

Enhanced distraction by magnocellular salience signals in schizophrenia



Carly J. Leonard^{a,*}, Benjamin M. Robinson^b, Britta Hahn^b, James M. Gold^b, Steven J. Luck^a

^a Center for Mind & Brain and Department of Psychology, University of California, Davis, CA 95618, United States

^b University of Maryland School of Medicine, Maryland Psychiatric Research Center, Baltimore, MD, United States

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ABSTRACT

Research on schizophrenia has provided evidence of both impaired attentional control and dysfunctional magnocellular sensory processing. The present study tested the hypothesis that these impairments may be related, such that people with schizophrenia would be differentially distracted by stimuli that strongly activate the magnocellular pathway. To accomplish this, we used a visual attention paradigm from the basic cognitive neuroscience literature designed to assess the capture of attention by salient but irrelevant stimuli. Participants searched for a target shape in an array of non-target shapes. On some trials, a salient distractor was presented that either selectively activated the parvocellular system (parvo-biased distractors) or activated both the magnocellular and parvocellular systems (magnocellular + parvo-biased distractors). For both manual reaction times and eye movement measures, the magnocellular + parvo-biased distractors captured attention more strongly than the parvo-biased distractors in people with schizophrenia, but the opposite pattern was observed in matched healthy control participants. These results indicate that attentional control deficits in schizophrenia may arise, at least in part, by means of an interaction with magnocellular sensory dysfunction.

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1. Introduction

Schizophrenia is associated with significant deficits in everyday functioning. This is in large part the result of deficits in cognitive functioning (Green, Kern, & Heaton, 2004), which may partly reflect an impairment in selecting goal-relevant information from the many sources of salient information in the environment. Accordingly, attentional impairment has been a key concept in schizophrenia research since the earliest theories (Bleuler, 1911) as well as in more recent investigations (e.g., Braff (1993), Nuechterlein and Dawson (1984)).

However, many laboratory tasks have shown surprisingly little impairment in selective visual attention in people with schizophrenia (PSZ) compared to matched healthy control subjects (HCS). The clearest evidence comes from variants of the Posner spatial cuing paradigm, in which the effectiveness of attentional selection can be quantified as the difference in performance for stimuli presented at cued versus uncued locations. Across a large number of studies, this cuing effect is typically just as large or even larger in PSZ than in HCS (Hahn et al., 2011; Spencer et al., 2011). In addition, Luck et al. (2006) found both behavioral and electrophysiological evidence that shifting attention to the location of a single, salient target in a visual search

array is unimpaired in PSZ compared to HCS. Furthermore, both PSZ and HCS can efficiently encode task-relevant visual stimuli into working memory and suppress the encoding of equally salient distractors (Gold et al., 2006). These results suggest that PSZ do not experience difficulty in implementing attentional selection if attention can be easily guided to the correct target. Instead, PSZ may be impaired in their ability to select task-relevant information in the presence of strong competition from highly salient distractors (Luck & Gold, 2008).

Consistent with this hypothesis, PSZ were worse than HCS at selectively encoding non-flickering, task-relevant objects into working memory in the presence of more salient flickering distractors (Hahn et al., 2010). However, the failure of selective attention in this experiment may reflect the fact that flickering stimuli are particularly effective at stimulating the magnocellular pathway (Merigan & Maunsell, 1993). Because the magnocellular system appears to be dysregulated in PSZ (Butler & Javitt, 2005; Butler et al., 2007; Martinez et al., 2008), the finding of impaired filtering of flickering objects may reflect a specific interaction between attentional control and magnocellular processing rather than a general impairment in controlling attention in the face of salient distractors.

Given the many findings showing reduced sensitivity and neural activation for stimuli that activate the magnocellular pathway in PSZ (Butler et al., 2007; Keri, Kelemen, Benedek, & Janka, 2004; Schechter et al., 2005), one might expect PSZ to exhibit reduced rather than increased distraction by stimuli that activate

* Corresponding author: Tel.: +1 530 297 4425.

E-mail address: cjleonard@ucdavis.edu (C.J. Leonard).

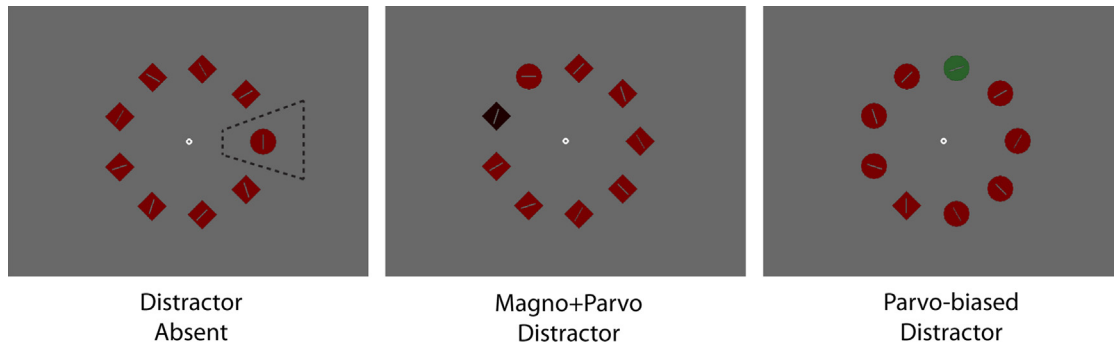


Fig. 1. Example stimuli. The region indicated by the dotted line in the salient distractor absent panel shows an example interest area used for analysis, and is not part of the experimental display. Also note that printed colors do not accurately depict those used in the experiment.

the magnocellular pathway (although see [Skottun and Skoyles \(2007\)](#) for a critique of the magnocellular hypothesis). However, increased distraction might be expected given previous research showing that PSZ show potentiated backward masking, an effect that arises when target discrimination is impaired by trailing distracting information (for a review see, [Green, Lee, Wynn, and Mathis \(2011\)](#)). One potential explanation is that magnocellular information from the mask catches up to and interferes with the detailed, sustained-channel processing of the target ([Breitmeyer & Ganz, 1976](#)). Indeed, dysregulated processing of magnocellular input has been hypothesized to be the cause of increased masking deficits in PSZ ([Butler et al., 2003](#); [Cadenhead, Serper, & Braff, 1998](#); [Green, Nuechterlein, & Mintz, 1994](#); [Schechter, Butler, Silipo, Zemon, & Javitt, 2003](#); [Slaghuys & Curran, 1999](#)). However, given that dysregulated magnocellular processing appears to yield greater interference by magnocellular stimuli in tasks that involve masking, it is plausible that dysregulated magnocellular processing might also yield greater interference by magnocellular distractors during visual search paradigms in PSZ.

Here we sought to address this possibility by using a well-studied visual search task in which we have previously shown that healthy young adults show largely equivalent capture independent of whether or not the stimuli activate the magnocellular pathway ([Leonard & Luck, 2011](#)). This general paradigm is frequently used in the basic cognitive neuroscience literature to assess interference from a salient yet irrelevant distractor (e.g., [Bacon and Egeth, \(1994\)](#), [Theeuwes \(1994\)](#), [Yantis and Jonides \(1990\)](#)). Typically, the target is an object that is unique in the shape dimension (i.e., a single circle among multiple diamonds or a single diamond among multiple circles) and the irrelevant salient distractor is a color singleton (see [Fig. 1](#)). Under conditions in which the specific target shape is unknown (i.e., participants are instructed to look for the unique shape in the display but are not told whether it will be the circle or the diamond), the color singleton attracts attention and thus slows search times for the shape target ([Bacon & Egeth, 1994](#); [Theeuwes, 1991](#)).

In the current experiment, we used two types of irrelevant distractors, one designed to activate both the magnocellular and parvocellular pathways (magno+parvo distractors), and the other designed to selectively activate the parvocellular pathway (parvo-biased distractors).¹ The magnocellular system is largely blind to differences in hue between stimuli that are equal in luminance, but both the magnocellular and parvocellular systems can easily discriminate large luminance differences ([Kaplan & Shapley, 1982](#);

[Merigan & Maunsell, 1993](#)). Our magno+parvo distractor differed greatly in luminance from the other objects and the background and therefore activated both processing streams. In contrast, our parvo-biased distractor differed in hue from the other objects and background but was equal in luminance, therefore minimizing activation of the magnocellular system. It is impossible to be certain that the parvo-biased distractor was completely indistinguishable from the other stimuli by the magnocellular system, but it should have been much more salient to the parvocellular system than to the magnocellular system.

This design makes it possible to distinguish among three specific types of impairment that might plausibly be present in PSZ. First, PSZ might show more capture than HCS for both parvo-biased and magno+parvo distractors, which would indicate a general failure in using top-down control mechanisms to avoid distraction. Second, PSZ might show less capture than HCS for the magno+parvo distractor but not the parvo-biased distractors. This would indicate that reduced sensitivity to magnocellular stimulation in PSZ leads to reduced magnocellular-based salience. Third, PSZ might show exaggerated capture relative to HCS for the magno+parvo distractors but not the parvo-based distractors. This would reflect a more complex dysregulation of the magnocellular pathway, and it would be analogous to the increased magno-based masking observed in PSZ. To preview the results, we find evidence from multiple measures that supports the third alternative in which there is dysregulation of magnocellular input in schizophrenia, similar to that found in backward masking.

2. Methods

2.1. Participants

In this experiment, 26 HCS and 33 PSZ were tested. Two PSZ were excluded due to the reaction time criteria described below, and the subsequent demographics and analyses are from the remaining sample of 26 HCS and 31 PSZ. All participants passed Ishihara's Test for Color Deficiency (2001, Kanehara Trading Inc., Tokyo, Japan).

There were no significant differences between HCS and PSZ in age, race, gender, or parental education (see [Table 1](#) for statistics). As is typically found, PSZ completed significantly fewer years of education than HCS, likely due to interference in education attainment owing to disease onset in early adulthood.

Material from past medical records, collateral informants (when available), and the results of the Structured Clinical Interview for DSM-IV-TR Axis 1 Disorders ([First, Spitzer, Miriam, & Williams, 2002](#)) were combined to make a diagnosis based on the standard operational criteria in the Diagnostic and Statistical Manual of Mental Disorders IV (DSM-IV). Final diagnoses were reached at a consensus conference chaired by co-author J.M.G. All PSZ were clinically stable outpatients who had been receiving the same medications, at the same dose, for at least 4 weeks prior to study participation. Three were receiving typical antipsychotic medication, 27 atypical antipsychotic medication, and 1 both. Additionally, 18 of the PSZ were on an antidepressant, 4 were on a mood stabilizer, 11 were on an anxiolytic, 6 were on an antiparkinsonian, and 1 was on Modafinil for sleep apnea.

¹ Magno+parvo distractors were used instead of magno-specific distractors because it is difficult to create a small but potent visual search object that selectively activates the magnocellular pathway.

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