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Attentional capture in schizophrenia: Failure to resist interference from motion signals

M. G. Ducato a, G. A. Michael b, P. Thomas a, P. Despretz a, J. L. Monestes c, G. Loas c, M. Boucart a

a Lab. Neurosciences fonctionnelles & pathologies, CNRS Université Lille, Lille, France
b Lab. Etude des Mécanismes Cognitifs, CNRS Université Lyon 2, Lyon, France
c Lab. Neurosciences fonctionnelles & pathologies CNRS, CHU Amiens, Amiens, France

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Attentional capture in schizophrenia: Failure to resist interference from motion signals

M. G. Ducato
Lab. Neurosciences fonctionnelles & pathologies, CNRS Université Lille, 2 CHU Lille, France

G. A. Michael
Lab. Etude des Mécanismes Cognitifs, CNRS Université Lyon 2, Lyon, France

P. Thomas and P. Despretz
Lab. Neurosciences fonctionnelles & pathologies, CNRS Université Lille, 2 CHU Lille, France

J. L. Monestes and G. Loas
Lab. Neurosciences fonctionnelles & pathologies CNRS, CHU Amiens, Amiens, France

M. Boucart
Lab. Neurosciences fonctionnelles & pathologies, CNRS Université Lille, 2 CHU Lille, France

Introduction. Patients with schizophrenia show high susceptibility to distraction but the neural mechanisms underlying sensitivity to distraction are not clearly established. We designed a paradigm to assess whether sensitivity to distraction and dorsal stream dysfunction are related in schizophrenia.

Method. 60 patients, 37 schizotypals, and 58 healthy controls were asked to locate a target square appearing above or below fixation and to ignore a distractor that either moved abruptly (in Experiments 1 and 3) or changed in colour (in Experiment 2). The distractor condition was compared to a baseline condition with no distractor. Resistance to interference was assessed by manipulating the
probability of the distractor changing more frequently (50%, 75%, 100%) on one side of fixation.

**Results.** Patients, schizotypals, and controls showed attentional capture with longer response times when the distractor changed as compared to the baseline condition. In contrast to controls, the magnitude of interference from distractors remained stable for patients and schizotypals across all probability conditions and this was confined to attentional capture by motion, not by colour.

**Conclusion.** We found a similar pattern of results in patients and in schizotypals. Our attentional capture paradigm could help to identify early cognitive impairments in populations at risk to develop schizophrenia. The data are interpreted in terms of dysfunction of frontal control on dorsal stream functions in schizophrenia.

**INTRODUCTION**

It has been shown for several decades that patients with schizophrenia display exaggerated susceptibility to distraction. In the 1960s, (Ludwig, Stilson, Wood, and Downs, 1963; Ludwig, Wood, & Downs, 1962) found that patients were less adept than controls at discriminating signals from irrelevant noise. Maruff et al. (1995, 1998) reported that patients with schizophrenia exhibit difficulties to inhibit overt reflexive shifts of attention in an antisaccade task, in which observers were asked to make eye movements in the direction opposite to that of a sudden-onset peripheral target. More errors and increased latencies were observed in the patients’ group as compared to controls. In the Stroop task, patients with schizophrenia usually display greater interference in the card version in which coloured words are surrounded by other coloured words than in the single trial version with isolated coloured words (Boucart, Mobarek, Cuervo & Danion, 1999; Henik & Salo, 2004, for a review). Several explanations have been proposed for this oversensitivity to distraction including reduced selective attention, failure to sustain attention on the relevant stimuli, inability to inhibit automatic attentional shifts, inability to maintain task set, or impaired conflict monitoring (Henik & Salo, 2004; Maruff, Danckert, Pantelis, & Currie, 1998; Maruff, Hay, Malone, & Currie, 1995; Yücel et al., 2002).

Attentional impairments in patients with schizophrenia are often observed in tasks requiring inhibition of a prepotent response, for instance, in tasks in which observers are explicitly asked to move their eyes in the direction opposite to the target in the antisaccade task, to name the colour and to inhibit the automatic reading of the words in the Stroop task, to name the opposite colour of a target in the reverse flanker condition (e.g., respond green for a red square surrounded by green flankers; Yücel et al., 2002). In terms of neural substrate it has been suggested that functional abnormalities within frontocingulate regions may underlie some of the findings of abnormal performance in patients with schizophrenia especially
in tasks involving working memory, selection of relevant information, and action planning (Andreasen, 1999).

In order to function efficiently in natural environments it is important to be able to rapidly distinguish between different types of signals occurring in the visual field. Sometimes a signal may require immediate action. At other times, no action is required, as when this information is irrelevant for the current goal of the observer. Under certain conditions a signal (e.g., the sudden opening of a window) can involuntarily draw attention to its location in a stimulus-driven manner. This situation is referred to as attentional or exogenous capture.

Implicit attentional capture occurs when a salient and irrelevant stimulus affects performance on another task regardless of whether or not the observer is aware of the stimulus (Simons, 2000). The classical paradigm of attentional capture involves a visual search task in which a salient singleton (or distractor) is presented in the display. This singleton is unrelated and irrelevant to the search task. This condition is compared to one in which the irrelevant singleton is not present and/or in which the singleton is the target. Time to find the target increases when an irrelevant singleton captures attention before attention can be redirected to the target. Theeuwes, Kramer, and Kingstone (2004) showed that attentional capture by a distractor also affects target’s detectability (as measured by the $d'$ index of sensitivity in the signal detection theory). Attention shifts to the distractor are usually initiated by abrupt peripheral changes. The bottom-up shift of attention to a salient item is thought to be the result of relatively inflexible hardwired mechanisms. A variety of experimental tasks have been developed to explore what properties of the stimulus draw attention. What emerges from the literature is that mostly dynamic discontinuities such as abrupt onsets grab attention automatically. Moving targets have a high salience in attracting attention in the peripheral field. The sudden appearance of a light, a motion, or the abrupt appearance of a new object draws our attention regardless of our current task (Jonides & Yantis, 1988; Yantis & Hillstrom, 1994), whereas colour and form seem to be less efficient though attentional capture by colour has been reported (Theeuwes et al., 2004; Turatto & Galfano, 2000; Turatto, Galfano, Gardini, & Mascetti, 2004). It has been suggested (Yantis & Hillstrom, 1994) that abrupt onsets receive attentional priority because the ability to detect and respond to them has adaptive significance and might require an immediate response.

The fact that attentional capture is very sensitive to motion and flicker, to abrupt onsets, that it is strongly elicited by peripheral signals (Abrams & Christ, 2003; Jonides & Irwin, 1981; Yantis & Hillstrom, 1994; Yantis & Jonides, 1984, 1990) suggests that automatic attentional capture might be subserved by rapid transient mechanisms.
In order to function efficiently we also have to be able to control automatic attentional capture. For instance, if the opening of the window occurs repeatedly and regularly the automatic orienting of attention towards this signal has to be inhibited and this requires top-down control processes. Few studies have been designed to investigate the neural substrate of attentional capture. These studies suggest the involvement of a neural network including regions of the frontal operculum, the superior colliculus, and the superior parietal cortex (Michael, Garcia, Fernandez, Sellal, & Boucart, 2006). It has been shown that defective top-down attentional control may result in continuous automatic attentional capture by known task-irrelevant events (Gaymard, Francois, Ploner, Condy, & Rivaud-Pechoux, 2003; Michael, Kleitz, Sellal, Hirsch, & Marescaux, 2001). Such effects were observed following a disruption of a frontocولlicular pathway, either following a lesion of the frontal cortex (Michael et al., 2001) or a lesion of a direct tract that connects the frontal cortex to the superior colliculus (Gaymard, Shomstein, Leber, Golay, Egeth, and Yantis, 2003). The involvement of the frontal cortex in the control of interference from attention-capturing distractors was recently confirmed in fMRI studies. De Fockert and colleagues (2004) found a strong negative correlation between the frontal activity and the magnitude of attentional capture, a result that suggests that the weaker the frontal activity the stronger the attentional capture. Furthermore, the authors found increased activity in the parietal cortex associated with spatial shifts towards distractors. Serences, Shomstein, Leber, Golay, Egeth, and Yantis (2005) also found activity in the temporoparietal junction and the ventral frontal cortex elicited by to-be-ignored distractors. There is thus converging evidence (1) on signals transmitted from the frontal cortex to the superior colliculus conveying a command for diminishing attentional capture (de Fockert, Rees, Frith, & Lavie, 2004; Gaymard et al., 2003; Michael et al., 2001, 2006), and on location signals provided by the parietal cortex (de Fockert et al., 2004) that may guide attention toward the spatial source of sudden events, and (2) behavioural and anatomical evidence that automatic attentional capture involves mainly the dorsal stream. Research on attentional capture thus offers important insights as for the neural substrates and cognitive processes underlying visual distraction. As distraction is one of the main problems encountered by schizophrenic patients and in the schizophrenia spectrum, we investigated automatic (stimulus-driven) and controlled shifts of attention in schizophrenia and in schizotypals through attentional capture.

To this aim we designed an attentional capture paradigm in which the observer’s task was to locate a target while a to-be-ignored distractor underwent a change in the spatial environment of the target. To investigate the patient’s ability to control attention and filter out irrelevant information,
we manipulated the probability of the location of the distractor’s change, that is, the change in the state of the distractor (motion or colour) could occur randomly left and right of fixation or be more frequent on one side or, even, always occur on the same side of fixation. If schizophrenia is characterised by oversensitivity to distractors and impaired filtering of irrelevant information, it can be expected that patients with schizophrenia will exhibit automatic attentional capture even when there is a high probability for the distractor to appear at the same spatial location. Given that abnormalities found in patients with schizophrenia are often also reported in healthy people with high scores of schizotypy (e.g., Schwartz, Tomlin, Evans, & Ross, 2001; Uhlhaas, Silverstein, Phillips, & Lovell, 2004), we expected a similar pattern of results in patients and in schizotypals.

GENERAL METHOD

Unless otherwise mentioned the same method was used in the three experiments.

Participants

The study was approved by the ethical committee of Lille. Sixty inpatients meeting DSM-IV criteria for schizophrenia admitted at the psychiatric departments of the hospitals of Lille, Amiens, and Armentières (France) provided written informed consent to participate to the study. They ranged in age from 20 to 67. Diagnosis of schizophrenia was defined by DSM-IV on the basis of the Mini International Neuropsychiatric Interview Plus (MINI Plus; Sheehan et al., 1998) and a short diagnostic structured interview assessed by an experienced clinician. Positive and Negative Syndrome Scale (PANSS) was used to measure the severity of psychopathology (Kay, Fiszbein, & Opler, 1987). Fifty-five healthy volunteers ranging in age from 19 to 64 signed a written informed consent and were paid for their participation. Thirty-six schizotypals were selected in the following way: 600 undergraduate students were asked to fill the French version of the Chapman social anhedony scale (Chapman, Chapman, & Raulin, 1976; Dumas et al., 2000). They had never seen the scale before. They were told that this questionnaire was a first stage and that they might be asked to participate to experiments on attention. Only 5% of the students refused to fill the questionnaire. Students whose score was two standard deviations above the mean score were called and asked to participate. The score required to be included in the experiment was not given to the students. The mean score was 7.4 (+ 3.6). None of them had a history of psychiatric illness. Schizotypals ranged in age from 20 to 34. All
participants were checked for their visual acuity and colour perception (Ishihara test). Any of the following criteria excluded a participant from the study: ophthalmic or neurological disease, uncorrected myopia, and mental retardation.

**Stimuli and task**

The stimuli were displayed on a colour screen connected to a laptop computer (Dell Latitude D520). The software was written by one of the authors (P. Despretz). Participants responded on a box containing two keys connected to the computer. The stimuli were geometrical shapes. A black square subtending $3^\circ$ of visual angle, at a viewing distance of 35 cm, served as target. The distractors were two disks, also subtending $3^\circ$, and centred $4^\circ$ left and right of fixation. The fixation cross (+) and the two lateral disks (distractors) were always present. The target square appeared either above ($4^\circ$ eccentricity) or below fixation. The display is presented in Figure 1. The interval between response and the display of the target square (next trial) varied randomly from 1500 to 2000 ms. The task was to locate the target

![Figure 1](image-url)
(top/bottom) in pressing one of the two response keys placed vertically in front of the participant. As the target appeared one of the distractors changed in state. The type of change is described in each experiment. In the capture condition one of the distractors changed (in 50% of the trials). In the baseline condition both distractors remained fixed (in the other 50% of the trials).

Performance was compared in three conditions determined by the probability of the side of change. On trials in which one of the distractors changed, the change could occur with an equal probability (50%) left or right of fixation or it could be more frequent on the left of fixation (75% or 100%). Participants were informed that one of the disks could move (or change in colour according to the experiment). They were told to focus their attention on the target, to respond as fast as possible to its spatial location, and to ignore the disks (the distractors). The target remained on the screen until response. The three probability conditions (50%, 75%, 100%) were presented in separate blocks of 100 trials each. Within each block the baseline and the capture conditions were randomly presented. The order of the three blocks was mixed between participants. Response times (RTs) and errors were automatically recorded by the computer. Since the task was very easy, no practice session was given. The whole session lasted about 15 minutes.

**Statistical analysis**

Analyses were conducted on both response times (RTs) and error rates. Between-group comparisons were performed by using analysis of variance. Comparisons between baseline and capture conditions were performed by using paired t-tests. Statistical analyses were performed with the software SYSTAT 8. The between-subject factor was group (controls, schizotypals, patients). The within-subject factors were the condition (capture vs. baseline) and the probability of the distractor changing on the left side (50%, 75%, and 100%).

**EXPERIMENT 1: CAPTURE BY MOTION ONSET (JITTER)**

**Method**

*Participants.* 27 patients with schizophrenia (22 males), 20 schizotypals, and 20 healthy controls took part in the experiment. Data about the patients group (duration of illness, medication, etc.) are presented in Table 1. Their score for positive and negative symptoms at the PANSS are presented in Table 2.
### TABLE 1
Average age, gender, education, duration of illness, and medication (chlorpromazine equivalence and benzodiazepines) for patients in each experiment

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Age mean (±SD)</th>
<th>Gender</th>
<th>Education (±SD)</th>
<th>Duration of illness equivalence (±SD)</th>
<th>Chlorpromazine mean (±SD)</th>
<th>Benzodiazepines mean (±SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1: Capture by motion onset (jitter)</td>
<td>34 (±12.5)</td>
<td>22M/5F</td>
<td>10.5 (±3.4)</td>
<td>11.3 (±11.4)</td>
<td>292 mg (±174)</td>
<td>9 mg (±17)</td>
</tr>
<tr>
<td>Exp. 2: Capture by colour</td>
<td>35.8 (±10.5)</td>
<td>11M/7F</td>
<td>11.5 (±2.4)</td>
<td>12.2 (±9.5)</td>
<td>322 mg (±152)</td>
<td>16 mg (±36)</td>
</tr>
<tr>
<td>Exp. 3: Capture by motion (contraction/expansion)</td>
<td>39 (±14)</td>
<td>12M/3F</td>
<td>10.8 (±2.9)</td>
<td>14.7 (±13)</td>
<td>508 mg (±225)</td>
<td>15 mg (±33)</td>
</tr>
</tbody>
</table>

### TABLE 2
Mean scores at the PANSS for patients with schizophrenia for each experiment

<table>
<thead>
<tr>
<th>Experiment</th>
<th>PANSS Positive Scale</th>
<th>PANSS Negative Scale</th>
<th>PANSS General Scale</th>
<th>PANSS total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exp. 1: Capture by motion onset (jitter)</td>
<td>21.4 (±4.8)</td>
<td>23.5 (±8.4)</td>
<td>46.4 (±8.4)</td>
<td>91.4 (±18.7)</td>
</tr>
<tr>
<td>Exp. 2: Capture by colour</td>
<td>22.8 (±5.7)</td>
<td>24.8 (±7.4)</td>
<td>49.9 (±8.4)</td>
<td>97.5 (±17.0)</td>
</tr>
<tr>
<td>Exp. 3: Capture by motion (contraction/expansion)</td>
<td>19.6 (±6.0)</td>
<td>22.6 (±7.5)</td>
<td>45.4 (±10.0)</td>
<td>87.6 (±20.5)</td>
</tr>
</tbody>
</table>


Stimuli and task. In the attentional capture condition one of the distractors (lateral disks) moved abruptly (horizontal jitter motion of 35 pixels) during 34 ms (speed: 14.7/s). In the baseline condition the distractors remained fixed.

Results and discussion

The data are displayed in Figure 2. The mean RT was 341 ms (401 ms for patients, 303 ms for schizotypals, and 321 ms for controls, $F(2, 64) = 13, p < .001$, and the mean error rate was 0.8% (1.1% for patients, 0.7% for schizotypals, and 0.6% for controls, $F < 1$). Due to very low error rates statistical analyses were conducted only on RTs. The between-subject factor was group (controls, schizotypals, patients). The within-subject factors were the condition (distractor vs. baseline) and the probability of the distractor changing on the left side (50%, 75%, and 100%).

There was a significant main effect of condition, $F(1, 64) = 6.19, p < .015$, with longer RTs (by 13 ms) when one of the distractors moved than on trials in which distractors did not move: the attentional capture effect. On average

![Figure 2](image-url)
there was no significant main effect of probability (50%: 346 ms; 75%: 338 ms; 100%: 340 ms), $F(2, 128) = 0.9, ns$.

Probability interacted with condition, $F(2, 128) = 14.2, p < .001$. As can be seen from Figure 2 the magnitude of attentional capture decreased with the increase in probability of the distractor moving on one side of fixation for controls (50%: 14 ms; 75%: 6 ms; 100%: 3 ms) but the magnitude of interference remained stable across the three probability conditions for patients (50%: 19 ms; 75%: 17 ms; 100%: 17 ms) and for schizotypals (50%: 12 ms; 75%: 14 ms; 100%: 15 ms). The three way interaction between group, probability, and condition was significant, $F(4, 128) = 2.82, p < .027$.

For patients no significant correlation (Pearson) was found between the magnitude of attentional capture and the dose of either benzodiazepine, 50%: $r = -.142, ns, df = 25$, 75%: $r = .023, ns, df = 25$, 100%: $r = -.085, ns, df = 25$, or neuroleptic, 50%: $r = .043, ns, df = 25$, 75%: $r = -.187, p = .39, df = 25$, 100%: $r = .045 ns, df = 25$. There was also no significant correlation between the magnitude of attentional capture and the scores of PANSS, either for positives symptoms, 50%: $r = -.392, ns, df = 25$, 75%: $r = .181, ns, df = 25$, 100%: $r = -.045, ns, df = 25$, or negatives symptoms, 50%: $r = .25, ns, df = 25$, 75%: $r = -.134, ns, df = 25$, 100%: $r = .342, ns, df = 25$.

RTs were longer when a distractor moved than in the baseline condition: the attentional capture effect. This result is consistent with previous data having shown that motion onset can capture attention in an involuntary manner (Abrams & Christ, 2003; Franconeri & Simons, 2003; Hillstrom & Yantis, 1994). For instance, Franconeri and Simons (2003) showed that jitter motion (as the one used here) reliably affected stimulus detection in a visual search paradigm.

The magnitude of interference from moving distractors decreased with the increase in probability of distractors moving on the same side of the screen for controls. Interference disappeared when the distractor always moved on the same side (on 100% of the trials). In contrast to control participants, the magnitude of interference was equivalent in the three probability conditions for patients with schizophrenia and for schizotypals. Patients with schizophrenia are known to show a high susceptibility to distractors (Watson et al., 1988). This result thus confirms difficulties to resist interference from distractors but does not indicate the underlying mechanisms. The impairment observed might result from higher sensitivity to transient signals or it could reflect a deficit to inhibit the processing of any distractor in the visual environment. Experiment 2 tested whether failure to resist interference from a distractor was confined to motion signals. The same paradigm was used but abrupt motion of distractors was replaced by a slower change in colour.
EXPERIMENT 2: CAPTURE BY COLOUR

Method

Participants. Eighteen new in-patients, 17 new schizotypals, and 19 new healthy controls took part in the colour-distractor task. Demographic data and medication are presented in Table 1. Scores at the PANSS are presented in Table 2.

Stimuli and task. In the capture condition one of the distractors changed progressively in colour (red-green-red) in 300 ms. The colour change was smooth. It was accomplished by changing randomly the colour of each pixel composing the disk. In the baseline condition the distractors remained red.

Results and discussion

The data are displayed on Figure 3. The mean RT was 377 ms for patients 324 ms for controls and 296 ms for schizotypals, $F(2, 51) = 7.484$, $p < .001$, and the mean error rate was 0.7% for patients, 0.8% for controls, and 0.6% for schizotypals, $F(2, 51) = 0.816$, $ns$. Due to very low error rates statistical analyses were conducted only on RTs.

RTs were longer in the distractor condition than in the baseline condition (337 ms vs. 329 ms), $F(1, 51) = 20.53$, $p < .001$. No significant difference in RTs was found in the three probability conditions (50%: 334 ms; 75%: 330 ms; 100%: 334 ms), $F(2, 102) = 0.235$, $ns$. As can be seen from Figure 3 the attentional capture effect mainly occurred when the distractor changed in colour with an equal probability left and right of fixation, by 17 ms, $t(17) = 2.45$, $p < .025$ for patients, by 12 ms, $t(16) = 2.119$, $p = .05$ for schizotypals, and by 14 ms, $t(18) = 3.2$, $p < .005$ for controls. As the distractor changed more frequently at the same spatial location the interference decreased in all groups, 75%: 5 ms, $t(17) = 1.3$, $ns$ for patients, 5 ms, $t(16) = 2.025$, $p < .06$ for schizotypals, and 6 ms, $t(18) = 1.4$, $ns$ for controls, and 100%: 6 ms, $t(17) = 1.1$, $ns$ for patients, 1 ms, $t(16) = 0.122$, $ns$ for schizotypals, and 5 ms, $t(18) = 1.09$, $ns$ for controls). No interaction was statistically significant.

Capture by motion (Experiment 1) was compared to capture by colour (Experiment 2). The between-subject factors were the groups (controls, schizotypals, and patients) and the experiments (motion vs. colour). The within-subject factors were the condition (distractor vs. baseline) and the probability of the distractor changing on the left side (50%, 75%, and 100%). The analysis of variance was performed on the index of attentional capture (RTs for baseline—RTs for distractor). There was no main effect of experiment, $F(1, 118) = 1$, $ns$, indicating that the two experiments were
equivalent in difficulty. No interaction involving experiment reach statistical significance.

No significant correlation (Pearson) was found between the magnitude of attentional capture and the dose of either benzodiazepines, 50%: \(r = .171, \text{ns}, df = 16\), 75%: \(r = -.331, \text{ns}, df = 16\), 100%: \(r = -.356, \text{ns}, df = 16\), or neuroleptic, 50%: \(r = -.08, \text{ns}, df = 16\), 75%: \(r = -.001, \text{ns}, df = 16\), 100%: \(r = .072, \text{ns}, df = 16\). There was also no significant correlation (Pearson) between the magnitude of attentional capture and scores of PANSS, either for positives symptoms, 50%: \(r = -.123, \text{ns}, df = 16\), 75%: \(r = -.174, \text{ns}, df = 16\), 100%: \(r = -.352, \text{ns}, df = 16\), or negatives symptoms, 50%: \(r = .17, \text{ns}, df = 16\), 75%: \(r = -.16, \text{ns}, df = 16\), 100%: \(r = .15, \text{ns}, df = 16\).

The results show that the magnitude of the attentional capture effect was equivalent for patients, schizotypals, and controls. A slow change of colour gave rise to an attentional capture effect only when the change occurred randomly left or right of fixation. As the probability of change on one side of fixation increased, the magnitude of interference decreased and became nonsignificant in all groups. The ability to resist interference from colour change but not from motion onset (Experiment 1) and the fact that patients failed to resist interference from motion in the high probability condition
supports the hypothesis of an oversensitivity to motion signals in schizophrenia. Experiment 3 was designed to test whether failure to resist interference from motion-jitter in patients with schizophrenia generalised to other types of motion (e.g., brief contraction/expansion).

**EXPERIMENT 3: CAPTURE BY MOTION (CONTRACTION/EXPANSION)**

**Method**

*Participants.* Fifteen new in-patients and 18 new healthy controls took part in the experiment. Demographic data and medication about patients are presented in Tables 1 and 2.

*Stimuli and task.* In the capture condition one of the distractors was animated by a contraction/expansion/contraction (size $2.5^\circ$ to $3.5^\circ$ to $2.5^\circ$) movement for 34 ms. In the baseline condition the distractors remained fixed. As this experiment was a control to test the generalisation of attentional capture by motion to another type of motion, only the two critical probability conditions (50%, 100%) were tested in separate blocks of 100 trials each. The order of the two blocks was mixed between participants.

**Results and discussion**

The data are graphically presented on Figure 4. The mean RT was 345 ms (388 ms for patients and 310 ms for controls), $F(1, 31) = 12.7, p < .001$. The mean error rate 3.1% (3.6% for patients and 2.6% for controls), $F(1, 31) = 0.9, ns$. Due to a low error rate statistical analyses were conducted only on RTs. The between-subject factor was group (controls vs. patients). The within-subject factors were the condition (distractor vs. baseline) and the probability of the distractor changing on one side of fixation (50% vs. 100%).

RTs were longer when one of the distractors moved than in the baseline condition (356 vs. 342 ms), $F(1, 31) = 31.9, p < .001$. On average RTs were not affected by the probability of the distractor moving more frequently on the left side, 50%: 347 ms vs. 100%: 351 ms, $F < 1$. Group interacted significantly with probability of distractors moving on one side of fixation, $F(1, 31) = 4.7, p < .038$. For controls the attentional capture effect occurred only in the 50% condition, by 15 ms, $t(17) = 4.5, p < .001$, and was not statistically significant in the 100% condition, 5 ms, $t(17) = 1.7, ns$. In contrast, the magnitude of interference was not affected by the probability of the distractor moving more frequently on one side for patients, 50%: 21 ms, $t(14) = 7.8, p < .001$, and 100%: 19 ms, $t(14) = 3.4, p < .004$. 
No significant correlation (Pearson) was found between the magnitude of attentional capture and the dose of either benzodiazepines, 50%: $r = -0.221$, $p = 0.437$, $df = 13$, 100%: $r = 0.013$, $p = 0.962$, $df = 13$, or neuroleptic, 50%: $r = -0.223$, $p = 0.424$, $df = 13$, 100%: $r = -0.067$, $p = 0.812$, $df = 13$. No significant correlation was found between the magnitude of attentional capture and scores of PANSS, either for positives symptoms, 50%: $r = -0.354$, $p = 0.441$, $df = 13$, 100%: $r = -0.274$, $p = 0.564$, $df = 13$, or negatives symptoms, 50%: $r = -0.49$, $p = 0.261$, $df = 13$, 100%: $r = -0.553$, $p = 0.203$, $df = 13$.

Both patients and controls showed attentional capture by motion either by jitter (in Experiment 1) or by a movement induced by contraction/expansion of a disk (in Experiment 2). However, in both cases only patients exhibited difficulties to resist interference from the motion signal even when there was a high probability for the distractor to change always on the same side of space (100%). This result indicates that the automatic capture of attention in patients with schizophrenia generalises to different types of motion signal.

**GENERAL DISCUSSION**

The main results can be summarised as follows: (a) Attentional capture with equivalent magnitude was found in all groups and both for transient motion...
(Experiments 1 and 3) and relatively slow colour change (Experiment 2) when the distractor changed in state with an equal probability left and right of fixation. (b) As the probability of the change increased on one side of fixation (in 75% of the trials) or always on the left (in 100% of the trials) healthy participants resisted interference in both the motion and the colour conditions. (c) In contrast to healthy controls patients with schizophrenia displayed attentional capture with an equivalent magnitude in all probability conditions, but (d) this effect was confined to motion (Experiments 1 and 3). (e) Attentional capture by colour was similar in the three groups, it decreased with increasing distractor probability, but the effect of probability on capture was the same for all three groups. (f) The same pattern of results was found for patients with schizophrenia and for schizotypals. This last point is in favour of the existence of a cognitive trait independent of the stage of the disease. It cannot be linked only to the negative dimension of schizophrenia, first because our patients were not selected on their positive or negative scores at the PANSS or on their subtype of schizophrenia, and second, because factor analytic studies of the psychosis proneness scales, using exploratory or confirmatory factorial analyses, support the view that schizotypy is multidimensional comprising a cognitive/perceptual dimension and a negative dimension centred on anhedonia (Bentall, Claridge, & Slade, 1989; Lewandowski et al., 2006; Lipp, Arnold, & Siddie, 1994; Muntaner, Garcia-Sevilla, Fernandez, & Torrubia, 1988).

Our results replicate those observed with healthy observers in previous studies with motion-jitter. Abrams and Christ (2003) have reported evidence that motion is effective in eliciting bottom-up capture of attention (see also Franconeri & Simons 2003). Exogenous capture has also been found with colour (Turatto & Galfano 2000, 2001). With patients, our results are also consistent with previous findings suggesting an inability to inhibit attentional shifts to compelling external stimuli in schizophrenia with the antisaccade paradigm, a task in which observers are asked to make eye movements in the direction opposite to that of a sudden-onset peripheral target (Fukushima et al., 1988; Fukushima, Morita, & Yamashita, 1990). In the same line, Maruff et al. (1998; see also Danckert & Maruff, 1997; Danckert, Maruff, Crowe, & Currie, 1998) reported deficits in overt attentional shifts in patients with schizophrenia. In their study overt shift of attention was measured in a spatial attention task in which participants had to respond to a peripheral target. A transient luminance increase (the cue) appeared before the target. When the target occurred at the uncued location on 80% of the trials healthy observers showed faster response times to targets appearing at the uncued location as compared to the cued location, suggesting that they used the probability information. In contrast, patients with schizophrenia could not direct attention away from peripheral cues despite the high probability that the target would not appear...
at the cued location, suggesting impaired ability to inhibit reflexive shifts of attention. This result was interpreted as reflecting difficulties in using the implicitly learned probability information to guide the orienting behaviour rather than any specific deficit of voluntary control, and associated with frontal dysfunction. Sereno and Holzman (1996) also reported an enhanced exogenous (reflexive) component of attention in patients with schizophrenia in a spatial cueing paradigm. They suggested that the superior colliculus plays a crucial role in the generation of exogenous attentional facilitation, whilst the prefrontal cortex is more involved in the generation of endogenous attentional facilitation. Using fMRI in healthy observers to assess whether exogenous and endogenous orienting are mediated by similar or different neural systems, Rosen et al. (1999) found that both controlled (endogenous) and reflexive (exogenous) orienting activated the dorsal premotor area, the frontal eye field, and the superior parietal cortex but the right dorsal prefrontal cortex (area 46) was selectively activated by the endogenous condition. In a review, Munoz and Everling (2004) showed that many cortical and subcortical structures are involved in the generation or the suppression of saccadic eye movements including the dorsolateral prefrontal cortex, the lateral intraparietal area, the supplementary eye field, the frontal eye field, and the superior colliculus. Unlike studies of exogenous orienting and the antisaccade task, our paradigm did not require participants to inhibit attentional shifts or eye movements to the distractor. Participants were told that one of the disks could change but they were not informed about the probability and they were explicitly asked to attend to the target square and to ignore the lateral disks.

We found that motion was more efficient than colour in capturing attention in patients with schizophrenia and in schizotypals. It can be argued that colour is less efficient than properties involving the dorsal pathway (e.g., motion, abrupt onset) in eliciting attentional capture effects. However, first, attentional capture has been observed before with colour changes. For instance, Turatto and Galfano (2000, 2001) found evidence that an irrelevant colour or form singleton was able to grab attention automatically in a visual search task for a vertical-line target among tilted-line distractors (see also Serences et al., 2005; Theeuwes et al., 2004). Second, in our study attentional capture by a colour change was observed in all groups in the 50% probability condition, suggesting that colour can indeed capture attention. The main difference between capture by colour and capture by motion was that the magnitude of interference from moving distractors remained stable across all probability conditions for patients and schizotypals whilst it decreased as probability for the distractor to occur more frequently on one side increased for colour change in all groups.

Why do patients with schizophrenia and schizotypals fail to resist interference from irrelevant motion signals whilst they display normal
attentional filtering with colour? There are several possible explanations for this result, which we will consider in turn.

**Deficit in habituation**

Normally attention is a balance between controlled endogenous mechanisms allowing goal-driven orientation and automatic exogenous mechanisms allowing a flexibility of this behaviour as a function of changes occurring in the spatial environment (Allport, 1989). Habituation is one of the mechanisms allowing inhibition of automatic orienting towards a repeated nonrelevant stimulus. Tissot (1979) proposed that the increased distractibility of patients with schizophrenia might result from a deficit of habituation. For these patients, any signal, even repeated and nonrelevant, would be processed as a new signal. Evidence for habituation deficit in schizophrenia has been reported in some studies. Most of them primarily designed for the assessment of startle habituation have provided inconsistent results: a significant deficit for Bolino et al. (1994), Geyer, Swerdlow, Mansbach, and Braff (1990), and Potter (2006), and a lack of deficit for Braff, Swerdlow, and Geyer (1999). There is to date no robust evidence for selective deficit in habituation for motion. An account in terms of deficit in habituation can be eliminated in the present study given that impaired habituation would have affected both the colour and the motion conditions.

Moreover, our results cannot be accounted for in terms of general impairment in filtering irrelevant information. For instance, Ducato, Thomas, Monestes, Despretz, and Boucart (2008) found that patients with schizophrenia are able to resist interference from distractors. A variant of the present paradigm was used, with other patients. Performance was compared in three conditions based on the attentional load of the central task: a low-load condition in which participants were asked to locate a square, a medium load condition in which participants were asked to locate the larger number between two 1-digit numbers and a high load condition in which they were asked to locate the larger number between two several-digit numbers. It was found that, as the attentional load of the central task increased, participants (both patients and controls) were able to resist interference from moving distractors that captured their attention in the low-load condition. This suggests that patients are able to resist interference when their attention is engaged in a demanding task. However, probability was not manipulated in that study.
Dysfunction of the magnocellular pathway

There is now substantial evidence for deficits in functions associated to the magnocellular (M) pathway in schizophrenia and in the schizophrenia spectrum (e.g., schizotypy and first-degree relatives of patients; Bedwell, Brown, & Miller, 2003; Bedwell, Miller, Brown, McDowell, & Yamasak, 2004; Keri, Antal, Szekeres, Benedek, & Janka, 2000; Schwartz et al., 2001; Uhlhaas et al., 2004; Vidyasagar, 1999). The dorsal occipitoparietal pathway (predominantly magnocellular) conveys low contrast, low resolution information and is involved in attentional capture. The M system is a fast transient system well suited for the analysis of moving stimuli. It involves the location of objects in visual space and plays a crucial role in detecting visual change and motion and in controlling eye movements (Bullier, 2001; Lamme & Roelfsema, 2000; Nowak, James, & Bullier, 1997; Vidyasagar, 1999). Various psychophysical approaches that include tasks on visible persistence, evoked potentials for gratings varying on contrast, spatial, and temporal frequencies, flicker contrast sensitivity, velocity discrimination, motion and trajectory tasks, backward visual masking and eye movements tasks, double frequency doubling, and localisation tasks have documented the impairment (Braus, Weber-Fahr, Tost, Ruf, & Henn, 2002; Butler et al., 2001; Evans & Schwartz, 1997; Green, Nuechterlein, Breitmeyer, & Mintz, 2006; Keri et al., 2000; Keri, Janka, & Benedek, 2002; Koelkebeck, Ohrmann, Hetzel, Arolt, & Suslow, 2005; Schechter, Butler, Silipo, Zemon, & Javitt, 2003; Schwartz et al., 2001; see Butler & Javitt, 2005, and Laycock, Crewter, & Crewter, 2007, for reviews) in contrast to relatively unimpaired performance in parvocellular-biased conditions (e.g., object recognition, colour, and pattern processing, e.g., Keri et al., 2000; O’Donnell et al., 1996). Moreover, analogies in performance have been found between people showing a high score in schizotypy and patients with dyslexia (Richardson & Gruzelier, 1994), a pathology also thought to result from impairments in the M pathway (Borsting et al., 1996; Evans & Schwartz, 1997; Slaghuis & Lovegrove, 1985; Stein, Talcott, & Walsh, 2000). The hypothesis of an overactivity of the M system has been proposed to account for the results of backward visual masking. The longer stimulus-mask interval in patients with schizophrenia was interpreted as a defect of inhibition of the magnocellular system on the parvocellular (P) system. The overactive M system would enhance the inhibition on the P system and a longer interval would be needed to give the P system involved in the processing of the target the opportunity to complete the processing (Cadenhead, Serper, & Braff, 1998; Green, Nuechterlein, & Mintz, 1994a, 1994b; McClure, 2001; Schechter et al., 2003). This hypothesis has been criticised by other authors who suggest that the backward masking effect in schizophrenia is more compatible with a hypofunctioning of the M system (e.g., Bedwell et al., 2004; Slaghuis, 2004).
Deficit in control of dorsal stream function

Another explanation, related to impaired M system, is a deficit in control of signals from the M system whilst control of information from the P system is normal. This is possible if the functional differences between the M and the P system are still present in the prefrontal cortex (Klauer & Zhao, 2004; Sala, Rama, & Courtney, 2003; Ungerleider, Courtner, & Haxby, 1998; Wilson, Scalaidhe, & Goldman-Rakic, 1993). The prefrontal cortex is involved in the inhibition of irrelevant information (see Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004, for a review). Moreover, an involvement of the frontal cortex in attentional capture has been reported by de Fockert et al. (2004) in an fMRI study in which a negative correlation was found between the magnitude of attentional capture and the degree of activation of the lateral precentral gyrus of the frontal lobe. May, Kane, and Hasher (1995), in their review of negative priming, suggested the existence of two inhibitory systems, one on the identity and one on the spatial location of information. The results of normal ageing support this account with normal inhibition on spatial location and impaired inhibition on identity. It has been suggested that the ventrolateral prefrontal cortex, which gets inputs from the inferotemporal cortex, maintains nonspatial information in working memory (Chavis & Pandya, 1976; Ungerleider, Gaffan, & Pelak, 1989; Webster, Bachevalier, & Ungerleider, 1994), whilst the dorsolateral prefrontal cortex which gets inputs from the dorsal stream maintains spatial information in working memory (Barbas & Mesulam, 1985; Cavada & Goldman-Rakic, 1989; Ungerleider & Desimone, 1986). Numerous studies have reported a dysfunction of the frontal cortex in schizophrenia (Goldman-Rakic & Selemon, 1997; Kurachi, 2003), of the dorsolateral prefrontal cortex (Glahn et al., 2005; Selemon & Rajkowska, 2003), and of the frontoparietal circuit involved in the modulation of bottom-up and top-down connections between the dorsolateral prefrontal cortex and the dorsal stream (Braus et al., 2002; Freckska et al., 2004; Matsuda et al., 2004). Evidence for a hypoactivation of the dorsolateral prefrontal cortex in schizophrenia has been shown in tasks involving visuospatial working memory (Cannon et al., 2005; Pantelis et al., 2004; Takahashi et al., 2005) and selective attention (Ojeda et al., 2002; Weiss et al., 2003). Therefore, it might be that a dysfunction of the dorsolateral prefrontal cortex affects the processing of inputs from the dorsal stream (motion signals and spatial location) whilst the processing of inputs from the ventral stream (colour) would be spared.
CONCLUSION

We designed a simple paradigm to assess attentional control in schizophrenia. We found a similar pattern of performance in patients with schizophrenia and in nonpsychotic subjects with schizotypal traits suggesting that the impaired attentional control does not result from medication but could be a cognitive trait of the schizophrenia spectrum. This paradigm can easily be applied to young children (Deltour et al., 2007) and could therefore help to identify early cognitive impairments in populations at risk to develop schizophrenia.

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