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Altered 'three-flash' illusion in response to two light pulses in schizophrenia

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Abstract

Background: Disorganization is a core dysfunction in schizophrenia. Coherent thought and behavior rely on the interactive neural responses to temporally discrete external events. Previous studies have demonstrated that a single visual stimulus (event) is abnormally affected by another (as in backward masking), but the integration (or 'synthesis') of temporally discrete events remains largely unexplored in schizophrenia. We examined the perceived interaction of two elementary visual events in schizophrenia patients, using a psychophysical approach.
Methods: Two brief, spatially-coincident foveal light pulses (5 ms) were presented with different inter-stimulus intervals (ISIs). At ISIs around 100 ms, a substantial proportion of the light pulse pairs was paradoxically perceived as three flashes, a known phenomenon in normal subjects. The subjects reported the number of flashes perceived ('one', 'two' or 'three').
Results: Schizophrenia patients ($n=28$) reported fewer 'three flashes' than normal controls ($n=26$) at the ISIs where 'three flash' reports were greatest in normal subjects (90 to 110 ms). On the other hand, at longer ISIs (130–310 ms) patients reported 'three flashes' in more trials than did normal subjects. The perception of three flashes in patients was correlated with certain aspects of clinical status, including the positive and general subscales of the PANSS.
Discussion: The alteration of the 'three-flash' illusion in schizophrenia suggests that the synthesis of discrete visual events is temporally 'dilated' or distorted, which might contribute to disorganized thought and behavior.

Keywords: Visual processing; Schizophrenic; Temporal organization; Sensory; Cognitive

1. Introduction

Disorganized thought and behavior are prevalent in schizophrenia. For normal behavior, one must respond to a host of temporally discrete stimuli and integrate, or 'synthesize', the responses to these stimuli. Alteration of this synthesis might cause a coherent flow of events to become a barrage of more disjointed information. Studying the synthesis of temporally disparate events may thus shed light on the pathophysiology of schizophrenia.

Altered temporal processing of visual information in schizophrenia has been shown in studies on visual backward masking (Green et al., 1994a; Butler et al., 1996) and temporal contrast detection (Butler et al., 2001a; Slaghuis,

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1998; Chen et al., 2000; Keri et al., 2000). These studies reveal two general effects in schizophrenia. First, there is a reduced sensitivity for contrast detection of temporally modulated stimuli. Second, there is temporal elongation in backward masking—a measure of how one visual event is affected by a later, masking event. The present study evaluated another type of temporal interaction in schizophrenia—the way in which two *equivalent* temporally discrete events interact to yield a 'synthesized' perceptual response.

We measured the synthesized perceptual response to two temporally discrete visual events (brief light pulses) in both patients and normal controls, and we compared this to the processing of single visual events (temporal contrast detection). The results were evaluated in terms of relevant clinical features.

We adopted the paradigm of Bowen (1989). Two supra-threshold, spatially-coincident light pulses (5 ms) were presented to the fovea with varying inter-stimulus intervals (ISIs). For ISIs around 100 ms the two pulses are regularly mis-perceived as three flashes by normal subjects (Bowen, 1989). At this ISI, the 'three-flash' illusion occurs for 40–70% of the presentations. According to Bowen, the 'three-flash' illusion represents the interaction (the linear sum) of the *multi-phase* Impulse Response Functions (IRF) to *each* of the two flashes. The

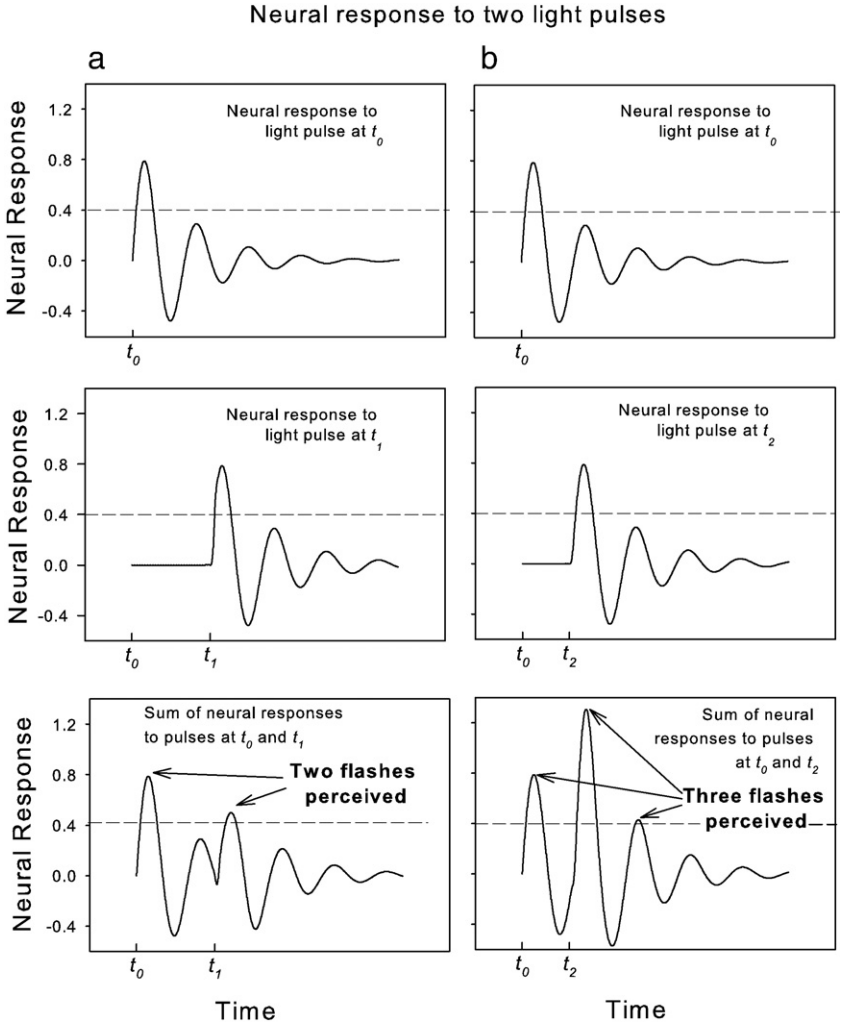

Fig. 1. Model of the neural response to single light flashes (top and middle panels) and their linear sum (bottom panels)—adopted from Bowen (1989). The horizontal dashed lines represent the hypothetical threshold that must be exceeded for perceiving a flash—as in Bowen. a. The top left panel shows the response to a single light pulse presented at time t_0. The middle left panel shows the neural response to the second pulse, presented at time t_1, (greater than ~100 ms after t_0). The bottom left panel is the summed responses for the pair of pulses—at this ISI, two flashes are perceived. b. The right panels show the same schema, but the second flash occurs at t_2, about 100 ms after t_0, leading to a peak to peak summation of the two IRFs, —now three flashes are perceived.