

# The Backward Masking Red Light Effect and Schizotypy: The Influence of Sex

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**ABSTRACT:** Previous research has shown a unique effect of red light on visual processing related to both schizophrenia and positive schizotypy. The current study examines whether this effect is influenced by sex in a more broadly-defined schizotypy sample. A location backward masking (BM) task with three color background conditions (red, green, and gray) was administered to 34 undergraduate students (59% female) with a high score on the Schizotypal Personality Questionnaire (SPQ) and 39 students (51% female) with a low score. Results revealed that the group by color interaction was significant for the male participants, while it did not approach significance in the females. The male schizotypy participants showed a significant decrease in BM accuracy to the red (vs. green) background, and the male control participants showed a non-significant mean increase in accuracy. A decrease in accuracy to the red background in the male participants showed the strongest relationship with higher scores on the Interpersonal (negative symptom) factor of the SPQ (particularly with the Constricted Affect subscale). The decrease in BM accuracy to red light was related to higher accuracy (reduced masking) on the “baseline” green background condition in the males, which may relate to a hypoactive magnocellular visual pathway in some of the schizotypy participants. Findings suggest that the previously reported schizophrenia red light effect is limited to males when examining a SPQ-defined sample, and appears to be primarily related to negative schizotypy symptoms. The red light effect continues to show promise as a new endophenotype for schizophrenia-spectrum disorders.

**KEYWORDS:** schizotypy, sex difference, backward masking, red light effect, magnocellular visual pathway

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## INTRODUCTION

The “red light effect” in schizophrenia refers to the fact that individuals with schizophrenia tend to show a unique reaction of the visual system to a diffuse red light background (Bedwell, Orem, Rassovsky, Allen, & Sutterby, 2009). This has also been found in first-degree relatives of schizophrenia patients (Bedwell, Brown, & Miller, 2003; Bedwell, Brown, Yanasak, & Miller, 2006) and college students with positive schizotypy (Bedwell & Orem, 2008). Therefore, this effect has initial promise as a qualitative endophenotype for schizophrenia, as it is a categorical feature that seems to be related to genetic loading for schizophrenia but is not visible to the naked eye. The majority of vision studies in schizophrenia suggest that the magnocellular visual pathway (MVP) is hypoactive in schizophrenia, while the parvocellular visual pathway (PVP) appears relatively intact (Brittain, Surguladze, McKendrick, & Ffytche, in press; Butler et al., 2007; Coleman et al., 2009; Kiss, Fabian, Benedek, & Keri, 2010; Lalor, Yeap, Reilly, Pearlmutter, & Foxe, 2008; Martinez et al., 2008).

The MVP is primarily responsible for processing location information and movement, while the complementary PVP is primarily responsible for processing detail and color (Breitmeyer & Ganz, 1976; Livingstone & Hubel, 1987). Diffuse red light suppresses a portion of the neurons along the MVP, which has been demonstrated with single-cell recording in monkeys (de Monasterio, 1978; Livingstone & Hubel, 1984), and inferred from psychophysical tasks in nonpsychiatric adults by disrupted behavioral performance on cognitive tasks that heavily rely on the M pathway (Chapman, Hoag, & Giaschi, 2004; West, Anderson, Bedwell, & Pratt, 2010). This phenomenon in healthy adults remains a theoretical puzzle because there does not appear to be a reasonable evolutionary reason why red (long wavelength) light would suppress the MVP.

Backward masking is one psychophysical task that has been used to demonstrate the effect of red light on visual processing. This task involves an initial brief target stimulus followed by a brief “mask” that either overlaps or surrounds the location of the initial target. Stimulus-onset asynchrony (SOA) is the primary variable manipulated in the task and represents the length of time between the onset of the target and the onset of the mask. The SOA is usually comprised of a fixed target

duration with a variable interstimulus interval. If the SOA is sufficiently short (approximately < 100 ms), the mask is thought to interfere with the processing of the target (Breitmeyer & Ganz, 1976). Several previous visual backward masking studies in nonpsychiatric adults have demonstrated an increase in accuracy (decreased masking) with a red background, relative to accuracy on a comparison color background (Bedwell, Brown, & Orem, 2008; Breitmeyer & Williams, 1990; Edwards, Hogben, Clark, & Pratt, 1996). This is consistent with suppression (by red light) of the MVP signal resulting from the mask, thereby reducing the interference from the mask, which makes the target more visible.

In contrast, recent research indicates that inpatients with schizophrenia (Bedwell et al., 2009) and undergraduate students with positive schizotypy (Bedwell & Orem, 2008) display increased masking to a red background. In both studies, this differential masking effect of red background between the target group and controls has been either strongest at (Bedwell et al., 2009), or limited to (Bedwell & Orem, 2008), an SOA of 60 ms.

Schizotypal personality disorder (SPD) can be characterized as a milder variant of schizophrenia with symptoms including, but not limited to, magical ideation, perceptual aberrations, disorganized thought, anhedonia, paranoid ideation, odd or eccentric behavior, social anxiety, and lack of close friends outside of immediate family (American Psychiatric Association, 2000). Likewise, schizotypy refers to a latent taxon, which is similar to the concept of SPD, but refers to less extensive and/or milder symptoms that occur in about 10% of nonclinical adult samples (Fossati, Raine, Borroni, & Maffei, 2007; Korfine & Lenzenweger, 1995). Like SPD, schizotypy is also thought to relate to similar genetic liability as schizophrenia (Docherty & Sponheim, 2008; Nuechterlein et al., 2002).

Bedwell and Orem’s 2008 study examined the red light effect and schizotypy using a rarely reported measure of schizotypy that only assessed positive schizotypy symptoms – the Abbreviated Youth Psychosis At-Risk Questionnaire (Ord, Myles-Worsley, Blailes, & Ngiralmu, 2004). This limited the ability to assess which aspects of schizotypy were most strongly related to the red light effect. In addition, a growing body of research over the last decade has shown sex differences in neurocognitive performance in schizotypy or SPD samples, with schizotypy males showing more severe

neurocognitive deficits (Johnston, Rossell, & Gleeson, 2008; Krabbendam, Myin-Germeys, Hanssen, & van Os, 2005; Lubow & De la Casa, 2002; Voglmaier et al., 2005). Also, Bedwell and Orem's 2008 study that examined the red light effect and positive schizotypy (Bedwell & Orem, 2008) did not examine for a possible sex difference, partly due to the small number of males in each group (e.g., only 6 of the 23 schizotypy participants were male).

The current study addresses these earlier limitations by using a broader measure of schizotypy that is commonly used in the literature (Schizotypal Personality Questionnaire – [SPQ], Raine, 1991), which allows for the examination of the relationship between the red light effect and three established factor scores from the SPQ: Cognitive-Perceptual (positive symptoms), Interpersonal (negative symptoms), and Disorganized.

In addition, this study examines a larger sample size with a more equal representation of males and females in order to examine possible sex differences in the red light effect as it relates to various dimensions of schizotypy. Based on the previous literature of sex differences on other neurocognitive tasks in schizotypy samples, it was hypothesized that males would show a stronger red light effect. In addition, recent unpublished data (under review) has revealed that the red light effect is related more to negative symptoms in individuals with schizophrenia. It was thus hypothesized that the red light effect would be more strongly related to the negative (Interpersonal) factor of the SPQ.

As previous papers have found the effect is strongest around a backward masking SOA value of 60 ms, it was hypothesized that this finding would be replicated and that the effect would be either limited to or strongest at a 60 ms SOA (Bedwell & Orem, 2008; Bedwell et al., 2009). The current study also added a new background color control condition (gray) to assess whether the change to red light is specific to the green control condition that was used in the previous studies using this paradigm. As gray contains some red (as well as all colors), it was hypothesized that the green background contrast (which contains no red) would show a larger effect size for the red light effect.

## MATERIALS AND METHODS

### *Participants*

Participants were recruited from a sample of undergraduate students who completed an initial screening questionnaire online for course credit. In addition to demographic questions and the SPQ, the questionnaire included the Abbreviated Marlowe-Crowne Social Desirability Scale (Reynolds, 1982) and eight questions from the Infrequency Scale of Personality Research Form (Jackson, 1984). If a participant scored higher than two standard deviations from the group mean on the social desirability scale, they were excluded from the current study. Similarly, if a participant endorsed more than one item in the wrong direction on the Infrequency Scale, they were excluded from recruitment due to the high potential of inadequate attention to the item content on the SPQ. Finally, if participants did not answer a question from any of the scales, they were excluded. To form recruitment groups, we chose a cutoff of the top tenth percentile for the schizotypal group (raw SPQ total score > 38) and the bottom tenth percentile for the control group (raw SPQ total score < 15), based on the first 200 valid responses.

These parameters resulted in a final recruitment sample of 223 potential schizotypy participants with a mean SPQ score of 44.85 (SD = 5.58, range = 39 to 64) and 612 potential control participants with a mean SPQ score of 9.22 (SD = 3.45, range = 0 to 14). Following recruitment efforts on these two groups, a further exclusionary criterion was implemented for participation in the in-person phase of the study. For both groups, any individual was excluded who reported significant substance use in the past 48 hours, visual acuity less than 20/40 (estimated using a Snellen wall chart), evidence of color blindness (assessed with Ishihara Color Blindness Test), a history of head trauma that resulted in loss of consciousness for more than ten minutes, self-report of a history of strokes, seizures, or neurological illness, self-report of dyslexia, and self-report of a lifetime diagnosis of schizophrenia or schizoaffective disorder or neuroleptic medication use. For the control group, we also excluded individuals reporting any biological relative who diagnosed with schizophrenia or schizoaffective disorder.

Study measures were completed with 34 schizotypy participants and 38 controls. The demographic and clinical characteristics of the groups can be found on

Table 1. All participants were interviewed with the schizotypal personality disorder (SPD) section of the Structured Clinical Interview for DSM-IV Disorders-II (SCID-II, First, Gibbon, Spitzer, Williams, & Benjamin, 1997). No participant met full criteria for SPD. Three individuals in the SPD group reported a biological relative with a lifetime diagnosis of either schizophrenia or schizoaffective disorder (in each case this was a second- or third-degree relative). In the schizotypy group, two individuals were taking a stimulant medication and one was taking antidepressant medication. In the control group, one individual was taking a stimulant medication and two were taking antidepressant medications.

#### *Visual Backward Masking Task*

The visual backward masking task was modeled after recent versions that have been used to explore the “red light effect” in schizophrenia, using the same target and mask stimuli (Bedwell et al., 2009). The current study added a third color condition (gray) to the red and green conditions reported in the earlier manuscripts, as earlier work theorized that a green background may increase accuracy on the task in individuals with schizophrenia (because green is the opponent color of red and thus contains no red; Bedwell et al., 2009).

The backward masking task was presented on a 22-inch CRT monitor (Iiyama Vision Master Pro 514; 150 Hz). E-Prime 2.0 software (Psychology Software Tools) was used to build and run the backward masking task. Participants were placed in a forehead/chin rest (18” from monitor). During each trial, a small black cross was presented in the center of the screen for 300 ms, followed by a blank screen for 100 ms. A target then appeared for 13 ms as a small black square (subtending a visual angle of 0.75°). Targets could appear at any one of four corners from the center of the screen, at a distance of 2.51° from center screen. The target was followed by a blank screen interstimulus interval that varied randomly from a predefined list of possible values. The mask then appeared for 27 ms, which consisted of clusters of small squares that spatially overlapped and resembled the initial target. The trials were self-paced, as each subsequent trial was triggered when the investigator entered the participant’s oral response.

Four SOAs were used (0, 40, 60, and 93 ms) with twelve trials presented at each SOA (three trials of each of the four target locations). These SOAs were selected to keep

them consistent with the most recent study in patients with schizophrenia and so that they are far enough apart to distinguish. In the case of the 0 ms SOA, the mask appeared simultaneously with the target. In addition, twelve trials in which there was no mask following the target were included as a baseline measure of attention during the task.

This task was presented on three different color backgrounds (red, green, and gray; random order). The three colored backgrounds were approximately matched for physical luminance (29.6 cd/m<sup>2</sup>). Participants received a practice session prior to the actual task.

## RESULTS

A mixed ANOVA was used to examine the interaction of group (two levels) by sex (two levels) by color (three levels) by SOA (four levels) on backward masking accuracy. The interaction involving these four factors was not statistically significant,  $F(6,408) = 0.49, p = .82, \eta^2 = .007$ . However, the interaction of group by color by sex was a statistical trend,  $F(2,136) = 2.91, p = .06, \eta^2 = .04$ . Therefore, the simple effects of this interaction were explored by examining the group by color interaction within each sex separately. There was no suggestion of a group by color interaction for the females,  $F(2,74) = 0.10, p = .91, \eta^2 = .003$ . However, there was a statistically significant interaction between group by color for the males,  $F(2,62) = 5.20, p = .01, \eta^2 = .14$ . Therefore, the remaining analyses are restricted to the male participants.

Simple effects of the significant group by color interaction in the male participants were then explored by examining the group by color interaction within each of the three possible color contrasts in the male participants. When examining the red vs. green contrast in the male participants, there was a statistically significant interaction of group by color,  $F(1,31) = 7.70, p = .01, \eta^2 = .20$  (see Figure 1), but no suggestion of a group by color by SOA interaction,  $F(3,93) = 1.01, p = .39, \eta^2 = .03$ . When examining the green vs. gray contrast in the male participants, there was also a statistically significant interaction of group by color,  $F(1,31) = 8.05, p = .01, \eta^2 = .21$ , but no suggestion of a group by color by SOA interaction,  $F(3,93) = 1.24, p = .30, \eta^2 = .04$ . Finally, when examining the red vs. gray contrast in the male participants, there was no suggestion of either a group by color interaction,  $F(1,31) = 0.18, p = .68, \eta^2 = .01$ , or a group by color by SOA interaction,  $F(3,93) = 0.61, p = .61, \eta^2 = .02$ .

As we only had an *a priori* hypothesis for the red vs. green contrast, this significant group by color contrast in the males was further explored. In this contrast, the males with schizotypy showed a statistically significant decrease in average accuracy (across SOAs) with the red, as compared to green, background,  $t(13) = 3.50, p = .004$ . In comparison, the male controls showed a non-significant mean increase in average accuracy with the red, as compared to green, background,  $t(18) = 0.96, p = .35$ . Although there was not a statistically significant group by color by SOA interaction for this color contrast, the group by color interaction is reported for each of the SOAs here for descriptive purposes: 0 ms SOA:  $F(1,31) = 3.52, p = .07, \eta^2 = .10$ ; 40 ms SOA:  $F(1,31) = 3.44, p = .07, \eta^2 = .10$ ; 60 ms SOA:  $F(1,31) = 2.33, p = .14, \eta^2 = .07$ ; and 93 ms SOA:  $F(1,31) = 0.48, p = .50, \eta^2 = .02$ .

We created a contrast score from the overall accuracy with the red background minus the overall accuracy from the green background. This was highly correlated in the male participants with “baseline” average backward masking performance from the green background,  $r(33) = -.58, p < .001$ . Thus, males who had higher accuracy (i.e., weaker masking) from the green background were more likely to show a relative decrease in accuracy with the red background.

We then examined the relationship of this contrast score with the SPQ scores in the male participants ( $N = 33$ ). Pearson correlations revealed a statistically significant negative correlation between this contrast score and: (1) SPQ total score ( $r = -.41, p = .02$ ); (2) SPQ Interpersonal subscale ( $r = -.42, p = .02$ ); and (3) SPQ Disorganized subscale ( $r = -.38, p = .03$ ). In addition, the contrast score showed a statistical trend with the SPQ Cognitive-Perceptual subscale ( $r = -.32, p = .07$ ). When examining the nine subscale scores from the SPQ in the males, the strongest relationship arose between the contrast score and Constricted Affect ( $r = -.44, p = .01$ ; see Figure 2), followed by Social Anxiety ( $r = -.43, p = .01$ ). All of these correlations were in the hypothesized negative direction, with a relative decrease in accuracy when moving from the green to the red background relating to higher SPQ scores. We then examined the relationship between the “baseline” average backward masking accuracy from the green background with each of the SPQ factors in the males. There was a statistically significant positive relationship with the Disorganized factor ( $r = .35, p = .05$ ) and a statistical trend with the Interpersonal factor ( $r = .33, p = .06$ ). This baseline green background masking

was also correlated with the Constricted Affect subscale ( $r = .41, p = .02$ ). In all of these relationships, the males who had the highest backward masking accuracy with the green background (weaker masking) had a greater number of these schizotypy symptoms. Interestingly, none of the above correlations approached statistical significance in the 39 female participants (all  $ps > .25$ ).

## DISCUSSION

Consistent with the hypotheses, we replicated the earlier red light effect in this sample of SPQ-defined schizotypy in undergraduates. Similar to earlier papers on this effect in patients and positive schizotypy, the schizotypy participants showed a statistically significant decrease in backward masking accuracy to a red (relative to green) background. Conversely, the control participants showed no decrease and instead a non-significant increase in mean accuracy to the red background (see Figure 1). Also consistent with the hypotheses, the males showed a stronger color by group interaction than the females, but surprisingly this was because the females showed no suggestion of such an interaction ( $p = .91$ ). This experiment was the first time that sex had been examined with the red light effect in any schizophrenia-spectrum sample. Therefore, this study needs to be corroborated in new samples to confirm similar findings with the sex by color by group interaction (without an interaction with SOA). However, this sex difference is in line with recent research that shows stronger neurocognitive deficits in males with schizotypy (Johnston, Rossell, & Gleeson, 2008; Krabbendam, Myin-Germeys, Hanssen, & van Os, 2005; Lubow & De la Casa, 2002; Voglmaier et al., 2005). Contrary to the hypotheses, the red light effect in males with schizotypy was not limited to or even strongest at the 60 ms SOA. Both the 0 and 40 ms SOA showed the strongest effect size ( $\eta^2 = .10$ ), followed by a slightly weaker effect size at the 60 ms SOA ( $\eta^2 = .07$ ), and a notably weaker effect size at the longest SOA of 93 ms ( $\eta^2 = .02$ ). Consistent with this pattern, there was no interaction of the effect with SOA as a similar effect was seen across SOAs. It remains unclear why the effect was not strongest at the 60 ms SOA as found in some of the earlier studies, but may reflect the current focus on only the male participants and the use of SPQ-defined schizotypy. In the previous Bedwell & Orem (2008) study, the Abbreviated Youth Psychosis At-Risk Questionnaire was used to screen participants for schizotypy symptoms instead of the SPQ, and this previous study did not include sufficient males to allow examination of interactions with sex.

It was also hypothesized that the red light effect would be strongest when using the green background as the comparison condition rather than the gray background. Results confirmed this hypothesis, as the effect was only statistically significant when comparing the red against the green background in the male participants. However, it was a surprising finding that the red vs. gray background comparison did not approach statistical significance ( $p = .68$ ). This result may be secondary to the fact that gray contains some red (as well as all colors), which may weaken a comparison to a red light background. However, this theory and current finding are not consistent with recent unpublished data that found the red vs. gray comparison to be slightly stronger than red vs. green in a sample of outpatients with schizophrenia (under review). Further replication in various schizophrenia-spectrum samples are needed to clarify which control contrast color may optimize this red light effect.

Finally, it was hypothesized that the red light effect would show the strongest relationship with the negative symptom factor from the SPQ (Interpersonal). This hypothesis was confirmed by the finding that the red light effect showed the strongest correlation with the SPQ Interpersonal factor in the male participants. This result was evident in that, as the expected direction that the Interpersonal score increased, the participant was more likely to show reduced accuracy to the red (compared to green) background. Exploration of the nine SPQ subscales that comprise the three factors demonstrated that the strongest relationship with the red light effect was aligned with the negative symptom of Constricted Affect (see Figure 2). This is highly consistent with the recent unpublished finding in the schizophrenia patients (under review), as the red light effect in that sample was most correlated with the Blunted Affect subscale of the Structured Clinical Interview for Positive and Negative Syndrome Scale (Kay, Opler, & Fiszbein, 1992). This provides converging evidence for Blunted/Constricted Affect as the symptom most related to the red light effect across both schizotypy and schizophrenia samples.

It was also examined if the red light effect was related to the “baseline” average backward masking from the green background in the males. Results revealed a strong correlation with participants who showed the highest backward masking accuracy (reduced masking) to the green background being more likely to show a greater relative decrease in masking accuracy with the red

background. This may relate to the ability of red light to decrease MVP functioning. As some individuals with schizophrenia show hypoactive baseline MVP functioning (e.g., Brittain, Surguladze, McKendrick, & Ffytche, in press; Butler et al., 2007), it is possible that some individuals with schizotypy have this dysfunction as well. This possibility also may explain why a positive correlation was found between baseline (green) background masking accuracy and several types of schizotypy symptoms in males. The males with more features of schizotypy (particularly constricted affect) may be more likely to have hypoactive MVP activity at baseline. As the MVP is primarily responsible for the interfering effect of the mask, the greater backward masking accuracy seen in the participants with more schizotypy may reflect a weaker masking effect from a weaker MVP (resulting in better accuracy at identifying the target). In these same individuals with schizotypy, red light resulted in lower accuracy. It seems unlikely that red light increased the MVP in the schizotypy individuals (causing reduced accuracy through increased mask interference). Thus, the reduced accuracy to red light in the schizotypy individuals may relate to a reduction in the ability to initially locate the target, which also relies on the MVP. This corresponds to the theory described in more detail in the manuscript that first reported this effect in individuals with schizophrenia (Bedwell et al., 2009). However, in recent unpublished data of this effect in a new sample of individuals with schizophrenia, the red light effect did not relate to the baseline backward masking accuracy as it did with this schizotypy sample. Further research is needed to better understand how these relationships may differ between other aspects of the schizophrenia spectrum.

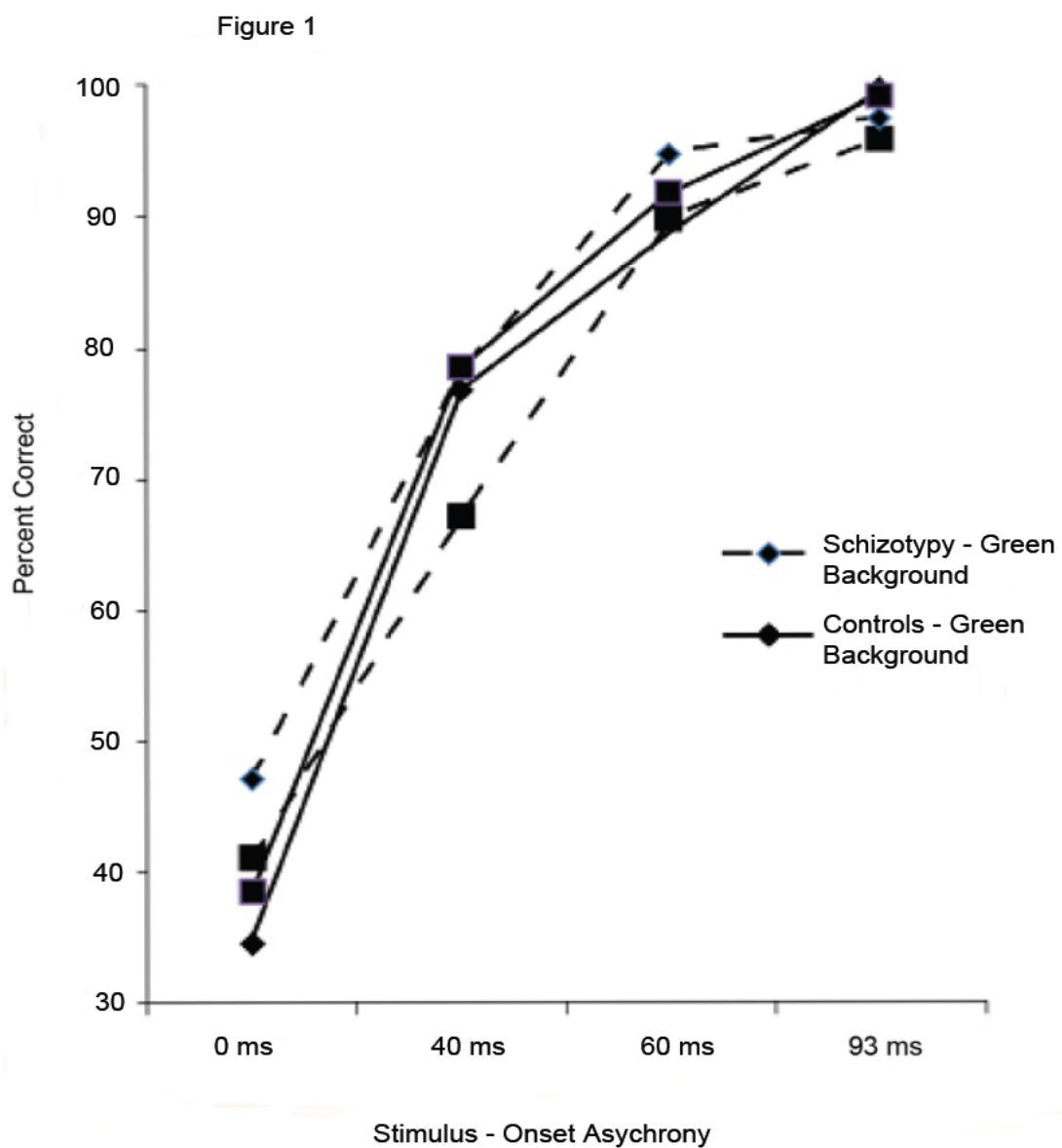
The current study is limited by its use of a college student sample that may not generalize to schizotypy as it occurs in the larger community. In addition, the study was limited by a relatively small number of males with schizotypy. Despite these limitations, the current findings provide new data that inform ongoing research on the potential of this red light effect as a useful endophenotype for schizophrenia-spectrum disorders. If this marker can help identify a previously unknown liability gene (or subset of genes) for schizophrenia, it may lead to improved treatment and/or prevention efforts. The physiological mechanism for this effect, which may involve a differential reaction of the MVP to diffuse red light in schizophrenia, remains unclear. Future research employing ERP and/or neuroimaging techniques may clarify the underlying physiological mechanism of this effect, which should then lead to a better understanding of the underlying

neuropathology involved in schizophrenia.

TABLE 1. DEMOGRAPHIC AND CLINICAL CHARACTERISTICS BY GROUP AND SEX

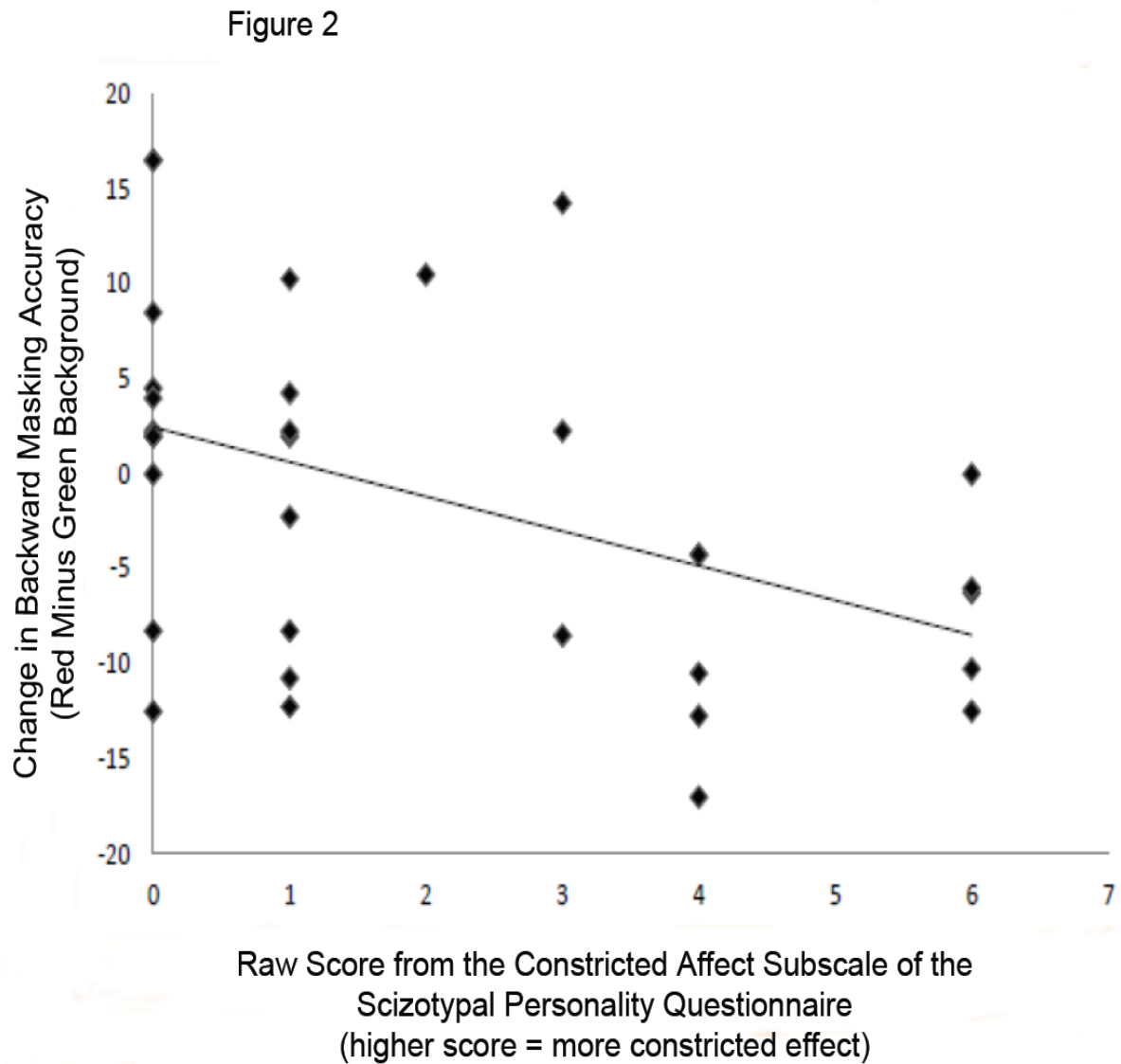
	Schizotypy Males	Schizotypy Female	Control Males	Control Females
N	14	20	19	19
Age [mean (SD)]	20.57 (5.85)	18.95 (1.54)	19.68 (2.36)	19.26 (1.10)
SPQ Total [mean (SD)]	45.43 (6.45)	44.15 (5.41)	9.84 (3.52)	9.47 (3.69)
SPQ Cognitive-Perceptual Score [mean (SD)]	19.07 (5.41)	18.90 (4.13)	5.63 (3.22)	4.32 (2.36)
SPQ Interpersonal Score [mean (SD)]	19.50 (6.41)	20.60 (4.78)	4.21 (2.51)	2.95 (2.50)
SPQ Disorganized Score [mean (SD)]	11.86 (2.35)	10.45 (2.86)	1.84 (1.54)	2.84 (1.89)

**Figure 1:** Backward masking accuracy in male participants by schizotypy status, stimulus-onset asynchrony, and background color.





**Figure 2:** The relationship between average background masking accuracy change to the red background and self-report of constricted affect symptoms in male participants.



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