



## Paracontrast and metacontrast in schizophrenia: clarifying the mechanism for visual masking deficits

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### Abstract

Schizophrenic patients consistently demonstrate performance deficits on visual masking procedures. Visual masking can occur through two distinctly different mechanisms: interruption and integration. One highly effective way to limit the masking mechanism to interruption is to use a mask that surrounds, but does not spatially overlap, the target. These procedures are called paracontrast and metacontrast (for forward and backward masking, respectively). Despite their clear advantages for interpretation, paracontrast and metacontrast have not been used previously in schizophrenia. In the present study, we examined the reliability of the paracontrast and metacontrast procedures by administering these tasks to 103 schizophrenic patients and 49 normal control subjects. In addition, we compared the results to those from a low-energy masking condition, which is an alternative way to limit masking to interruption. Patients showed deficits on both the paracontrast and metacontrast procedures. The deficits in paracontrast and metacontrast were comparable to those seen previously with low-energy masking. These results suggest that the paracontrast/metacontrast procedure and the procedure using a low-energy mask are roughly equally sensitive to deficits in early visual processing among schizophrenic patients. These results bolster previous conclusions that schizophrenic patients show deficits on visual masking tasks even when masking on those tasks occurs entirely through the interruption mechanism.

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### 1. Introduction

Visual masking procedures are thought to assess the earliest components of visual information processing (Green et al., 1994a,b; Saccuzzo, 1974; Schuck and Lee, 1989). In visual masking paradigms, the subject's ability to process a visual stimulus (target) is reduced by another visual stimulus (mask) presented

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shortly before (forward masking) or after (backward masking) the target. Schizophrenic patients consistently demonstrate performance deficits on visual masking procedures. Specifically, they require longer time intervals between target and mask to identify the target stimulus, as compared with controls (Braff et al., 1991; Cadenhead et al., 1998; Rund, 1993; Saccuzzo et al., 1974; Saccuzzo and Schubert, 1981). Because these deficits have been demonstrated in remitted schizophrenic patients (Green et al., 1999), as well as in unaffected siblings of schizophrenic patients (Green et al., 1997; Keri et al., 2001), they are thought to reflect vulnerability to schizophrenia and a potential trait marker of the disorder (Balogh and Merritt, 1985; Merritt and Balogh, 1984; Saccuzzo and Schubert, 1981).

Research into the underlying mechanisms of visual masking has suggested that this phenomenon occurs through a combination of two processes, referred to as integration and interruption (Turvey, 1973). Integration refers to the fusion of the mask and target due to their close temporal and spatial proximity, whereas interruption reflects a disruption of slightly later-stage processing of the target by the mask. Visual masking procedures typically employed in schizophrenia research generally have involved both of these processes, as they have used high-energy masks relative to a low-energy and spatially overlapping target. Under these conditions, the masking effect comes from target and mask integration at short intervals, and target processing interruption at longer intervals. When subjects' performance is represented graphically, this design produces a monotonic (Type A) masking function in which performance decreases with increasing intervals (Breitmeyer and Ganz, 1976).

Some attempts have been made in schizophrenia to isolate the two processes by using masks that were relatively weak (i.e., low energy) compared to the targets. This design minimizes the effects of integration on visual processing of the target, because the visual representation formed by integrating the target with a weak mask is still interpretable (Green et al., 1994a). Thus, the masking effect with a weak target occurs primarily through interruption. This type of masking typically produces a non-monotonic (i.e., Type B or U-shaped) function that can demarcate the point at which target processing is interrupted by the mask (i.e., minimum is the point of the strongest

masking effect) (Ganz, 1975; Michaels and Turvey, 1979; Stewart and Purcell, 1974).

Perhaps the most effective way to isolate the interruption mechanisms is through the use of a mask that surrounds, but does not spatially overlap, the target (Ganz, 1975). This procedure is called paracontrast (for forward masking) and metacontrast (for backward masking). As yet, we know of no studies that have employed this combination of methods in schizophrenia. One study employed this procedure in hypothetically schizotypic college students. These "psychosis prone" subjects showed increased susceptibility in the metacontrast, but not the paracontrast, condition, as compared with controls (Merritt et al., 1986).

The purpose of the present study was to examine the utility of the paracontrast/metacontrast procedure in revealing visual masking performance deficits among schizophrenic patients and a non-psychiatric control group. The primary goals were: (1) to develop a reliable computerized version of the paracontrast/metacontrast procedure and (2) to determine whether these procedures can detect performance deficits in patients in one or both of these conditions. In addition, we compared the results to recently published data using the low-energy masking procedure (Green et al., 2003), to examine whether the paracontrast/metacontrast procedure would be more sensitive to performance differences between patients and controls than the low-energy procedure.

## 2. Methods

### 2.1. Subjects

Participants were part of the project "Early Visual Processing in Schizophrenia" (Green et al., 1994a,b). All schizophrenia patients were outpatients recruited through outpatient clinics at the VA Greater Los Angeles Healthcare System, from patients in the UCLA Aftercare Research Program who were participants in the project "Developmental Processes in Schizophrenic Disorders" (Nuechterlein et al., 1992), and through presentations in the community. They were administered the Structured Clinical Interview for DSM-IV (SCID-P) (First et al., 1997) and met

the DSM-IV diagnostic criteria for Schizophrenia (American Psychiatric Association, 1994). All interviewers were trained to administer the SCID by the Diagnosis and Psychopathology Unit of the UCLA Clinical Research Center for Schizophrenia and were required to obtain a Kappa of 0.75 for key psychotic and mood items before proceeding to interview participants independently. Patients were excluded if they had an identifiable neurological condition, any signs of mental retardation, or met criteria for substance dependence in the last 6 months. All patients were receiving antipsychotic medications (66% atypical).

The control group was drawn from respondents to flyers placed at various locations at the UCLA and the VA medical centers and through newspaper advertisements. They were administered the SCID-P, as well as selected sections of the Structured Clinical Interview for DSM-IV Axis II Disorders (First et al., 1996). Exclusion criteria were the same for controls as for patients, with the additional exclusion for histories of any psychotic disorders, recurrent major depression, bipolar disorder, substance dependence, or if they met criteria for Paranoid, Schizoid, Schizotypal, Borderline, or Avoidant personality disorders. Controls were also excluded for family history (first-degree relatives only) of psychotic disorders. All participants gave written informed consent after receiving a full explanation of the research according to procedures approved by the Institutional Review Boards of UCLA and the VA Greater Los Angeles Healthcare System.

The present study included 103 schizophrenic patients (92% male) and 49 non-psychiatric controls (51% male). Mean age for patients was 37.9 (S.D.=10.1; range=18–56) and for controls 34.5 (S.D.=8.5; range=19–54). Mean education for patients was 13.2 (S.D.=1.7; range=8–18) and for controls 13.7 (S.D.=1.3; range=12–18). The schizophrenic group had a mean illness chronicity of 13.6 years (S.D.=9.5; range=0–36). Patients' average positive (hallucinations, unusual thought content, and conceptual disorganization) and negative (blunted affect, emotional withdrawal, and motor retardation) symptoms, based on Brief Psychiatric Rating Scale (BPRS) (Overall and Gorham, 1962), were 2.58 (S.D.=1.22; range=1–5.67) and 2.01 (S.D.=0.93; range=1–4.67), respectively.

## 2.2. Testing procedures

A specially designed computerized system with a high refresh rate was used to administer the masking procedures (Green et al., 2002). Tasks were administered on a Dell Pentium computer with a 17 Sony Multiscan 200PS monitor, driven at 150 Hz, with a graphics card from Number Nine Technologies. Each screen sweep was 6.67 ms. Stimuli were presented as dark on a light background. Background luminance, measured with a hand-held meter with diffuser against the screen, was  $lx=89$ .

All participants were screened for corrected visual acuity of at least 20/30. Participants were seated one meter from the screen. Prior to the masking procedures, a thresholding procedure was used to equate participants' unmasked target identification using a staircase method (Wetherill and Levitt, 1965). The duration of the target was set at two screen sweeps (13.3 ms) and was held constant throughout the procedures. During this thresholding procedure, the contrast of the target (i.e., the grey scale value) was systematically increased or decreased based on subject's performance to achieve performance of 84% performance accuracy. This contrast level was used for all subsequent masking procedures. Intervals between target and mask were measured by stimulus onset asynchronies (SOAs), which is the time interval between the onset of the target and the mask. The SOAs were spaced in 13.3-ms increments from  $-80$  to  $+93$  ms and also had an interval at  $+120$  ms. In all, 14 SOAs were included (negative SOAs indicate forward masking; positive SOAs indicate backward masking).

A fixation symbol (a small cross) was presented for 300 ms, starting 400 ms before target onset. The target was a square with a gap that could appear at the top, the bottom, or on the left side (see Fig. 1). Targets could appear at any one of four locations on the screen (upper left, upper right, lower left, lower right). Target location was  $1.03^\circ$  of visual angle from fixation, and it subtended  $0.27^\circ$  of visual angle. In the paracontrast/metacontrast conditions, the energy of the mask was equal to that of the target (two screen sweeps). "Energy" in this context refers to light intensity times the duration of a stimulus. The mask was a square that surrounded, but did not overlap, all possible areas in which the target could appear (Fig. 1). To examine the

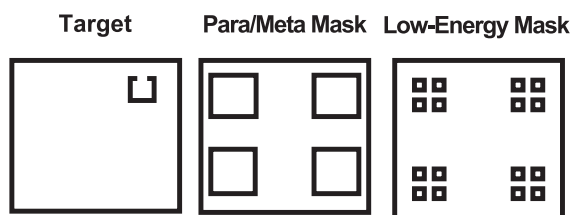


Fig. 1. Masking stimuli. The target was a square with a gap that could appear at the top, the bottom, or on the left side. Targets could appear at any one of four locations on the screen (upper left, upper right, lower left, lower right). The paracontrast/metacontrast mask was a square that surrounded, but did not overlap, all possible areas in which the target could appear. The low-energy mask was a composite square made up of four smaller squares and appeared at each of the four possible target locations, overlapping the area occupied by the target.

reliability of the procedure, we subdivided the trials into two blocks. In each block, 12 trials were presented in a randomized fashion at each SOA (three types of targets times four locations).

The parameters and results for the low-energy masking conditions are presented in detail elsewhere (Green et al., 2002, 2003). Briefly, the energy of the mask was half the energy of the target (i.e., one screen sweep for the mask and two for the target). The mask was a composite square made up of four smaller squares and appeared at each of the four possible target locations, overlapping the area occupied by the target (see Fig. 1). Twelve trials were presented in a randomized fashion at each SOA.

### 2.3. Statistical analyses

To examine the reliability of the procedures, the paracontrast and metacontrast conditions were averaged separately across the SOA's (the SOA at 0 was not included) within each of the two testing blocks. Reliability was then evaluated by calculating both Pearson and intraclass correlation coefficients (ICCs) across blocks. Thus, this is a form of split-half reliability. Separate coefficients were calculated for schizophrenic patients and controls within the paracontrast and metacontrast conditions.

The statistical design was a factorial repeated measures analysis of variance (ANOVA). Diagnosis (schizophrenia versus control) was the between-subject factor. The within-subject design was structured as a 2 (low-energy masking versus para-metacontrast)

by 2 (forward/para versus backward/meta masking)  $\times$  7 (SOA) factorial. Based on very high between-block reliability (see Results), scores at each SOA were averaged across the two blocks in these analyses. Although SOA was included in the design to permit graphing of the complete results, primary interest focused on the two- and three-way interactions of diagnosis with the other two within-subject factors (low-energy versus para-metacontrast; forward/para versus backward/meta) and the three-factor interaction (i.e., the  $2 \times 2 \times 2$  factorial component of the overall design).

### 3. Results

In the patient group, the reliability between first and second block of paracontrast was 0.876 (Pearson  $r$  between blocks) and 0.875 (ICC). Reliability for metacontrast in the patient group was 0.866 (Pearson  $r$ ) and 0.858 (ICC). For the control group, the values for paracontrast were 0.854 and 0.848, and for metacontrast 0.897 and 0.879, for test–retest and ICC, respectively. All correlation coefficients were highly significant,  $p < 0.0001$ . The Pearson and intraclass coefficients are in each case almost identical because there was virtually no mean shift or change in variance between blocks. The two blocks of the paracontrast and metacontrast procedures are presented in Fig. 2.

The high reliability between the two blocks justified the decision to average across blocks for the substantive analyses. The repeated measures ANOVA revealed a significant main effect for diagnosis ( $F=17.90$ ,  $df=1,150$ ,  $p < 0.0001$ ), indicating that patients performed more poorly than controls in both forward/para and backward/meta paradigms in both para-metacontrast and low-energy conditions. There was also a significant main effect for condition ( $F=219.00$ ,  $df=1,150$ ,  $p < 0.0001$ ), due to the tendency for both patients and controls to perform more poorly in metacontrast than the paracontrast condition. However, no significant condition by diagnosis interaction was found ( $F=0.40$ ,  $df=1,150$ , ns), suggesting that the masking deficits were comparable in magnitude for both conditions (i.e., paracontrast and metacontrast). Furthermore, we found a significant main effect for SOA ( $F=32.48$ ,  $df=5,750$ ,  $p < 0.0001$ ), but no signifi-

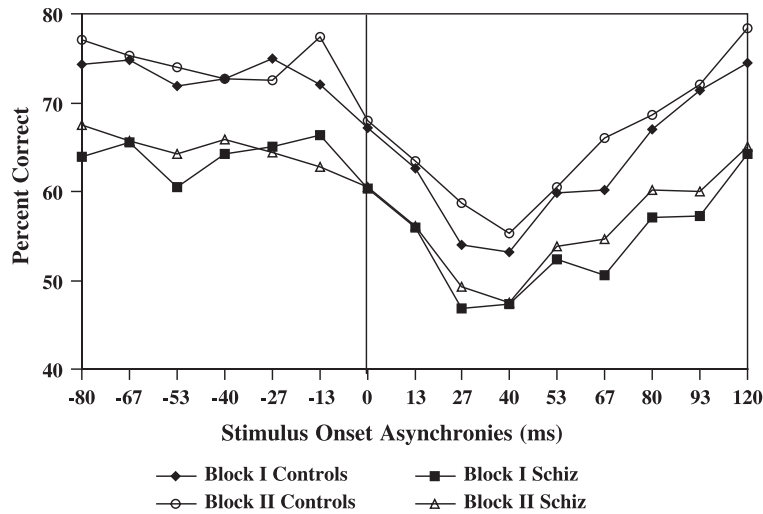


Fig. 2. Paracontrast- and metacontrast-masking performance for patients and controls in two trials. Paracontrast-masking trials are on the left (negative values), and metacontrast-masking trials are on the right (positive values). The vertical line at 0 indicates a simultaneous onset of the target and mask.

cant SOA by diagnosis interaction ( $F=0.64, df=5,750, ns$ ), suggesting similar shaped masking functions for both patients and controls. Finally, in comparing the para-metacontrast procedure to a previously published data using the low-energy masking procedure, we found neither a main effect for procedure ( $F=1.22, df=1,150, ns$ ) nor a procedure by diagnosis interaction

( $F=0.61, df=1,150, ns$ ), indicating that the deficits were comparable in magnitude in both procedures. These comparisons are illustrated in Fig. 3.

Based on a recent study (Chen et al., 2003) that reported differential visual contrast detection thresholds between schizophrenia patients receiving typical and atypical antipsychotic medications, we conducted

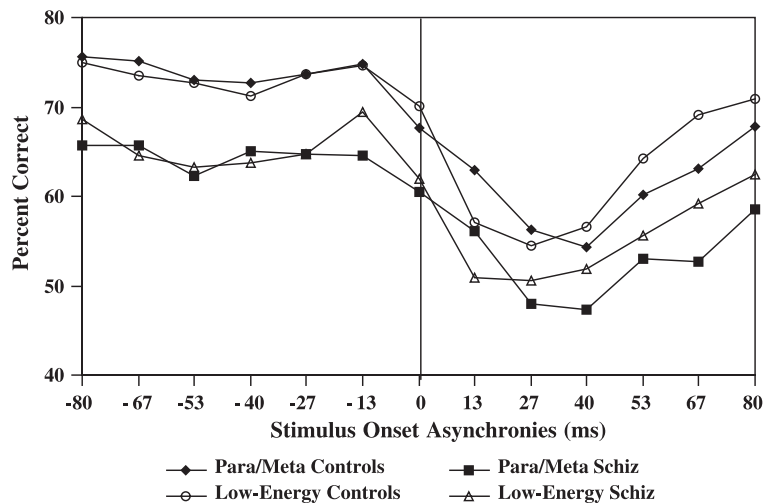


Fig. 3. Masking performance for patients and controls in the paracontrast/metacontrast and the low-energy procedures. Paracontrast and forward-masking trials are on the left (negative values), and metacontrast and backward-masking trials are on the right (positive values). The vertical line at 0 indicates a simultaneous onset of the target and mask.

an exploratory analyses to determine if type of antipsychotic medication influenced performance. The pattern of results remained essentially identical, with no differences between patients receiving typical and atypical antipsychotic medications.

#### 4. Discussion

In the current study, the computerized paracontrast/metacontrast procedure was found to be highly reliable across two blocks of administration. In terms of patient and control performance, we found a highly significant main effect for diagnosis, but no significant interaction effects. Thus, compared with controls, patients showed deficits in both paracontrast and metacontrast conditions to roughly the same extent. The deficits were also comparable in magnitude in the paracontrast/metacontrast and the low-energy masking procedures. These results, therefore, suggest that the paracontrast/metacontrast procedure is roughly as sensitive in detecting deficits in early visual processing among schizophrenic patients as the low-energy procedure, despite the fact that it does not involve any spatial overlap of target and mask. Finally, based on observation of *Figs. 2 and 3*, it appears that the paracontrast/metacontrast procedure yielded a slightly better defined U-shaped function than the low-energy procedure, with the strongest masking effects occurring between +27 and +40 ms.

A number of strengths of the present study should be highlighted. First, a relatively large sample size (especially of schizophrenia patients) was used for present analyses (103 patients and 49 controls). Furthermore, all participants were equated on initial target identification (at 84% performance accuracy) using a staircase method (*Wetherill and Levitt, 1965*) prior to the masking procedure. This way of equating participants has advantages over the ascending method that has been used previously in studies of visual masking in schizophrenia (i.e., gradually increasing target duration until the participant obtains a number of consecutive correct responses). Because target duration is always increased following an error in the ascending method, momentary lapses in attention would artificially inflate stimulus duration thresholds, thereby obscuring group differences (*Badcock et al., 1988*). By using the staircase method, it is reasonably

safe to conclude that group differences found in the present study are not attributable to simple perceptual difficulties in detecting the unmasked target.

Only one study to date has employed the paracontrast/metacontrast procedure in the schizophrenia spectrum disorders (i.e., hypothetically schizotypic college students), and that study reported deficits in metacontrast, but not paracontrast, masking conditions (*Merritt et al., 1986*). A number of other studies in schizophrenia patients have also found differential performance deficits on backward, but not forward, masking (*Saccuzzo et al., 1996; Slaghuis and Bakker, 1995*). The latter studies, however, did not employ the paracontrast/metacontrast procedure. In the current study, the patients had performance deficits on both para- and metacontrast, a finding that is consistent with a previous study from our laboratory in which patients showed deficits on both forward and backward masking (*Green et al., 2003*). Given the substantial methodological differences between the present study and prior ones, it would be difficult to explain the differential findings. One potential explanation for the differences in results across studies might be attributed to the relatively large number of closely spaced SOA's used in the current study, which might have provided sufficient resolution to detect group differences on both backward and forward components of masking.

The computerized procedures in the current study yielded highly reliable data on both paracontrast and metacontrast procedures. Further, these masking procedures detected performance deficits in schizophrenia patients. By comparing the current results to those obtained previously with a low-energy mask, the results bear on the question of which masking mechanism is relevant to the performance differences between patients and controls. Because the stimuli for the paracontrast and metacontrast procedures do not overlap, they are rather pure measures of masking by interruption and, hence, the results indicate that schizophrenia patients differ from controls even when there is little or no masking by integration.

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