cognitive paradigm that isolated the most important conditions from previous work. We achieved this by restricting the display sizes to one or four. We also tested whether or not the one-absent slowing effect observed in schizophrenia depended on group differences in managing display-size switching. This was achieved by carrying out repeat versus switching trial analyses, for which we expected the one-absent slowing pattern to be observed on switch trials, but not on repeat trials. In addition, we tested the contribution of cueing to the one-absent slowing effect. This was achieved by carrying out the ''shared features'' and ''one-absent preceded by one-present'' follow-up analyses mentioned above. Finally, a version of the experiment for which display sizes of one and four were presented in separate blocks was developed, for which the one-absent slowing pattern was expected to be eliminated.

## EXPERIMENT 1

### Method

*Participants*. A total of 57 inpatients (40 males, 17 females) diagnosed with schizophrenia or schizoaffective disorder according to DSM-IV criteria were recruited from Riverview Hospital and the Forensic Psychiatric Services Commission, Port Coquitlam, BC, Canada. A total of 38 control subjects (15 male, 23 females), consisting of Riverview Hospital staff and undergraduate students, also participated in the study. For the patients, the mean length of illness (since first hospitalisation) was 11.67 years ($SD$ = 9.38). Potential subjects were excluded if their premorbid IQ, as assessed by the QUICK IQ screen (Ammons & Ammons, 1962) was less than 70, if they had a history of acquired brain damage or traumatic head injury (e.g., with a loss of consciousness for more than 10 minutes), epilepsy, encephalitis, diabetes, HIV, hepatitis C, or hypothyroidism. For all but one of the subjects their primary language was English, and the eyesight for all subjects (assessed corrected and bilaterally) was 20/40 or better. At the time of testing, all but one patient was receiving atypical neuroleptic medication (chlorpromazine equivalent dosage in mg: $M$ = 784.67, $SD$ = 591.65).[1] The patient and control groups were matched on age: the mean age for patients was 36.84 years ($SD$ = 10.17), while the mean age for controls

[1] Medications, number of hospitalisations, and length of illness information for 2 patients were not obtained due to patient discharge.

was 32.34 (*SD* = 11.74). The mean number of years of education for patients was 11.58 (*SD* = 1.93) and 15.07 years (*SD* = 1.89) for controls.[2] There were significant differences between the two groups in years of education, $t(85) = 8.07$, $p < .001$, IQ (as assessed by the QUICK) $t(83) = 3.45$, $p < .005$, and gender $\chi^2(1) = 8.82$, $p < .005$.

*Materials*. Psychopathology was assessed using the Signs and Symptoms of Psychotic Illness scale (SSPI; Liddle, Ngan, Duffield, Kho, & Warren, 2002). The SSPI is a 20 item, 5-point rating scale that can be completed after a 25–30 minute semistructured interview with 15 direct questions about symptoms. The severity of each item is rated in the range of 0 to 4. The SSPI is criterion referenced, providing specific examples of behaviour that correspond to severity levels for each item. Generally, a score of 1 denotes questionable abnormality, 2 denotes definite but mild abnormality, 3 denotes pathology of moderate severity that has a substantial impact on mental functioning, and 4 indicates severe psychopathology. Based on previous work (Woodward, Ruff, Thornton, Moritz, & Liddle, 2003b; Woodward, Thornton, Ruff, Moritz, & Liddle, 2004), the following core items from the SSPI were summed to quantify the three-syndrome model of psychotic illness: underactivity, flattened affect, and poverty of speech for psychomotor poverty; inappropriate affect and disordered form of thought for disorganisation, and delusions and hallucinations for reality distortion.

*Procedure*. Subjects were presented with displays of one or four stimuli. In order to maintain consistency with previous studies, the letters presented consisted of a black X as the target (for target-present trials), and white Xs, white Os, and black Os as distracters. All stimuli were presented against a grey background in Arial 40 point font. Stimuli were presented in a square formation with 7.5 cm sides. At the four corners of the square, and at evenly spaced locations along the sides, 12 possible stimulus locations were allocated. The square was centred on a dark grey fixation point, and spanned a visual angle of approximately 9 degrees. No more than one black X was presented on any given trial. Each trial consisted of a blank screen presented for 800 ms, a fixation cross presented for 800 ms, another blank screen presented for 500 ms, and the stimulus display, which was ended by the subject's response. Stimuli were presented on a 14 inch monitor, using Superlab version 2.01 (Cedrus, 1999) for PCs. Visual search RT was recorded using a Cedrus RB-610 response box.

One experiment file of 240 trials was created and administered to all subjects. The 240 trials were split evenly among the four possible combinations of

[2] Years of education and IQ were not recorded for 8 of the 12 University of British Columbia undergraduate students in the control group. These 8 control subjects ranged in age from 18 to 22 years.

number of stimuli and target presence or absence. For the 120 target-present trials, the target (black X) appeared 10 times at each of the 12 possible screen locations. For the 60 four-stimulus-target-present trials, and for the 120 target-absent trials, the distracter stimuli were randomly assigned from colour and location parameters, under the restriction that no two stimuli could occupy the same location. The 240 experimental trials were presented in a different random order to each subject. This methodology resulted in 30 repeat and 30 switch trials per combination of number of stimuli and target presence or absence, averaged over subjects, and this did not differ between groups. The average length of a run of repeated display sizes was 2.97 (*SD* = 0.27).

Subjects began with a practice block of 14 trials, which was repeated if necessary until instructions were understood clearly. Prior to the practice run, subjects were instructed to press a key labelled ''YES'' if a black X was present or a key labelled ''NO'' if no black X was present, and were instructed to respond as quickly and accurately as possible. Responses were made with the index and middle fingers of the dominant hand, and the index/middle YES/NO correspondences were alternated over subjects.

## Results

The results, averaged over switch and nonswitch trials, are displayed in Figure 1. All reported tests of statistical significance were assessed at a level of .05, and all *t*-tests and correlations were assessed with two-tailed tests. The percentage of correct responses ranged, over conditions, from 96.26% to 97.36% for controls,

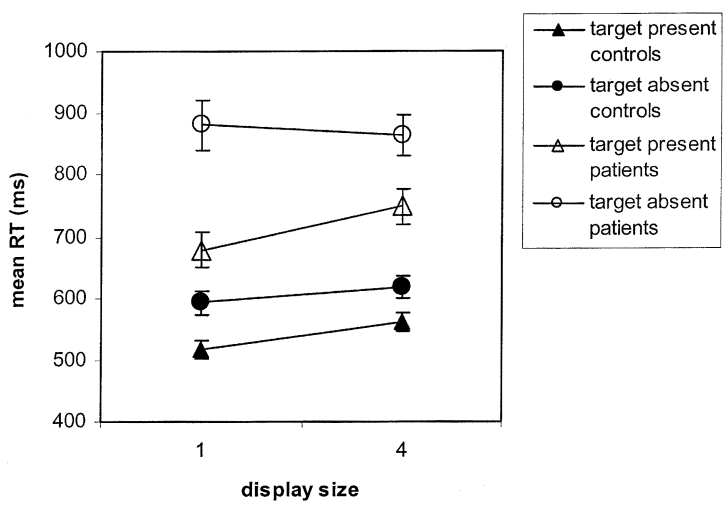


**Figure 1.** Experiment 1: Mean reaction times for patients and controls when the target was present and absent, plotted as a function of display size. Error bars represent standard errors.

and from 94.07% to 96.10% for patients, so errors were not analyzed due to the limited variability. Mean RT computed on correct trials was the unit of measurement for all analyses reported below. The visual search RTs were submitted to a 2 × 2 × 2 mixed-model analysis of variance (ANOVA) with target presence (or absence) and display size (1 vs. 4) as within-subject factors, and group (patient vs. control) as a between-subjects factor. This analysis resulted in a significant three-way interaction, $F(1, 93) = 8.45$, $p < .01$. In order to interpret this three-way interaction, two ANOVAs with target presence/absence and display size as factors were carried out separately for patients and controls. For patients, there were significant main effects of target presence/absence, $F(1, 56) = 64.79$, $p < .001$, and display size, $F(1, 56) = 9.87$, $p < .01$, and a highly significant interaction of target presence/absence by display size, $F(1, 56) = 24.01$, $p < .001$. For the controls, there were also significant main effects of target presence/absence, $F(1, 37) = 57.80$, $p < .001$, and display size, $F(1, 37) = 40.85$, $p < .001$, but the interaction only just reached significance, $F(1, 37) = 3.96$, $p = .05$. This set of analyses demonstrates that the significant three-way interaction is attributable to the presence of substantial one-absent slowing for the schizophrenic group only. For patients, when the target was present, faster RTs were associated with a display size of one than with a display size of four, $t(57) = 7.88$, $p < .001$. However, when the target was absent, RTs did not differ by display size, $t(57) = -1.06$, $p = .29$. For controls, a display size of one elicited significantly faster reaction times than a display size of four, regardless of target presence, $t(37) = 8.06$, $p < .001$, or absence, $t(37) = 2.87$, $p < .01$. The disorganisation syndrome was associated with RTs in all conditions (see Table 1). Medication parameters were not significantly associated with performance speed in any condition.

To assess the impact of display-size switching, trials were split on the basis of whether the preceding trial was of the same display size as the current trial (repeat trial) or not (switch trial). A 2 × 2 × 2 × 2 mixed-model analysis of variance (ANOVA) was carried out with target presence (or absence), display size (1 vs. 4), and switch versus repeat as within-subject factors, and with group

TABLE 1
Correlations between aggregate scores and reaction times in Experiment 1 (switching; $N = 57$)

| *Conditions* | *Psychomotor poverty* | *Disorganisation* | *Reality distortion* |
|---|---|---|---|
| Target-present, one stimulus | −.040 | .338* | −.056 |
| Target-present, four stimuli | −.066 | .355* | −.002 |
| Target-absent, one stimulus | .076 | .446** | −.065 |
| Target-absent, four stimuli | .122 | .423** | −.038 |

* $p < .05$; ** $p < .01$, two-tailed.

(patient vs. control) as a between subjects factor. This analysis resulted in a significant four-way interaction, $F(1, 93) = 3.92$, $p = .05$. As displayed in Figure 2, this interaction resulted from a pathological RT pattern in the patient group. Specifically, RTs in the one-absent condition were 81 ms *slower* than those in the four-absent condition in patients on switch trials, $t(57) = -2.67$, $p = .01$, and 47 ms *faster* on repeat trials, $t(57) = 3.10$, $p < .01$.

To explore the possibility that the one-absent slowing effect could be due to demographic differences between the patient and control groups, the effects of demographic variables on the one-absent/four-absent difference score were computed for the overall RTs (Figure 1), and switch trial RTs (Figure 2). Females and males did not differ on these variables for the controls or patients (*p*s. > .3 for all), and the difference scores also did not correlate significantly with IQ or years of education within either group (*p*s > .2 for all). It is therefore unlikely that these potential confounds contributed to the group differences on the effects of interest.

In order to better distinguish between the stimulus-response overlap and cueing accounts of the switching effect on one-absent slowing, a more detailed analysis of the one-absent responses was carried out in each group separately. This analysis revealed that white Os ($M = 910$) were responded to more slowly than white Xs ($M = 868$) or black Os ($M = 858$) for patients, $t(57) = 2.16$, $p < .05$, but not for controls, $t(37) = 0.80$, $p = .43$ (white Xs and black Os averaged).

As a final test of the cueing account, one-absent trials were split on the basis of whether or not they followed a one-present trial, on which the relevant cognitive operations were presumably cued and effectively retrieved. A 2 × 2

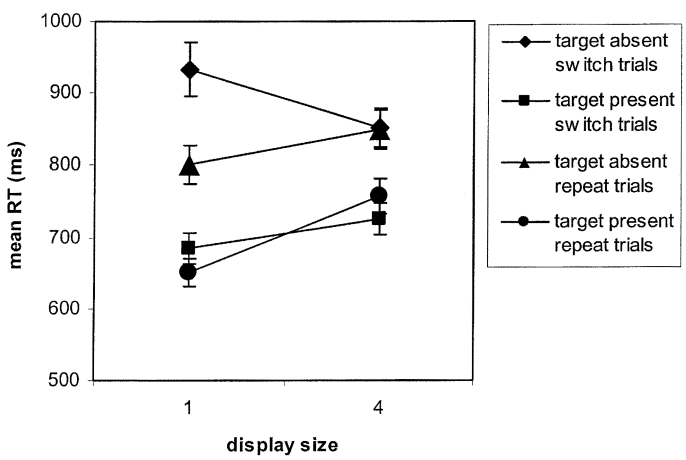


**Figure 2.** Experiment 1: Mean reaction times for patients on trials with display sizes that differ from (switch) or are the same as (repeat) the display size of the preceding trial, plotted as a function of display size. Error bars represent standard errors.

mixed-model ANOVA was performed, with cueing (whether or not the preceding trial was a one-present trial) as a within-subjects factor and group as a between-subjects factor. A significant main effect of cueing effect was found, $F(1, 93) = 9.05$, $p < .01$, as well as an interaction of cueing effect with group, $F(1, 93) = 5.31$, $p < .05$. The significant interaction was caused by speeded RTs on one-absent trials directly following a one-present trial for patients (80 ms RT speeding), $t(56) = 3.48$, $p < .001$, but not for controls, $t(37) = 0.81$, $p = .42$. From this it can be concluded that when cues are available, they effectively improve performance for patients, but not for controls.

## EXPERIMENT 2

In order to explicitly test whether the group differences in one-absent RTs depends on switching display size, in Experiment 2 trials of different display sizes were run in separate blocks.

### Method

*Participants*. A total of 36 inpatients (24 males, 12 females) diagnosed with schizophrenia or schizoaffective disorder according to DSM-IV criteria were recruited from Riverview Hospital and the Forensic Psychiatric Services Commission, Port Coquitlam, BC, Canada. A total of 17 control subjects (7 male, 10 females), consisting of Riverview Hospital staff participated in the study. For the patients, the mean length of illness (since first hospitalisation) was 15.68 years ($SD = 8.88$). Exclusion criteria were identical to those in Experiment 1. English was a second language for four of the control subjects, but all spoke English fluently. Eyesight assessed corrected and bilaterally was 20/40 or better for all but one patient (20/70). At the time of testing, all patients were receiving atypical neuroleptic medication (chlorpromazine equivalent dosage in mg: $M = 703.56$, $SD = 509.11$). The groups were matched for age: the mean age for patients was 36.28 years ($SD = 10.61$), while the mean age for controls was 37.76 ($SD = 11.05$). The mean number of years of education for patients was 11.86 ($SD = 2.32$) with a mean of 15.76 years ($SD = 2.25$) for controls. As was the case for Experiment 1, there were significant differences between the two groups on years of education, $t(51) = 5.77$, $p < .001$, and IQ (as assessed by the QUICK IQ screen), $t(51) = 5.58$, $p < .001$, but these groups did not differ significantly in gender make-up, $\chi^2(1) = 3.09$, $p = .08$. Seventeen patients and 4 controls who participated in Experiment 2 were also participants in Experiment 1.

*Materials and procedure*. Materials and procedures were identical to those in Experiment 1, except that in Experiment 2, trials were grouped into blocks by display size rather than being intermixed. The ordering of the blocks with a display size of one and four was counterbalanced across subjects. Subjects

carried out a practice task with the display size order consistent with the main experiment. For example, for a subject assigned to the four followed by one condition, a practice block of 7 trials with a display size of four followed by a block of 7 trials with a display size of one would be administered. The subsequent two experimental blocks would then consist of a block of 120 trials with a display size of four followed by a block of 120 trials with a display size of one.

## Results

All reported tests of statistical significance were assessed at a level of .05, and the significance of all *t*-tests and correlations were assessed using two-tailed tests. Over conditions, the percentage of correct responses ranged from 97.12% to 98.51% for controls, and from 95.38% to 97.69% for patients, so errors were not analysed due to the limited variability. Mean RT computed on correct trials was the unit of measurement for all analyses reported below. The RTs for the blocked visual search task were submitted to a 2 × 2 × 2 mixed-model analysis of variance (ANOVA) with target presence (or absence) and display size (1 vs. 4) as within-subject factors, and group (patient vs. control) as a between-subjects factor. There were highly significant main effects of target presence, $F(1, 51) = 56.18$, $p < .001$, and display size, $F(1, 51) = 46.17$, $p < .001$. There was also a significant interaction between target presence and group $F(1, 51) = 13.41$, $p = .001$. As shown in Figure 3, the effect of target presence was greater in the patient group than in the control group; in the target present condition, patients were 131.87 ms slower than controls, $t(51) = 3.39$, $p = .001$, while in the target-absent condition, patients were 173.67 ms slower than controls, $t(51) = 3.75$, $p <$

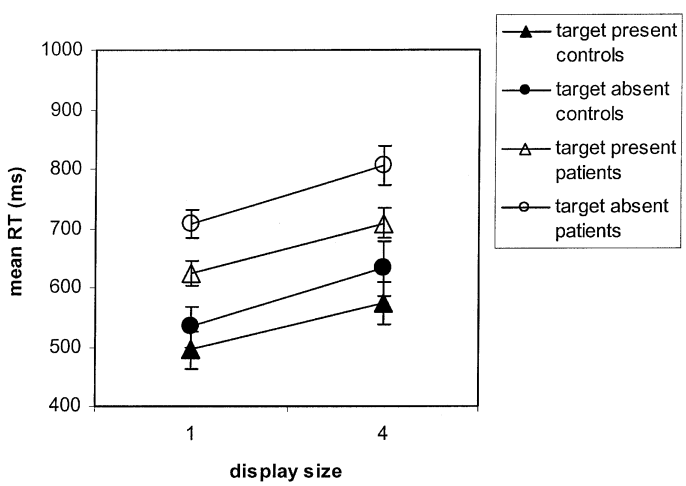


**Figure 3.** Experiment 2: Mean reaction times for patients and controls when the target was present and absent, plotted as a function of display size. Error bars represent standard errors.

.001. However, in contrast to the results of Experiment 1, RTs in the target-absent condition were significantly faster in for a display size of one than for a display size of four for both patients, $t(35) = 4.87$, $p < .001$, and controls, $t(16) = 4.52$, $p < .001$.

RTs were not correlated with symptomatology or medication dosage in this experiment. Thus, in combination with the Experiment 1 results, this experiment confirms that single- and multiple-stimulus search displays must alternate in order for the one-absent effect to be observed.

## DISCUSSION

In previous research, it was demonstrated that in a visual search paradigm when participants were required to locate a black X within a field of distracters, when the target was absent, the pattern of performance for the schizophrenia group was abnormal. Namely, when the display size was one (i.e., the display consisted of only one stimulus) and the target was absent, RT was notably slow compared to when the display size was four, seven, or ten and the target was absent. In the present investigation we replicated the finding of increased RT slowing in the one-absent condition. Moreover, we demonstrated that this effect was restricted to display-size switching trials, and when the display sizes of one and four were presented in separate blocks the effect was eliminated. This suggests that the display-size switching component is essential to the one-absent slowing effect. In addition, the one-absent slowing was reduced when one-absent stimuli shared features with the target (black O and white X trials), and when one-absent trials followed one-present trials, implicating cuing as an important contributor to the one-absent slowing effect. This set of results suggests that a combination of cueing and switching effects may underlie the one-absent slowing observed in patients, such that switching to the one-absent condition is impaired due to insufficient cueing of the relevant cognitive operations.

Task switching performance is known to decrease when stimuli provide poor or ambiguous cues for the relevant task, due to the additional cognitive operations required to choose the appropriate task set from those currently held on line (Arbuthnott & Woodward, 2002; Jersild, 1927; Shallice, 1994; Woodward et al., 2003a). Moreover, people with schizophrenia are impaired at switching tasks (Meiran et al., 2000), switching attention (Smith et al., 1998), switching response sets (Lafont et al., 1998; Moelter et al., 2001; Robert et al., 1998), effectively allocating attentional resources (Hutton et al., 2002; Strandburg et al., 1994; Strauss et al., 1993), and on working memory tasks (Barch, 2003; Barch, Sheline, Csernansky, & Snyder, 2003; Meyer-Lindenberg et al., 2001). If the one-absent condition provides the most ambiguous task cue, interrelated deficits in switching, allocation of attentional resources and working memory would be most salient in this condition.

It has been suggested that the commonly cited ''impaired representation and use of cognitive context'' deficit attributed to schizophrenia (Cohen, Barch, Carter, & Servan Schreiber, 1999; Cohen & Servan-Schreiber, 1992; Servan-Schreiber, Cohen, & Steingard, 1996) may be considered to be a key role of working memory (Elvevåg, Duncan, & McKenna, 2000). The current set of results suggests that the concept of ''context'' may be further unpacked to include *application* of temporarily stored rules and representations that are not explicitly cued by the external environment. Application of stored, but poorly cued rules and representations is referred to as ''internal cueing'' in the Parkinson's disease literature (Brown & Marsden, 1988; Fimm, Bartl, Zimmermann, & Wallesch, 1994), and requires expenditure of attentional resources (Woodward, Bub, & Hunter, 2002a). The one-absent condition, due to minimal cueing of task demands, may expose interrelated deficits in switching and effectively allocating attentional resources. This could be interpreted as one aspect of applying the context-appropriate strategies that are maintained in working memory.

What is the nature of the tasks that may be differentially required in the one- and four-stimulus displays? The visual search literature suggests that when multiple stimuli are searched, the most efficient strategy is to implement a *two-filter* approach, in which both relevant features (i.e., the colour black and the shape X) are maintained in working memory. The task would involve two substeps, both involving grouping and rejecting (Baylis & Driver, 1992; Duncan, 1995; Grossberg, Mingolla, & Ross, 1994; Humphreys, Riddoch, Quinlan, Price, & Donnelly, 1992; Treisman, 1982). In contrast, for a display size of one, an efficient strategy may be to maintain a mental image of the target stimulus on-line, such that evaluation of the stimulus would require the single step of *matching* to this mental image, such as that required in a choice response (e.g., Acosta & Nasman, 1992). When alternating between display sizes of one and four, it may be necessary to efficiently switch between tasks such as the two-filter and matching tasks, such that the internal cueing operations that facilitate task switching would be required for efficient performance.

The observed correlation between all switching conditions and the disorganization syndrome is consistent with prior reports of a significant negative relationship between the disorganisation syndrome and tests assessing mental flexibility, such as Trails B, the Wisconsin Card Sorting Test, verbal fluency and the Stroop task (Liddle & Morris, 1991; Moritz et al., 2001; Woodward et al., 2003b). Although several cognitive processes are implicated in these tasks (e.g., sustained attention, selective attention, and working memory), application of internal rules in the face of weak, ambiguous or misleading external cues is also common to all. Neurobiological research suggests that the anterior cingulate is critically involved in both processing conflicting information streams of information processing (Banich et al.,

2000; Carter et al., 2000; MacDonald, Cohen, Stenger, & Carter, 2000; Peterson et al., 1999; Ruff, Woodward, Laurens, & Liddle, 2001; Woodward, Ruff, & Ngan, 2002b), and the disorganisation syndrome (Liddle, 2001; Liddle et al., 1992; McGuire et al., 1998). Disorganised patients would therefore be expected to demonstrate impairment in tasks involving resolving conflict between competing tasks, such as the present visual search paradigm. Although data from the current study provide evidence for this association, the involvement of the anterior cingulate in visual search must remain speculative at this stage. Moreover, the connection between visual search performance and the disorganisation syndrome does not explain the one-absent slowing effect, which was present independently of symptom profile.

Future work on this paradigm will be needed to ensure that the effect is not procedure-specific. For example, the task should be designed using different stimuli, or using the same stimuli but randomly determining the target stimulus on a subject-by-subject basis. In addition, a wider variety of distracters should be used, in order to avoid repetition of distracter stimuli in the four stimulus displays, which may have enhanced performance in the four-absent condition. Another potential concern is that we used true randomisation of trials, and therefore did not specifically control repetition of target location, which may affect performance if it differed between groups. Additionally, gender, education, and IQ should be convincingly excluded as contributing factors by matching groups on these variables. Finally, it remains to be determined whether this pattern of performance discriminates between schizophrenia and other psychiatric groups, such as bipolar disorder.

This visual search paradigm is an excellent candidate for inclusion in the development of a neurocognitive profile specific to schizophrenia. The administration time is brief (approximately 15 minutes), the instructions are simple, the stimuli are language-independent, intact colour vision is not required, and the pattern of abnormal results is quantifiable and specific. In combination with repeated assessment of medication, this paradigm may also be useful for tracking medication effectiveness, as long-term learning effects are minimal (Lobley & Walsh, 1998). Similarly, it may be relevant to tracking rehabilitation efforts (e.g., training self-cueing of actions). In order to investigate more explicitly the theoretical account put forward here, manipulation of relevant cognitive variables, such as working memory load, number of stimulus dimensions, the nature of task cues, or the opportunity to prepare for switches in advance (e.g., see Meiran et al., 2000) will be necessary.

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## REFERENCES


Acosta, V. W., & Nasman, V. T. (1992). Effect of task decision on P300. *International Journal of Psychophysiology*, *13*, 37–44.

Aleman, A., Hijman, R., de Haan, E. H. F., & Kahn, R. S. (1999). Memory impairment in schizophrenia: A meta-analysis. *American Journal of Psychiatry*, *156*, 1358–1366.

Ammons, R. B., & Ammons, C. H. (1962). *Psychological Reports* [Monograph supplement], 1–VII.

Arbuthnott, K. D., & Woodward, T. S. (2002). The influence of cue-task association and location on switch cost and alternating-switch cost. *Canadian Journal of Experimental Psychology*, *56*, 18–29.

Banich, M. T., Milham, M. P., Atchley, R., N.J., C., Webb, A., Wszalek, T., Kramer, A. F., Liang, Z., Barad, V., Gullett, D., Shah, C., & Brown, C. (2000). Prefrontal regions play a predominant role in imposing an attentional ''set'': Evidence from fMRI. *Cognitive Brain Research*, *10*, 1–9.

Barch, D. M. (2003). Cognition in schizophrenia: Does working memory work? *Current Directions in Psychological Science*, *12*, 146–150.

Barch, D. M., Sheline, Y. I., Csernansky, J. G., & Snyder, A. Z. (2003). Working memory and prefrontal cortex dysfunction: Specificity to schizophrenia compared with major depression. *Biological Psychiatry*, *53*, 376–384.

Baylis, G. C., & Driver, J. (1992). Visual parsing and response competition: The effect of grouping factors. *Perception & Psychophysics*, *51*, 145–162.

Brown, R. G., & Marsden, C. D. (1988). Internal versus external cues and the control of attention in Parkinson's disease. *Brain*, *111*, 323–345.

Carter, C. S., Macdonald, A. M., Botvinick, M., Ross, L. L., Stenger, V. A., Noll, D., & Cohen, J. D. (2000). Parsing executive processes: Strategic vs. evaluative functions of the anterior cingulate cortex. *Proceedings of the National Academy of Sciences of the United States of America*, *97*, 1944–1948.

Cedrus. (1999). *SuperLab Experimental Lab Software* (*Version 2.01*). San Pedro, CA: Cedrus Corporation.

Cohen, J. D., Barch, D. M., Carter, C., & Servan Schreiber, D. (1999). Context-processing deficits in schizophrenia: Converging evidence from three theoretically motivated cognitive tasks. *Journal of Abnormal Psychology*, *108*, 120–133.

Cohen, J. D., & Servan-Schreiber, D. (1992). Context, cortex, and dopamine: A connectionist approach to behavior and biology in schizophrenia. *Psychological Review*, *99*, 45–77.

Corbetta, M., Shulman, G. L., Miezin, F. M., & Petersen, S. E. (1995). Superior parietal cortex activation during spatial attention shifts and visual feature conjunction. *Science*, *270*, 802–805.

Duncan, J. (1995). Target and nontarget grouping in visual search. *Perception & Psychophysics*, *57*, 117–120.

Elvevåg, B., Duncan, J., & McKenna, P. J. (2000). The use of cognitive context in schizophrenia: An investigation. *Psychological Medicine*, *30*, 885–897.

Fimm, B., Bartl, G., Zimmermann, P., & Wallesch, C. W. (1994). Different mechanisms underlie shifting set on external and internal cues in Parkinson's disease. *Brain and Cognition*, *25*, 287–304.

Green, M. F. (1998). *Schizophrenia from a neurocognitive perspective: Probing the impenetrable darkness*. Needham Heights, MA: Allyn & Bacon.

Grossberg, S., Mingolla, E., & Ross, W. D. (1994). A neural theory of attentive visual search: interactions of boundary, surface, spatial, and object representations. *Psychological Review*, *101*, 470–489.

Heinrichs, W. (2001). *In search of madness: Schizophrenia and neuroscience*. New York: Oxford University Press.

Heinrichs, W., & Zakzanis, K. K. (1998). Neurocognitive deficit in schizophrenia: A quantitative review of the evidence. *Neuropsychology*, *12*, 426–445.

Humphreys, G. W., Riddoch, M. J., Quinlan, P. T., Price, C. J., & Donnelly, N. (1992). Parallel pattern processing and visual agnosia. *Canadian Journal of Psychology*, *46*, 377–416.

Hutton, S. B., Joyce, E. M., Barnes, T. R., & Kennard, C. (2002). Saccadic distractibility in first-episode schizophrenia. *Neuropsychologia*, *40*, 1729–1736.

Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology*, *89*, 5–82.

Kraepelin, E. (1919). *Dementia praecox and paraphrenia*. Edinburgh: E. & S. Livingstone.

Lafont, V., Medecin, I., Robert, P. H., Beaulieu, F. E., Kazes, M., Danion, J. M., Pringuey, D., & Darcourt, G. (1998). Initiation and supervisory processes in schizophrenia and depression. *Schizophrenia Research*, *34*, 49–57.

Liddle, P. F. (2001). *Disordered mind and brain: The neural basis of mental symptoms*. London: Gaskell.

Liddle, P. F., Friston, K. J., Frith, C. D., Hirsch, S. R., Jones, T., & Frackowiak, R. S. (1992). Patterns of cerebral blood flow in schizophrenia. *British Journal of Psychiatry*, *160*, 179–186.

Liddle, P. F., & Morris, D. L. (1991). Schizophrenic syndromes and frontal lobe performance. *British Journal of Psychiatry*, *158*, 340–345.

Liddle, P. F., Ngan, E. T. N., Duffield, G., Kho, K., & Warren, A. J. (2002). The signs and symptoms of psychotic illness: A rating scale. *British Journal of Psychiatry*, *180*, 45–50.

Lobley, K., & Walsh, V. (1998). Perceptual learning in visual conjunction search. *Perception*, *27*, 1245–1255.

Lussier, I., & Stip, E. (1998). The effect of Risperidone on cognitive and psychopathological manifestations of schizophrenia. *CNS Spectrums*, *3*, 55–69.

Lussier, I., & Stip, E. (1999). Attention sélective et schizophrénie avant l'administration de neuroleptiques. *L'Encephale*, *25*, 576–583.

Lussier, I., & Stip, E. (2001). Memory and attention deficits in drug naive patients with schizophrenia. *Schizophrenia Research*, *48*, 45–55.

MacDonald, A. W., Cohen, J. D., Stenger, V. A., & Carter, C. (2000). Dissociating the role of the dorsolateral prefrontal and anterior cingulate cortex in cognitive control. *Science*, *288*, 1835–1838.

McGuire, P. K., Quested, D. J., Spence, S. A., Murray, R. M., Frith, C. D., & Liddle, P. F. (1998). Pathophysiology of 'positive' thought disorder in schizophrenia. *British Journal of Psychiatry*, *173*, 231–235.

Meiran, N., Levine, J., Meiran, N., & Henil, A. (2000). Task set switching in schizophrenia. *Neuropsychology*, *14*, 471–482.

Meyer-Lindenberg, A., Poline, J. B., Kohn, P. D., Holt, J. L., Egan, M. F., Weinberger, D. R., & Berman, K. F. (2001). Evidence for abnormal cortical functional connectivity during working memory in schizophrenia. *American Journal of Psychiatry*, *158*, 1809–1817.

Moelter, S. T., Hill, S. K., Ragland, J. D., Lunardelli, A., Gur, R. C., Gur, R. E., & Moberg, P. J. (2001). Controlled and automatic processing during animal word list generation in schizophrenia. *Neuropsychology*, *15*, 502–509.

Moritz, S., Andresen, B., Jacobsen, D., Mersmann, K., Wilke, U., Lambert, M., Krausz, M., & Naber, D. (2001). Neuropsychological correlates of schizophrenic syndromes in patients treated with atypical neuroleptics. *European Psychiatry*, *16*, 354–361.

Navon, D. (1990). Does attention serve to integrate features? *Psychological Review*, *97*, 453–459.

Peterson, B. S., Skudlarski, P., Gatenby, J. C., Zhang, H., Anderson, A. W., & Gore, J. C. (1999). An fMRI study of Stroop word-color interference: Evidence for cingulate subregions subserving multiple distributed attentional systems. *Biological Psychiatry*, *45*, 1237–1258.

Robert, P. H., Lafont, V., Medecin, I., Berthet, L., Thauby, S., Baudu, C., & Darcourt, G. (1998). Clustering and switching strategies in verbal fluency tasks: Comparison between schizophrenics and healthy adults. *Journal of the International Neuropsychological Society: JINS*, *4*, 539–546.

Ruff, C. C., Woodward, T. S., Laurens, K. R., & Liddle, P. F. (2001). The role of the anterior cingulate cortex in conflict processing: Evidence from reverse Stroop interference. *Neuroimage*, *14*, 1150–1158.

Rund, B. R., & Borg, N. E. (1999). Cognitive deficits and cognitive training in schizophrenia patients: A review. *Acta Psychiatrica Scandinavica*, *100*, 85–95.

Servan-Schreiber, D., Cohen, J. D., & Steingard, S. (1996). Schizophrenic deficits in the processing of context. *Archives of General Psychiatry*, *53*, 1105–1112.

Shallice, T. (1994). Multiple levels of control processes. In C. Umiltà & M. Moscovitch (Eds.), *Attention and performance: XV. Conscious and nonconcious information processing* (pp. 395–420). Cambridge, MA: MIT Press.

Smith, G. L., Large, M. M., Kavanagh, D. J., Karayanidid, F., Barrett, N. A., Michie, P. T., & O'Sullivan, B. T. (1998). Further evidence for a deficit in switching attention in schizophrenia. *Journal of Abnormal Psychology*, *107*, 390–398.

Stip, E., & Lussier, I. (1996). The effect of Risperidone on cognition in patients with schizophrenia. *Canadian Journal of Psychiatry*, *41*, S35–S40.

Stip, E., Lussier, I., Lalonde, P., Luyet, A., & Fabian, J. (1999). Neuroleptiques atypiques et attention sélective. *L'Encephale*, *25*, 260–264.

Strandburg, R. J., Marsh, J. T., Brown, W. S., Asarnow, R. F., Guthrie, D., Higa, J., Yee-Bradbury, C. M., & Nuechterlein, K. H. (1994). Reduced attention-related negative potentials in schizophrenic adults. *Psychophysiology*, *31*, 272–281.

Strauss, M. E., Buchanan, R. W., & Hale, J. (1993). Relations between attentional deficits and clinical symptoms in schizophrenic outpatients. *Psychiatry Research*, *47*, 205–213.

Treisman, A. (1982). Perceptual grouping and attention in visual search for features and for objects. *Journal of Experimental Psychology. Human Perception and Performance*, *8*, 194–214.

Treisman, A., & Gelade, G. (1980). A feature integration theory of attention. *Cognitive Psychology*, *12*, 97–136.

Wolfe, J. M. (1998). Visual search. In H. Pashler (Ed.), *Attention*. London: University College London Press.

Woodward, T. S., Bub, D. N., & Hunter, M. A. (2002a). Task switching deficits associated with Parkinson's disease reflect depleted attentional resources. *Neuropsychologia*, *40*, 1948–1955.

Woodward, T. S., Laurens, K. R., Ruff, C. C., Moritz, S., Tipper, C., Ngan, E. T. C., & Liddle, P. F. (2002b). A role for the anterior cingulate cortex in resolution of prior inhibition [abstract]. *Cognitive Neuroscience Annual Meeting Program 2002: A Supplement of the Journal Cognitive Neuroscience* (p. 47). Durham: Cognitive Neuroscience Society.

Woodward, T. S., Meier, B., Tipper, C., & Graf, P. (2003a). Bivalency is costly: Bivalent stimuli elicit cautious responding. *Experimental Psychology*, *50*, 233–238.

Woodward, T. S., Ruff, C. C., Thornton, A. E., Moritz, S., & Liddle, P. (2003b). Methodological considerations regarding the association of Stroop and verbal fluency performance with the symptoms of schizophrenia. *Schizophrenia Research*, *61*, 207–214.

Woodward, T. S., Thornton, A. E., Ruff, C. C., Moritz, S., & Liddle, P. (2004). Material-specific episodic memory associates of the psychomotor poverty syndrome in schizophrenia. *Cognitive Neuropsychiatry*, *9*, 213–227.