Visual Search Performance Among Persons With Schizophrenia as a Function of Target Eccentricity

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The current study investigated one possible mechanism of impaired visual attention among patients with schizophrenia: a reduced visual span. Visual span is the region of the visual field from which one can extract information during a single eye fixation. This study hypothesized that schizophrenia-related visual search impairment is mediated, in part, by a smaller visual span. To test this hypothesis, 23 patients with schizophrenia and 22 healthy controls completed a visual search task where the target was pseudorandomly presented at different distances from the center of the display. Response times were analyzed as a function of search condition (feature vs. conjunctive), display size, and target eccentricity. Consistent with previous reports, patient search times were more adversely affected as the number of search items increased in the conjunctive search condition. It was important however, that patients’ conjunctive search times were also impacted to a greater degree by target eccentricity. Moreover, a significant impairment in patients’ visual search performance was only evident when targets were more eccentric and their performance was more similar to healthy controls when the target was located closer to the center of the search display. These results support the hypothesis that a narrower visual span may underlie impaired visual search performance among patients with schizophrenia.

Keywords: schizophrenia, visual attention, visual search, visual span, target eccentricity

Evidence for attention impairment in schizophrenia (SCZ) has been found on a wide variety of tasks including the Simple Reaction Time task (SRT) (for a review, see Steffy & Oakman, 1997), Span of Apprehension Task (SOA) (e.g., Neale, McIntyre, Fox, & Cromwell, 1969), and Continuous Performance Test (CPT) (for a review, see Cornblatt & Keilp, 1994). However, successful performance on most of these tasks depends on the integrity of several cognitive operations. Therefore, a discrete disruption in visual attention cannot be inferred from poor performance on these tasks alone. Consequently, researchers have also employed the visual search paradigm to more narrowly investigate the attentional performance of patients with SCZ (Carr, Dewis, & Lewin, 1998; Fuller et al., 2006; Lieb, Merklin, Rieth, Schüttdler, & Hess, 1994; Mori et al., 1996).

The visual search task. A typical visual search task requires an individual to find a target among nontarget items (i.e., distractors) and indicate the presence or absence of the target by a button-press. Response time (RT) and/or error rate (ER) are indices of performance. When the target is salient, visual search becomes highly efficient; that is, plotting RT as a function of the number of items in the display (i.e., display size) yields a flat slope. It was further observed that flat search slopes occur when the target is specified by a single feature; conversely, when a target is specified by a conjunction of features, search times increase linearly as a function of display size. Such data spawned the Feature Integration Theory (FIT; Treisman & Gelade, 1980), which posits that searches for targets defined by a single feature are executed in parallel (i.e., across stimuli in unison), while those seeking conjunctive targets are accomplished serially. However, later studies showed that search efficiency is more dependent on the discriminability of the target from the distractors regardless of whether the target is defined by a single feature or a conjunction of features. To explain these findings the FIT was modified to suggest that attention may be focused on a clump of items. Further, the size of the clump that can be sufficiently processed in parallel depends on the discriminability of the target from the distractors. The Attentional Engagement Theory (AET) also conceptualizes visual search processes on a continuum of search efficiency, with parallel search (and flat slopes) on one end of the discriminability continuum and serial search (and steep slopes) on the other (for a review, see Duncan & Humphreys, 1989).

The spotlight of attention. Visual search research has been greatly influenced by the spotlight, or zoom lens, metaphor for attentional distribution. According to this analogy, attention moves through space and expands or contracts like the field of view of a camera (Posner, 1980; Eriksen & St. James, 1986). Some findings also suggest that processing efficiency may decline in a gradient-like manner as the distance from the focus of attention increases (e.g., Eriksen & St. James, 1986). Consistent with these models, it has been found that search performance also depends on target location (e.g., Carrasco, Evert,
The ‘spotlight of attention’ in schizophrenia. Although previous research has not directly tested the visual span of patients with SCZ, data from related studies are informative in this regard. For example, Cegalis and Deptula (1981) examined visual signal detection in the peripheral visual field among patients with SCZ and found that, compared to controls, chronic patients with SCZ were less sensitive to a peripheral signal presented at 71° (visual angle) from the center of the display. Their task required the simultaneous execution of a foveal task (i.e., indicating the number of lights presented in the center of the display), while indicating the presence or absence of the peripheral light. Due to the differences between this task and a typical visual search task, most importantly, the level of processing required for target detection, it is not easy to make strong inferences regarding visual span from this study. However, this finding does suggest that differences between patients and controls in detecting peripheral targets might also be observed under single task conditions, across narrower visual angles, and when target discrimination requires a greater degree of visual processing (i.e., a typical visual search task).

Studies of the partial-report Span of Apprehension Task (SOA) might also provide some information about the size of patients’ visual span. The partial-report SOA task (Estes, 1964) requires a person to report whether a target letter is among a group of letters briefly presented in a visual display. Accuracy on the SOA task declines as the number of letters in the display increases. Since the display is flashed briefly, the SOA can provide a measure of the number of items that can be processed together at any one time. Studies have shown that patients with SCZ detect fewer target stimuli in the presence of larger arrays (see Asarnow, Granholm, & Sherman, 1991, for a review). However, some studies have not been able to replicate these findings (e.g., Harvey, Weintraub, & Neale, 1985). Asarnow, Steffy, and Waldman (1985) speculated that inconsistent findings of SOA studies might have been caused by using displays with different visual angles. They further noted that studies failing to find SOA deficits in patients used a “narrow” visual angle (2° × 3°), whereas studies that found deficits used “wide” visual angles (9.5° × 10° or 21° × 22°). This possibility was further investigated by Granholm, Asarnow, and Marder (1996) using both narrow (3.7° × 3.6°) and wide (21.4° × 20.5°) visual angles. This study failed to reveal the predicted group by visual angle interaction. However, the brief presentation of stimuli (typically less than 100 ms) and the memory requirement of the SOA task make it difficult to generalize the SOA results to visual search performance.

In addition, other studies also suggest that patients with SCZ may have a narrower spotlight of attention. For example, chronic patients with SCZ were found to have restricted eye scanning behavior and significantly shorter mean eye scanning length than acute patients and healthy controls (Kojima et al., 2001). Since the saccadic length is positively correlated with visual span, the shorter saccade length suggests that patients with SCZ may have a smaller visual span. Also, patients with SCZ were less likely to make the first saccade toward the target in a high-pop-out task (Kojima, Katayama, Takaki, Yoshioka, & Kawahara, 2005). This suggests that patients deploy attention within a smaller area of the visual field and cannot process the whole display in parallel.

Some findings in healthy participants also suggest that patients with SCZ may have a narrower span of effective vision. Using the gaze-contingent methodology Pomplun, Reingold, and Shen
showed that visual span is reduced under conditions of divided attention. This finding suggests that, in general, processes that undermine available attentional resources may narrow visual span. The presence of a mental disorder, such as SCZ, can be construed as one such circumstance.

The purpose of the current study was to investigate a reduced visual span as a possible mechanism underlying impaired visual search performance among patients with SCZ. It was hypothesized that patients will demonstrate disproportionately longer search times for more eccentric targets as compared to centrally located targets in the conjunctive search condition. Such a result would be consistent with the hypothesis of a narrower visual span among patients with SCZ.

Method

Participants. Twenty-three patients diagnosed with SCZ or Schizoaffective Disorder (according to the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association [DSM–IV–TR], 2000) and 22 healthy controls participated in the study. Patients were recruited from the Schizophrenia Research Registry at the Centre for Addiction and Mental Health (CAMH) and their diagnosis was confirmed using the Structured Clinical Interview for Diagnosis of DSM–IV–TR Axis I Disorders Patient Edition (SCID-P; First, Spitzer, Gibbon, & Williams, 2001a). All SCZ participants were outpatients, clinically stable and receiving a single antipsychotic medication: 19 patients were receiving second generation antipsychotics and 4 patients were receiving first generation antipsychotics. Patients receiving medication with known cognitive effects (i.e., benzodiazepines, tricyclic antidepressants, anticonvulsants, analgesics, anticholinergics) were excluded from the study. Healthy controls were recruited from the community via newspaper advertisements to match the patient participants based on age and sex and were confirmed as free of Axis I psychiatric disorders using the SCID Non-Patient Edition (SCID-N/P; First, Spitzer, Gibbon, & Williams, 2001b). In addition, individuals who reported a lifetime history of an Axis I disorder or had a first-degree relative with SCZ or other psychotic disorders were excluded from the control group. All participants were between 18 and 60 years old, had normal/corrected visual acuity, normal color vision, and reported having acquired English as a primary language before the age of 5. Individuals were excluded from participating in the study if they reported using illicit drugs within the past month or if they met criteria for lifetime history of substance dependence. They were also excluded if they had a self-reported history of learning disability, neurological injury/disease (including a history of head injury with loss of consciousness more than half an hour), or any other medical condition known to have cognitive effects (e.g., severe heart or pulmonary disease, insulin-dependent diabetes, thyroid disease, epilepsy, or neurological illness such as Parkinson’s or Huntington’s disease).

Experimental apparatus. The experiment was designed and built using the Experiment Builder Software (SR Research Ltd.). Stimuli were presented on a 17-inch Viewsonic Professional Series PF775 monitor. A chin-rest was used to keep the participants’ viewing distance fixed at 60 cm from the monitor. Participants used a Targus PAUK10C keypad to indicate their response.

Stimuli and design. A total of three different stimuli were used: a green ‘X’, a red ‘X’, and a green ‘O.’ At a viewing distance of 60 cm, each individual stimulus subtended a visual angle of 0.84° (27 pixels) horizontally and 0.91° (29 pixels) vertically. All stimuli were presented in a 22° × 22° field (704 × 704 pixels) and the minimum distance between the centers of neighboring items was 1.8°. The red and green items were matched in luminance and presented on a white background. The target was always the green ‘X’ and the distractors were green ‘O’s (in the shape feature search condition), red ‘X’s (in the color feature search condition), or a 50-percent mixture of green ‘O’s and red ‘X’s (in the conjunctive search condition). To eliminate response bias and to reduce the possibility of speed–accuracy trade-off, the search displays always contained a target, either on the right or the left half of the display, and the participants were asked to respond via a forced-choice format and indicate the location of the target (right or left) by pressing one of two buttons. Three different display sizes were used: 12, 30, and 48 items. Each participant performed a total of 576 trials, which amounted to 64 trials for each cell of the design (display size × search condition). The order of the stimulus displays was randomized with a restriction that no more than three displays of a given target location (right or left) appeared in a row. Before the test trials, the participant received 18 practice trials, with 1 trial for each possible combination of display size, search condition (shape feature, color feature, and conjunctive) and target location. The start of trials was signaled by a centrally presented fixation cross. After 500 ms, the fixation cross disappeared and the search display appeared on the screen. Trials were terminated by participants’ response. Correct responses were signaled via a bell and errors via a buzzer. RT, key selection, and accuracy were recorded for each trial.

Procedure. After acquiring consent and general demographic/clinical information, participants’ vision was tested using a Snellen acuity chart and the Ishihara color vision test. Next, participants were interviewed using the SCID, after which they completed the visual search task. At the beginning of the task, participants read aloud the instructions and were instructed to respond as quickly and accurately as possible. Test trials were presented in a total of 12 blocks of 48 trials each. Rest breaks were allowed between each two blocks, as needed. After the completion of the experimental task, a neuropsychological assessment was performed using the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, 1998) Form A. Finally, participants in the patient group were also interviewed using the Positive and Negative Symptoms Scale (PANSS; Kay, Opler, & Fiszbein, 1992).

Results

Demographic and clinical data. The demographic information for the two participant groups is shown in Table 1. The control group was on average 1.9 years more educated than the patient group and had higher scores on all RBANS indices.

Visual search data. Both groups were highly accurate (mean accuracy of above 98% for both groups across all conditions). This suggests that speed–accuracy trade-offs were similar across both groups. Trials with incorrect responses were removed from the data and each participant’s RT values in each condition (search type × display size) were examined for the existence of outliers. At this stage the trials in the color feature and shape feature conditions were collectively analyzed as the feature search type.
RT values exceeding 3 standard deviations from the mean in each condition were eliminated from further analyses. The removed RTs amounted to 1.8% and 1.7% of the total number of trials for patients and controls respectively. After removal of outliers, RT distributions for each cell of the design (search type × display size) for each participant were screened for violations of distribution normality—all values for skewness and kurtosis were non-significant. In order to evaluate the two groups’ visual search performance in the two search conditions, mean RT was obtained for each cell of the design and search slopes were calculated as the index of each individual’s search efficiency using a least squares fit of the average RT at each array size. A 2(search type) × 2(group) mixed models analysis of variance (ANOVA) was performed on the search slopes with search type (feature or conjunctive) as the within-subject factor and group as the between-subjects factor. The results of this ANOVA showed a main effect of search type, \( F(1, 43) = 275.84, p < .001, \eta^2_p = .87 \); target eccentricity, \( F(1, 43) = 167.66, p < .001, \eta^2_p = .80 \); and group, \( F(1, 43) = 27.1, p < .001, \eta^2_p = .39 \), indicating greater RTs in the conjunctive search condition, for more eccentric targets, and among patients with SCZ. There was also a significant search type × eccentricity × group interaction, \( F(1, 43) = 6.01, p = .018, \eta^2_p = .12 \); as well as significant eccentricity × group, \( F(1, 43) = 5.77, p = .02, \eta^2_p = .12 \); search type × group, \( F(1, 43) = 9.23, p = .004, \eta^2_p = .18 \); and search type × eccentricity, \( F(1, 43) = 115.39, p < .001, \eta^2_p = .73 \), interactions.1

Results thus far have demonstrated less efficient visual search performance by patients with SCZ in the conjunctive search condition and an exaggerated effect of target eccentricity on patients’ search time in the conjunctive search condition. Therefore, in order to study the impact of target eccentricity on the two groups’ visual search performance in the conjunctive search condition, search slopes were separately obtained for the two eccentricity levels and analyzed using a 2(target eccentricity) × 2(group) mixed models ANOVA with target eccentricity as the within-subject factor and eccentricity, such that half of the displays, which had target eccentricities less than 9.5° visual angle, were categorized as eccentricity 1 and the other half, with targets located 9.5° visual angle or greater from the center, were denoted as eccentricity 2. Mean RT was calculated for each participant in each search type × eccentricity condition and a 2(search type) × 2(eccentricity) × 2(group) mixed models ANOVA was performed with RT as the dependent variable, search type (feature or conjunctive) and target eccentricity as the within-subject factors and group as the between-subjects factor. The results of this ANOVA showed a main effect of search type, \( F(1, 43) = 275.84, p < .001, \eta^2_p = .87 \); target eccentricity, \( F(1, 43) = 167.66, p < .001, \eta^2_p = .80 \); and group, \( F(1, 43) = 27.1, p < .001, \eta^2_p = .39 \), indicating greater RTs in the conjunctive search condition, for more eccentric targets, and among patients with SCZ. There was also a significant search type × eccentricity × group interaction, \( F(1, 43) = 6.01, p = .018, \eta^2_p = .12 \); as well as significant eccentricity × group, \( F(1, 43) = 5.77, p = .02, \eta^2_p = .12 \); search type × group, \( F(1, 43) = 9.23, p = .004, \eta^2_p = .18 \); and search type × eccentricity, \( F(1, 43) = 115.39, p < .001, \eta^2_p = .73 \), interactions.1

1 The described analysis treats target eccentricity as a dichotomous variable. Although this framework is intuitive and simplifies interpretation, it also results in a relative loss of information. Therefore, additional analyses were performed in which target eccentricity was treated as a continuous variable. The details of this analysis follow in this footnote. It should be noted that the overall results of this analysis perfectly replicate the results obtained when treating target eccentricity as a dichotomous variable. The eccentricity effect was defined as the increase in RT as a function of target eccentricity and was measured for each participant and in each search condition by obtaining the slope of RT as a function of target eccentricity (i.e., degrees visual angle). The obtained slopes were analyzed using a 2(search type) × 2(group) mixed models ANOVA with search type as the within-subject factor and group as the between-subjects factor. Main effects of group, \( F(1, 43) = 5.24, p = .03, \eta^2_p = .11 \); and search type, \( F(1, 43) = 193.11, p < .001, \eta^2_p = .82 \) were obtained, indicating a larger eccentricity effect among patients with SCZ and, as expected, in the conjunctive search condition. There was also a significant search type × group interaction, \( F(1, 43) = 6.14, p = .02, \eta^2_p = .13 \), whereby the relatively greater eccentricity effect among the SCZ group was accentuated in the conjunctive search condition. A separate comparison of the slopes in each search condition revealed that the eccentricity effect did not significantly differ between patients and controls in the feature search condition (mean slope difference = 4.22 ms/degree visual angle, \( r(43) = 1.2, p = .24 \), Cohen’s \( d = 0.36 \). However there was a significant between group difference in the eccentricity effect in the conjunctive search condition (mean slope difference = 20.44 ms/degree visual angle, \( r(43) = 2.5, p = .02 \), Cohen’s \( d = 0.75 \)). Data from this alternate analysis also support the hypothesis of a narrower visual span among patients with SCZ. There was also a negative correlation between an individual’s RBANS Total scale score and the slope of his or her RT as a function of target eccentricity in the conjunctive search condition, \( r(40) = -.37, p = .016 \).

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### Table 1

**Demographic Data**

<table>
<thead>
<tr>
<th></th>
<th>Patient (n = 23)</th>
<th>Control (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>36.7 (11.8)</td>
<td>35.7 (11)</td>
</tr>
<tr>
<td>Male/Female</td>
<td>16/7</td>
<td>14/8</td>
</tr>
<tr>
<td>Education (yrs)</td>
<td>13.9 (2.2)</td>
<td>15.8 (2.3)*</td>
</tr>
<tr>
<td>Illness length (yrs)</td>
<td>11.6 (11.3)</td>
<td>N/A</td>
</tr>
<tr>
<td>Hospitalizations</td>
<td>2.9 (4.4)</td>
<td>N/A</td>
</tr>
<tr>
<td>PANSS T-scores:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Positive</td>
<td>34.25 (4.87)</td>
<td>N/A</td>
</tr>
<tr>
<td>Negative</td>
<td>41.25 (9.46)</td>
<td></td>
</tr>
<tr>
<td>RBANS Index scores:*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immediate memory</td>
<td>90.15 (13.90)</td>
<td>102.40 (16.15)*</td>
</tr>
<tr>
<td>Visuospatial/constructional</td>
<td>99.75 (17.25)</td>
<td>109.73 (13.58)*</td>
</tr>
<tr>
<td>Language</td>
<td>88.70 (10.44)</td>
<td>101.14 (11.08)*</td>
</tr>
<tr>
<td>Attention</td>
<td>81.10 (11.76)</td>
<td>101.86 (14.57)*</td>
</tr>
<tr>
<td>Delayed memory</td>
<td>90.15 (14.29)</td>
<td>104.91 (12.74)*</td>
</tr>
<tr>
<td>RBANS Total Scale Score</td>
<td>86.50 (11.97)</td>
<td>105.36 (12.90)*</td>
</tr>
</tbody>
</table>

*Note. PANSS = Positive and Negative Symptoms Scale; RBANS = Repeatable Battery for the Assessment of Neuropsychological Status. *p < .05 (Standard deviations in parentheses). † Data were unavailable for three patients.
group as the between-subjects factor. Main effects of group, $F(1, 43) = 6.67, p = .01$, $\eta^2_p = .13$; and eccentricity, $F(1, 43) = 38.67, p < .001$, $\eta^2_p = .47$ were obtained. There was also a significant eccentricity × group interaction, $F(1, 43) = 5.19, p = .03, \eta^2_p = .11$, whereby the effect of eccentricity was greater for the SCZ group. A comparison of the slopes at each of the eccentricity levels revealed that there was only a modest—and statistically non-significant—difference between the search slopes of patients and controls when the target was closer to the center of the display, mean slope difference = 3.8 ms/item, $t(43) = 1.65, p = .11$, Cohen’s $d = 0.49$; however, there was a disproportionately larger difference between the slopes of patients and controls with more eccentric targets, mean slope difference = 7.41 ms/item, $t(43) = 3.2, p = .003$, Cohen’s $d = 0.96$ (see Figure 2).

**Discussion**

The results of the current study demonstrate a disproportionate effect of target eccentricity on patients’ visual search performance compared to that of healthy controls. Moreover, we found that patients’ impairment in conjunctive visual search was more salient when they searched for more eccentric targets. It was interesting that when the target was close to the center of the display, there was only a modest—and statistically nonsignificant—search difference between patients and controls. This finding is consistent with our hypothesis that patients with SCZ have a smaller visual span. With a narrower visual span, the more eccentric targets have a higher probability of falling outside the area that is being processed efficiently at the onset of the search display. Therefore patients take longer to find the target in these displays. This finding is consistent with the finding by Cegalis and Deptula (1981) of impaired peripheral signal detection by patients with SCZ. Despite notable paradigm differences, the current study demonstrates that their finding extends to a conventional visual search task where eye movements are allowed, and a single task is performed.

The results of the current experiment also replicate previous findings that patients’ conjunctive visual search performance declines disproportionately as a function of display size. An important difference in the visual search tasks used in the current study was the elimination of response biases by using only target-present trials. The fact that there is always a target present in the display reduces the probability of giving up the search before finding the target on more difficult trials and thus reduces the confounding effects of differential speed–accuracy trade-offs. The findings of the current study are consistent with findings of impaired performance on the SOA Task among patients with SCZ as a function of target eccentricity. We also find interesting that the results of a study by Granholm et al. (1996) that directly addressed this issue do not support this model. The reason for this discrepancy is not clear and is a potential area for future research. It may be possible that the brief presentation of 50 ms in the SOA task is not sufficient for the processing of the information within the visual span and reducing the duration of attention allocation or eye fixation beyond a critical level may limit visual processing before any limitations due to visual span can be evoked. Therefore, healthy controls, who according to the current model have a wider visual span, suffer relatively more compared to patients. As a result, Granholm et al. may have unexpectedly observed that patients were in fact more discriminable from the controls at the narrower visual angle of the display. Alternatively, the reason for this discrepancy may lie in the different search requirements of the SOA and visual search tasks. Notably, the search elements (i.e., targets and distractors) used in an SOA task may lead to parallel search due to high target discriminability. In this context, it is reasonable to speculate that the impact of target eccentricity on task performance would be minimized. As such, the findings would be expected to be similar to the results manifest under feature search conditions of the current study, where a significant between-groups difference was not found.

**Figure 1.** Mean search slopes (ms/item) in feature and conjunctive search illustrate the average increase in RT produced by each search item and a smaller slope is indicative of a more efficient and parallel search. Close to zero slopes for both patients and healthy controls in the feature search condition suggest that both groups were able to perform an efficient, parallel visual search in this condition. However patients demonstrated significantly steeper search slopes and less efficient search in the conjunctive search condition.

**Figure 2.** Mean search slopes in the conjunctive search condition by eccentricity. Patients’ impairment in conjunctive visual search is significant only when the target is located farther away from the center of the display.
The current data are also consistent with physiological findings that indicate impaired functioning of the dorsal visual pathways in SCZ (e.g., King, Christensen, Sekuler, & Bennett, 2003; Butler & Javitt, 2005; also see Christensen & Bilder, 2000). The dorsal visual pathway originates in the magnocellular retinal ganglion cells and projects to the magnocellular layers of the lateral geniculate nucleus (i.e., layers 1 & 2). It then proceeds as a separate pathway to the posterior parietal areas. Magnocellular neurons are known to be fast-responding, less sensitive to color, with high contrast sensitivity and low spatial resolution (for a review, see Merigan & Maunsell, 1993). It has also been proposed that peripheral vision is primarily mediated by the dorsal visual stream (e.g., Pandya & Yeterian, 1990). Collectively, these observations are in keeping with the current findings that patients are disproportionately impaired in detecting more peripheral targets. However, it is important to note that the target used in the current study was defined by color, which is a putative ventral visual processing stream function. Therefore, further research is warranted to understand whether the found deficit in the current study (i.e., impairment in detection of peripheral targets) can be directly attributed to impairments in the functioning of the dorsal visual pathway. In an interesting recent study, Li, Sampson, and Vidyasagar (2007) suggest that the dorsal stream can facilitate serial visual search involving red-green signals. That is, search for a red or green stimulus, while mediated by the parvocellular pathway, can benefit from the addition of even small amounts of luminance contrast (as low as 6%) carried by the magnocellular channel. Since the stimuli in the current study were only matched on average luminance and individual isoluminant points were not determined for each participant, we cannot rule out the existence of small luminance contrasts in individuals’ perception of the stimuli, nor the possibility that, as described by Li et al., search for the target in the current study could have been facilitated by small amounts of luminance contrast mediated by the magnocellular channel.

Alternatively, the reduction in patients’ visual span may be the result of mechanisms operating at later processing stages. Visual span studies in healthy individuals demonstrate that decreases in attentional resources (e.g., due to dual-tasking) cause a narrowing of the visual span (e.g., Pomplun et al., 2001; Wood et al., 2006). The data from the current study can be predicted from these normative data within the framework of a limited capacity model of SCZ proposed by Papanicolaou and Johnstone (1984); that is, limited attentional resources in patients with SCZ may result in a reduction of their visual span, similar to the effect of divided attention conditions among healthy individuals.

As with any difference in performance between healthy individuals and patients, it is important to examine whether the observed differences could not be accounted for by the existence of a generalized deficit among patients. In this context, the reliability of the slope was estimated by calculating a split-half reliability coefficient (odd-even trials). Results demonstrate that the reliability coefficient for the eccentricity 2 condition (r = .68) is greater than that of the eccentricity 1 condition (r = .62). We therefore calculated the true score variance of slopes in the eccentricity 1 (\(S^2_1 = 19.84\)) and eccentricity 2 (\(S^2_2 = 23.8\)) conditions. The difference between these variance estimates was evaluated with Hartley’s F-max test for the equality of variances, which demonstrated that the difference in true score variance (i.e., discriminating power) between the two eccentricity conditions is not statistically significant, \(F(21, 21) = 1.20, p > .25\) (\(F_{\text{max}}(21, [21]) = 1.67\)). This further asserts that differences in search efficiency between patients and controls in the eccentricity 2 condition cannot be accounted for by a greater discriminating power in this condition.

Some limitations of the current study must also be considered. First, patients with SCZ in the current study, may not accurately represent the general population of patients with SCZ, because of the exclusion criteria used in recruiting participants, such that participants taking medication with known cognitive effects (e.g., benzodiazepines, anticholinergics, anticonvulsants) or participants with a history of substance dependency were excluded from participation in the study. Since these factors are known to have a negative impact on cognition, we believe that it is safe to assume that removing these exclusion criteria would have increased the observed eccentricity effect, but also would have lead to a situation where the confounding effects of these factors could not be ruled out. Second, in the present study, inferences regarding visual span were made by comparing the eccentricity effect between patients with SCZ and healthy controls. It is important to note, however, that we cannot rule out the possibility that patients with SCZ executed different search strategies or eye movement patterns that may have resulted in an exaggerated eccentricity effect. This possibility could be productively investigated in the future using the eye-tracking methodology. With the eye-tracking technology and the gaze-contingent paradigm, it would also be possible to directly estimate and compare the visual span of patients with SCZ and healthy controls while performing visual search tasks.

In conclusion, the results of this study provide evidence for a narrower visual span or field of effective vision among patients with SCZ and speak to a need of measuring the visual span more directly using the gaze-contingent window paradigm. Further studies can also help elucidate whether this deficit is specific to SCZ or it may also occur in other psychiatric illnesses (e.g., major depressive disorder or bipolar disorder).

References


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