Schizophrenia Patients Show Deficits in Shifts of Attention to Different Levels of Global-Local Stimuli: Evidence for Magnocellular Dysfunction

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Abnormalities of attention and visual perception are well documented in schizophrenia. The global-local task is a measure of attention and perceptual organization that utilizes visual stimuli comprised of large letters (global level) made up of smaller letters (local level). Subjects identify target letters appearing at either the global or local level of the stimulus. In this study, we used a version of the global-local task specifically designed to examine lateralized hemispheric processing and attention shifting in 30 schizophrenia patients and 24 normal controls. Global-local stimuli were presented in couplets (consecutive pairs). Reaction time for the second target in a couplet was compared under conditions in which the target remained at the same level (global-global, local-local) and when the target changed levels (global-local, local-global). Level-specific priming (ie, global to global and local to local) and the local-to-global level shift were similar in both groups. Schizophrenia patients were significantly slower, however, shifting attention from the global to the local level. These results implicate an impairment in shifting attentional resources from predominantly right lateralized magnocellular/dorsal stream processing of global targets to predominantly left lateralized parvocellular/ventral stream processing of local targets. Local interference effects in global processing provide further support for impaired magnocellular processing in schizophrenia patients.

Key words: magnocellular/parvocellular/global-local/schizophrenia/dorsal visual stream/ventral visual stream

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Introduction

Abnormalities of attention and visual perception have long been considered core features of the cognitive dysfunction associated with schizophrenia.[1–3] In particular, impairments of visual attention and perception suggesting left hemisphere dysfunction have been well documented in schizophrenia. For example, the finding that schizophrenia patients are slower in shifting attention to uncued targets in the right visual field has been interpreted as a left hemisphere deficit.[4–6] Brain-damaged patients with unilateral lesions of the left hemisphere show a similar deficit.[7,8] In addition, processes related to early stages of visual perception like backward masking,[9,10] object recognition,[11,12] and processing of low spatial frequencies[13,14] are compromised in schizophrenia patients.

One method of assessing functional hemispheric asymmetries of selective visual attention and early visual information processing is to examine intrastimulus shifts of attention between different levels of hierarchically organized visual stimuli. The global-local task[15] is a measure of attention and perceptual organization that utilizes visual stimuli comprised of large letters (global level) made up of smaller letters (local level) and requires subjects to identify target letters appearing at either the global or the local level (see figure 1). In functional imaging studies, healthy participants tend to show a right hemisphere preference in processing global stimuli and a left hemisphere preference in processing local stimuli.[16–18] Divided visual field paradigms have also confirmed this lateralized asymmetry in healthy participants.[19–22] This lateralized specialization of local and global processing is consistent with findings from brain-damaged patients showing that distinct cortical pathways are selectively engaged in processing either global or local stimuli. Patients with left posterior hemisphere lesions (ie, left superior temporal gyrus and left temporal-parietal lobe) demonstrate a local processing deficit, whereas patients with right posterior hemisphere damage (ie, right temporal-parietal lobe) show a global processing deficit.[23–25] In addition to confirming a right/left hemispheric asymmetry for global/local processing, respectively, event-related potential (ERP) findings in healthy subjects document early sensory precedence for processing of global stimuli relative to local stimuli.[26–29]

		STIMULI			
		More Similar		Less Similar	
L E V E L	Local	H H H H H H H H H H H H H H	Target H Distractor A	S S S S S S S S S S S S S S	Target S Distractor A
	Global	E E E E E E E E E E E E E E	Target S Distractor E	E E E E E E E E E E E E	Target H Distractor E

Fig. 1. Stimuli Examples. In each stimulus presentation, the subject's task was to indicate whether a target "S" or "H" was present. The target could be presented at either the local level or the global level with a distractor, either "A" or "E," presented at the other level. The distractor could be similar in shape to the target (as "A" is to "H" and "E" is to "S") or dissimilar in shape to the target (as "A" is to "S" and "E" is to "H"). Four global targets: large "S" formed by small "E"s (similar), large "S" formed by small "A"s (dissimilar), large "H" formed by small "A"s (similar), large "H" formed by small "E"s (dissimilar). Four local targets: small "S"s forming a large "E" (similar), small "S"s forming a large "A" (dissimilar), small "H"s forming a large "A" (similar), small "H"s forming a large "E" (dissimilar).

Although the visual system generally gives precedence to the processing of global stimuli over local stimuli, a number of experimental conditions can influence processing at the local or global level, such as attentional manipulations,[24,25,30,31] interference,[23,25,30–32] priming,[33–35] visual angle,[31,36] and spatial frequency characteristics of the stimuli.[34,37] For example, the effects of attention shifting can be studied using the global-local paradigm by comparing the reaction time (RT) to sequential targets that remain at the same global or local level compared with the RT to sequential targets that change levels. Normal controls (NCs) show facilitation, demonstrated by faster RTs, when the second target in a pair remains at the same level as the preceding target.[31] This facilitation effect is understood in terms of level-specific priming for the spatial frequency characteristics of the first stimulus.[35] One component of the global processing advantage (ie, a faster RT for identifying global targets than local targets) typically seen in NCs is global interference with local response time (RT).[15,23,25] Interference effects are typically evaluated by manipulating the degree of similarity of stimuli presented at the global and local levels and calculating the amount of RT slowing for perceptually dissimilar, relative to perceptually similar, stimuli. Specifically, perceptually dissimilar information at one level (ie, the nontarget level) can interfere with (ie, slow down) processing of information at the other level (ie, the target) (see figure 1). Abnormally high levels of interference at one target level can correspond with a processing disadvantage at the other level, eg, increased local interference in global RT is consistent with

a global processing disadvantage, and vice versa. RT advantage and interference effects can vary independently in response to experimental manipulations (eg, changes in visual angle or retinal locus)[30,32,38] and are also differentially affected in certain pathological conditions.[23,25]

The association between local or global deficits and schizophrenia varies as a function of whether divided or directed attention paradigms were used. Local processing deficits have been consistently found in chronically ill schizophrenia patients in *divided* (ie, *unbiased*) attention conditions.[39,40] A local processing deficit was also found in early onset schizophrenia, but shifts of attention from the global to the local level accounted for the finding.[41] Directing attention toward the local level eliminated the local processing deficit in all 3 studies. Thus, in divided attention conditions, the existing literature is inconclusive as to whether schizophrenia patients have a local processing deficit per se, or whether a local deficit occurs only in the context of shifting from the global to the local level. Conversely, a global processing deficit has been found in *directed* (ie, *biased*) attention conditions, a finding that was interpreted as evidence of right hemisphere underactivity-left hemisphere overactivity.[42] A global processing impairment in schizophrenia patients consistent with an early visual processing deficit was also observed in an ERP study that minimized interference, facilitation, and level-shifting effects.[43]

A processing deficit that is evident in a RT disadvantage may not be observed in the interference conditions because interference effects can be less sensitive to processing deficits. Neither divided nor directed attention conditions support a significant interaction between interference effects and group that would be consistent with a global or a local processing impairment in schizophrenia patients.[40–42] In the only study that used a divided attention condition, schizophrenia patients and NCs showed similar interference effects at both target levels.[40] Studies that used directed attention conditions showed equivalent levels of global interference in local RT[41] and greater overall levels of interference in patients at both target levels.[40] One other study reported a post hoc finding of an association between higher positive symptoms and increased local interference in global RT that was interpreted as related to heightened distractibility in this subgroup of patients.[42]

In brief, whether schizophrenia patients show a local or a global processing impairment and the potential usefulness of interference effects to inform this issue remain unresolved. Here, we test the hypothesis that slowed local processing in chronically ill schizophrenia patients occurs as a function of shifting attention from the global to the local level. We also examine whether schizophrenia patients and NCs show the same patterns of interference effects on global and local processing tasks. We hypothesized that NC subjects would show the normal pattern of global interference in local RT. Significant variation

from this expected pattern of interference effects would implicate a global processing impairment in schizophrenia patients. The divided attention version of the global-local task (adapted from Filoteo et al[33]) is well suited for parsing the effects of level shifting (global-local and local-global pairs), level priming (global-global and local-local pairs), and interference (more similar distractors vs less similar distractors) on local and global processing in schizophrenia patients and healthy controls.

Materials and Methods

Participants

The subject groups included 30 right-handed individuals who met *Diagnostic and Statistical Manual of Mental Disorders* (Fourth Edition) (*DSM-IV*) criteria for schizophrenia or schizoaffective disorder and 24 right-handed NCs. Demographic characteristics of the sample are presented in table 1. The groups did not differ in age, years of education, or familial socioeconomic status.[44,45] The schizophrenia group had a slightly larger proportion of males than the controls. NC participants had higher Wechsler Adult Intelligence Scale-Revised (WAIS-R)[46]– estimated verbal IQ's (see table 1). The patients were chronically ill outpatients (mean duration of illness = 19.5 y, SD = 10.1) and were moderately symptomatic as measured by the Brief Psychiatric Rating Scale (BPRS)[47] (M = 46.6, SD = 15.1). All but 2 schizophrenia patients were medicated at the time of testing. Of the 28 schizophrenia patients who were medicated, 25 were on atypical antipsychotics, 1 was on a typical antipsychotic, and 2 were on both atypical and typical antipsychotics; mean dose in chlorpromazine equivalents: 531.1 ± 426.8 mg.[48,49] The control group was restricted to individuals who did not meet *DSM-IV* criteria for any psychotic disorder (lifetime), bipolar disorder without psychotic features, or a schizophrenia-spectrum personality disorder. The principal diagnostic instrument for assessing Axis I disorders was the Structured Clinical Interview for *DSM-IV*, Patient Edition.[50] Schizotypal, schizoid, and paranoid personality disorders were assessed in controls using the Structured Interview for Schizotypal Symptoms (Version 1.5).[51] An experienced clinician administered the interviews, and an independent group of senior diagnosticians reviewed the interview materials and all available hospital records and assigned consensus Axis I and Axis II diagnoses based on best estimate methods.[52] The interviews and diagnostic evaluations were performed blind to the experimental procedures and group membership. Subjects in this study are a subset of a much larger group that also included bipolar patients, relatives of schizophrenic, schizoaffective, and bipolar patients, as well as relatives of controls. The following exclusion criteria applied to all participants: (*a*) lack of fluency in English, (*b*) history of serious head trauma or diagnosed organic brain disease, and (*c*) history of substance abuse or dependence during the past 2 years or previous chronic dependence. All participants had an estimated verbal IQ of 85 or greater based on the vocabulary subtest of the WAIS-R.[53] All participants provided written informed consent and were paid for their participation.

Table 1. Demographic and Clinical Characteristics of the Sample

Characteristic	Normal Participants (n = 24), Mean (SD)	Schizophrenia Patients (n = 30), Mean (SD)
Age (y)	40.2 (12.9)	42.6 (11.0)
Estimated verbal IQ[a]	107.5 (9.1)	99.5 (10.4)
Education (y)	14.6 (2.5)	14.0 (2.0)
Familial SES	2.6 (1.1)	2.6 (1.2)
Gender ratio	13 females, 11 males	9 females, 21 males
BPRS		44.5 (13.5)
Duration of illness (y)		22.2 (9.7)

Note: BPRS, Brief Psychiatric Rating Scale.
[a]Verbal IQ ($t_{52} = 2.97$, $P = .005$), age ($t_{52} = -0.73$, $P = .47$), education ($t_{52} = 1.02$, $P = .31$), and SES ($t_{50} = 0.17$, $P = .87$), gender ratio ($\chi^2 = 3.2$, $df = 1$, $P = .07$).

Stimuli and Apparatus

Stimuli consisted of targets and distractors presented simultaneously within the same stimulus (see figure 1). The targets were the letters "S" or "H." The distractors were the letters "A" or "E." Targets were presented at either the global level (large letter) or the local level (small letters) with distractors always presented at the other level. Thus, whenever the target was at the local level, the distractor was at the global level and vice versa. Eight global-local figures were used: 4 figures required subjects to identify a global target and 4 figures required subjects to identify a local target. The block shaped stimuli were constructed in a 5 × 4 grid. The global stimuli were 11.0 cm in height and 7.5 cm in width and subtended about 10° of visual angle. The local stimuli were 1.5 cm in height and 1.0 cm in width and subtended about 1.4° of visual angle. Stimuli were white on a black background and were presented on an IBM ThinkPad notebook computer. Participants were seated approximately 60 cm from the computer screen. Responses were made on an external computer keyboard. The stimuli were displayed, and RTs to 1-millisecond accuracy were obtained using DMDX Display Software.[54]

Procedure

Participants were instructed to identify whether each stimulus contained an "S" or an "H" by pressing the "S" key with their left index finger or the "H" key with their right index finger as quickly as possible after

the onset of the stimulus. Each stimulus remained on the screen until a response was made or 5 seconds had elapsed. The "S" or "H" targets appeared randomly at either the global or local level with distractor letters (ie, "A" or "E") presented at the other level. Stimuli were presented consecutively in couplets. Prior to each couplet, a centrally located fixation cross was presented for 500 ms. Each couplet was presented at 1 of 2 level-shifting conditions: no shift, in which the target for the second stimulus in the couplet remained at the same level (global-global and local-local), or shift, in which the target for the second stimulus changed levels (global-local and local-global). In addition, the second stimulus within the couplet contained a distractor that was either similar or dissimilar to the target. Thus, there were a total of 8 conditions: 2 level-shifting conditions (shift or no shift) and 2 first-stimulus conditions (global first or local first), with each level-shifting and first-stimulus condition having 50% similar and 50% dissimilar distractors. The 8 conditions were randomly distributed across the 56 experimental couplets. The dependent measure was mean RT difference between the first and second stimulus in a couplet. Because the RT difference score is the degree to which responses to the second stimulus are slowed or facilitated relative to the first stimulus, RT difference scores were chosen in order to remove the effects of baseline RT. A positive RT difference score indicated that the subject responded more slowly on the second of the 2 consecutive trials, whereas a negative RT difference score indicated that the subject responded faster on the second trial. Incorrect responses and responses with RTs greater than 3000 milliseconds were not included in the analyses. This cutoff was chosen because priming effects have been shown to be robust for interstimulus intervals up to 3 seconds.[25] A significantly larger percentage of responses (8.0%) were dropped for schizophrenia patients than NC subjects due to slowed responsiveness (3.7%) ($t_{36.1} = -2.03$, $P = .05$). Ten practice couplets were administered prior to the task to insure that subjects understood the instructions.

Statistical Methods

A multivariate analysis of variance (MANOVA) was conducted to determine the effects of: (1) level shifting—shift global-local (GL) and local-global (LG) pairs] vs no shift (global-global [GG] and local-local [LL] pairs), (2) first-stimulus effects—global-first pairs (GG and GL) vs local-first pairs (LL and LG), and (3) interference—similar distractors vs dissimilar distractors. Effect sizes were calculated as Cohen d.[55]

Results

Significant MANOVA results with corresponding P values are summarized in table 2 and are presented below.

Table 2. MANOVA Results Showing Significant Group Interactions and Corresponding P Values

| Interactions	P Values
Group by level shifting	.04
Group by global first	.02
Group by global first by similar distractors	.05
Group by first stimulus by level shifting by interference	.009

Note: MANOVA, multivariate analysis of variance.

Level Shifting

Schizophrenia patients were disproportionately slower (M = 91.57 ms, SE = 21.32) than NC (M = 9.82 ms, SE = 21.32) when the target (ie, the second stimulus in a pair) shifted levels, resulting in a significant group-by-level shift interaction ($F_{1,53} = 4.29$, $P = .04$) (see figure 2). Both groups showed faster RTs when the second target in a pair remained at the same level as the preceding stimulus in the no-shift condition. This level-specific priming effect was not significantly different in the 2 groups ($P = 0.48$, effect size [e.s.] = 0.23).
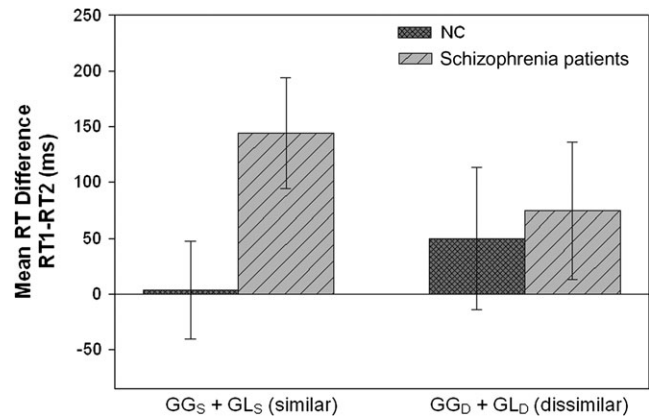
First Stimulus

Schizophrenia patients were disproportionately slowed for targets preceded by global stimuli (M = 88.40 ms, SE = 23.20) compared with NC (M = −6.71, SE = 31.17), resulting in a significant group-by-global first interaction ($F_{1,53} = 6.24$, $P = .02$) (figure 3). On the other hand, the groups did not differ in performance on targets preceded by local stimuli ($F_{1,53} = 0.08$, $P = .77$; schizophrenia patients: M = −20.86, SE = 35.47; NC: M = −33.44, SE = 19.09). The disproportionate slowing
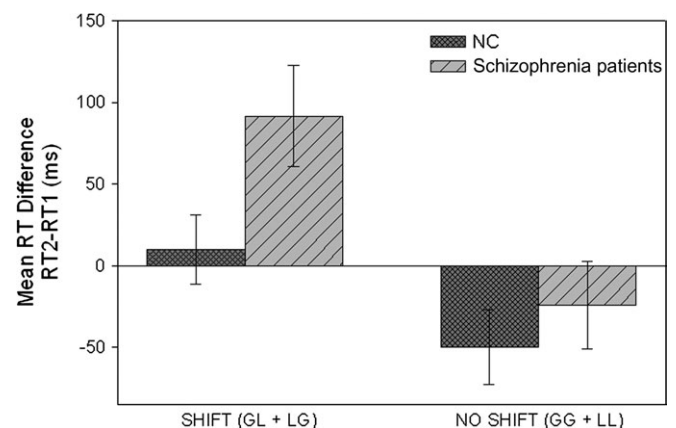
Fig. 2. Group-by-Level Shift Interaction. Group-by-level shift interaction showing that schizophrenia patients were significantly slower than normal controls (NCs) ($P = .04$) when targets shifted levels between consecutive stimulus presentations (ie, global-local and local-global pairs).
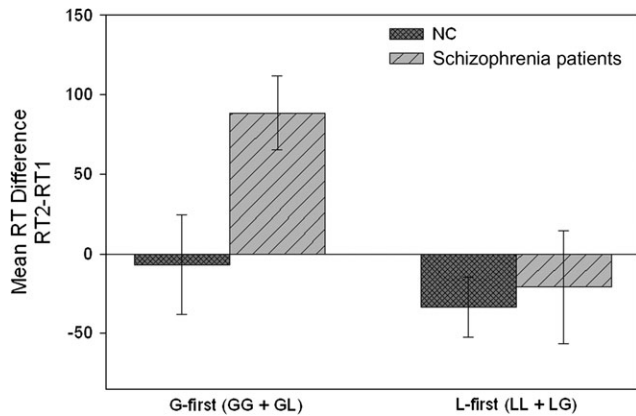
Fig. 3. Group-by-First-Stimulus Interaction. Group-by-first-stimulus interaction showing that schizophrenia patients were significantly slower than normal controls (NCs) ($P = .02$) when a global stimulus was the first stimulus in a pair (ie, global-global and global-local pairs).

Fig. 4. Group-by-First-Stimulus-by-Interference Interaction. Group-by-first-stimulus-by-interference interaction showing that schizophrenia patients were significantly slower than normal controls (NCs) for pairs in which global-first stimuli were followed by global or local stimuli containing similar distractors ($P = .05$).

of schizophrenia patients on global first pairs occurred only for targets containing similar distractors (s), ie, GG_S and GL_S. This finding was reflected in a significant group by global first by similar distractor interaction ($F_{1,53} = 4.20$, $P = .05$; schizophrenia patients: M = 144.03, SE = 50.04; NC: M = 3.89, SE = 43.91] (figure 4). Both groups were slowed equivalently on global first targets with dissimilar distractors (D), ie, GG_D and GL_D ($F_{1,53} = 0.08$, $P = .78$; schizophrenia patients: M = 74.48, SE = 61.56; NC: M = 49.56, SE = 63.89).
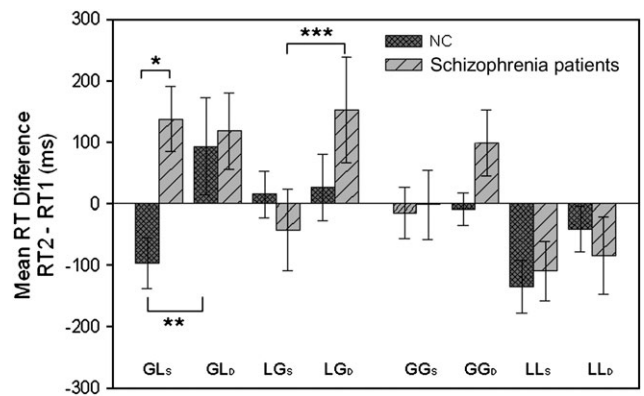
Interference

Interference effects were calculated as the amount of RT slowing for perceptually similar stimuli relative to perceptually dissimilar stimuli. NC subjects showed the expected pattern of global interference in local RT (figure 5), which is consistent with global precedence. The global interference effect was most apparent when local targets were preceded by global stimuli, ie, GL pairs (M = 189.9 ms, $P = .02**$) (symbols refer to significance notations in figure 5), but were also observed when local targets were preceded by local stimuli, ie, LL pairs [M = 93.08, $P = .06$]. In contrast, schizophrenia patients showed local interference in global RT, suggesting that local information was being attended to at an early stage of visual information processing that should predominantly involve the global level. This effect was strongest when global targets were preceded by local stimuli, ie, LG pairs [M = 194.8 ms, $P = 0.04***$].

Interaction of Level-shifting, First-Stimulus, and Interference Pair Combinations

Figure 5 also shows the source of a significant 4-way group-by-first stimulus-by-level shifting-by-interference

interaction ($F_{1,53} = 7.45$, $P = .009$). Schizophrenia patients had significantly slowed RTs to local targets when local targets were preceded by global stimuli but only in the presence of similar distractors, ie, GL_S pairs. The reason this deficit shifting from the global to the local level was observed only for similar distractors (GL_S) in schizophrenia patients is that NC showed the expected pattern of global interference in local RT on GL_D pairs. Planned comparisons confirmed significantly slower RTs to GL_S pairs in schizophrenia patients (M = 138.12 ms, SE = 53.23) than in NC subjects (M = −96.43, SE = 41.78) ($t_{52} = −3.34$, $P = .002*$, e.s. = 1.2). (Examinations of gender differences in global-local processing have not yielded a consistent pattern of results.[56–58] We observed a trend in schizophrenia patients [$P = .08$] for males to

Fig. 5. Mean Reaction Time (RT) Differences. Between-group effects: *global to local level-shifting deficit in schizophrenia patients compared with normal controls (NCs) ($P = .002$); Within-group interference effects: **global interference effect in NCs ($P = .02$); ***local interference effect in schizophrenia patients ($P = .04$). Between-group differences for all other conditions were not statistically significant.

have faster RT for GL$_S$ pairs. In all other conditions, gender differences were not observed in schizophrenia patients [all *P* values > .46] or NC subjects [all *P* values > .18]). On the other hand, the groups did not differ significantly in their ability to shift from the local to the global level irrespective of interference, ie, LG$_S$ or LG$_D$ pairs (all *P* values >.25). There was a trend for schizophrenia patients (M = 98.8, SE = 54.1) to have slower RTs than NC (M = −9.1, SE = 26.5) when global stimuli preceded global targets with dissimilar distractors, ie, GG$_D$ pairs ($t_{41.6} = −1.79$, *P* = .08, 2 tailed, e.s. = 0.83), suggesting that level-specific priming effects are vulnerable in schizophrenia subjects when the first stimulus in a pair is at the global level, at least in the presence of interference. There were no group differences in level-specific priming when global stimuli preceded global targets containing similar distractors, ie, GG$_S$ pairs, (*P* = .85) or when local stimuli preceded local targets, regardless of the degree of interference, ie, LL$_S$ or LL$_D$ pairs (all *P* values >.58).

Discussion

The key finding from this study was that schizophrenia patients showed an impaired ability to shift attention from the global to the local level of hierarchically organized stimulus pairs. This result in chronic schizophrenia patients replicates a previous finding in early-onset schizophrenia.[41] Bellgrove et al[41] interpreted their results in the framework of a disengage deficit reflecting impairments in the volitional control of attention. In both our study and theirs, however, schizophrenia patients and NC subjects did not differ in ability to shift attention from the local to the global level. Thus, a generalized disengage deficit would not account for the selectiveness of the impairment in shifting attention only from global to local levels. Below we suggest a framework that may more parsimoniously explain this specific pattern of results—that magnocellular/dorsal stream dysfunction associated with global processing may contribute to a secondary impairment in later downstream parvocellular/ventral stream processing of local targets.

One way to conceptualize this selective impairment in shifting attention from global to local levels is that it reflects an underlying impairment of lateralized visual information processing. There is a general consensus that global and local information are preferentially processed in the right and left hemispheres, respectively.[16,17,59] Thus, the global to local level-shifting impairment observed in schizophrenia patients is consistent with a specific deficit shifting attention from predominantly right hemisphere engagement to predominantly left hemisphere engagement.

Consistent with the lateralized processing preferences for global and local stimuli, low and high spatial frequencies are known to be key determinants of whether information is processed at the global or local level, respectively.[34,35,59–63] Right posterior brain regions are biased toward processing lower spatial frequencies, whereas left posterior brain regions are biased toward processing higher spatial frequencies.[22] The disproportionately slower global-to-local level shift observed in schizophrenia patients (figure 5) also suggests a selective deficit in shifting attention from low spatial to high spatial frequency channels. The groups were not differentially impaired in shifting attention from high spatial frequency channels (local) to low spatial frequency channels (global), underscoring the specific direction of this level-shifting impairment. The subject groups also did not differ in processing local-to-local pairs, indicating that an impairment in assigning attentional resources to the high (ie, local) spatial frequency channel per se does not account for the global to local level-shifting deficit.

The specific direction of the level-shift impairment (ie, global/low frequency to local/high frequency) observed in schizophrenia patients suggests a selective slowing of ventral stream processing of local targets only when preceded by dorsal stream processing of global targets. Low spatial frequency information, corresponding to low-resolution global stimuli, is processed first by rapidly conducting neurons in the magnocellular pathway.[64,65] High spatial frequency information, corresponding to high-resolution local stimuli, in contrast, is processed later by more slowly conducting neurons in the parvocellular pathway.[64,65] Magnocellular and parvocellular neurons project to dorsal and ventral visual streams, respectively. In addition, magnocellular/dorsal stream processes exert an organizing influence on later downstream parvocellular/ventral processing through crossover projections.[65–67] For an integrative review, see Hellige[68] study. ERP studies of global/local processing in normal participants confirm this interaction between the 2 systems. Beginning during early sensory-perceptual processing and continuing into later stages of response execution, the time course for global and local information processing is largely consistent with early magnocellular/dorsal system processing of global stimuli and later parvocellular/ventral system processing of local stimuli.[26–29]

Our finding of a disproportionately slower global-to-local level shift in schizophrenia patients is consistent with evidence that early visual processing deficits related to magnocellular dysfunction lead to secondary processing impairments within both the dorsal and ventral stream pathways.[10,12,69–72] Magnocellular impairment in schizophrenia is also implicated in the global processing deficit described in an ERP study.[43] Specifically, schizophrenia patients showed a primarily right lateralized deficit that implicated processing abnormalities in areas V3/V3a of the extrastriate cortex. Importantly, the authors concluded that the physiological data provided strong support for ''bottom-up'' processing of global-local stimuli.

Do Schizophrenia Patients Have a Local Processing Deficit?

Previous studies have concluded that schizophrenia and clinical schizotypy patients have a local processing deficit that is revealed when subjects are required to divide their attention between randomly presented local and global targets but that the local impairment can be overcome when attention is biased toward the local level.[39,40,73] This pattern of findings has been interpreted as evidence of an attentional deficit that can be compensated by exogenous manipulation of attention. Although this interpretation may be correct, it is not possible to rule out the alternative possibility that the local processing deficit is a secondary effect of an impairment shifting attention from the global to the local level. The reason for this ambiguity is that trials involving level shifting and level priming were analyzed in aggregate rather than parsed on the basis of the preceding trial. Thus, the inference of a local processing deficit was made without consideration of level-shifting and level-priming effects on local processing. Indeed, when we looked at median RTs to just the first target in a pair we found a pattern similar to that seen in previous studies. Schizophrenia patients were nonsignificantly slower (61 ms) in detecting local targets compared with global targets, whereas NC subjects showed a slight local advantage (17 ms). The very small local processing advantage in NC is consistent with other studies that used similar stimulus parameters that minimize a global advantage (ie, when the visual angle subtended by the stimuli approaches 10°).[30,33,36,74] When we analyzed our results on the basis of RT differences, however, level-specific priming and the local-to-global level shift were largely unimpaired in schizophrenia patients. In contrast, shifts of attention from the global to the local level were selectively impaired in the patient group.

In this study, NC participants and schizophrenia patients were not differentially susceptible to *overall* interference (distractibility) effects (i.e., the extent to which perceptually dissimilar information at one level slows processing at the other level). This finding is consistent with reports from other divided attention paradigms in which subjects switched between processing randomly presented global and local targets.[40,73] However, when interference effects were parsed by level-shifting and level-priming conditions, a dissociable pattern of interference effects was observed. In NC subjects, perceptually dissimilar information at the global level interfered with local processing, a finding consistent with global precedence.[15,23,25–27,36] In schizophrenia patients, in contrast, dissimilar local stimuli interfered with global processing. The reversal of the normal pattern of interference effects implicates an early visual processing impairment in schizophrenia, which is consistent with magnocellular dysfunction. This dissociable pattern of interference effects was strongest for the level-shifting

pairs in both groups, suggesting that level shifting increased susceptibility to interference effects. The fact that this same pattern of dissociable interference effects persisted in an attenuated fashion in both groups even when consecutive targets remained at the same level suggests that the facilitative effect of level-specific priming modifies, but does not eliminate, interference.

The same pattern of local interference in global processing observed in this study has been reported in a smaller sample of acutely psychotic schizophrenia inpatients. Ferman et al[42] suggested that a heightened distractibility to feature detail associated with severe positive symptoms might account for this finding. We did not find an association between local interference and the positive symptom subscale of the BPRS[75,76] in our sample of chronic schizophrenia outpatients ($r = -0.02$, $P = .92$), suggesting that local interference effects may reflect a more enduring neurocognitive processing impairment that cannot be attributed to the distracting effects of acute psychosis. Local interference in global processing, particularly in the right hemisphere, has also been reported in psychometrically identified schizotypes in divided visual field paradigms.[19,20] Goodarzi et al[19] interpreted this finding to suggest that local information was being preferentially processed at a very early stage of visual information processing when global processing should predominate. This interpretation is consistent with our results in implicating magnocellular dysfunction in local interference effects in schizophrenia.

In summary, the selective deficit observed shifting from the global to the local level suggests a secondary processing impairment related to shifting from magnocellular/dorsal stream processing of global information to parvocellular/ventral stream processing of local information. Local interference in global RT is also consistent with a global processing impairment implicating magnocellular dysfunction in schizophrenia. Importantly, these findings in chronically ill schizophrenia patients extend findings first observed in acutely ill patients.[41,42]

Our interpretations are based on findings in the literature that strongly link global targets with low spatial frequencies involving primarily right lateralized magnocellular/dorsal stream processing and local targets with high spatial frequencies and primarily left lateralized parvocellular/ventral stream processing. Nevertheless, it is important to note that the global-local stimuli are complex and include a mixture of high and low spatial frequencies. Future studies with more psychophysiologically specific stimuli and objective brain imaging measures would be useful in parsing the roles of magnocellular/parvocellular pathways in the processing of global/local targets, respectively.

Acknowledgments

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