Behavioral and Brain Functions BioMed Central

Research

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Simultaneity in the millisecond range as a requirement for effective shape recognition

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Published: 29 November 2006

Behavioral and Brain Functions 2006, **2**:38 doi:10.1186/1744-9081-2-38

Received: 05 September 2006

Accepted: 29 November 2006

This article is available from: http://www.behavioralandbrainfunctions.com/content/2/1/38

Abstract

Neurons of the visual system are capable of firing with millisecond precision, and synchrony of firing may provide a mechanism for "binding" stimulus elements in the image for purposes of recognition. While the neurophysiology is suggestive, there has been relatively little behavioral work to support the proposition that synchrony contributes to object recognition. The present experiments examined this issue by briefly flashing dots that were positioned at the outer boundary of namable objects, similar to silhouettes. Display of a given dot lasted only 0.1 ms, and temporal proximity of dot pairs, and among dot pairs, was varied as subjects were asked to name each object. In Exp 1, where the display of dots pairs was essentially simultaneous (0.2 ms to show both), there was a linear decline in recognition of the shapes as the interval between pairs increased from 0 ms to 6 ms. Compared with performance at 0 ms of delay, even the 2 ms interval between pairs produced a significant decrease in recognition. In Exp 2 the interval between pairs was constant at 3 ms, and the interval between pair members was varied. Here also a linear decline was observed as the interval between pair members increased from 0 ms to 1.5 ms, with the difference between 0 ms and 0.5 ms being significant. Thus minimal transient discrete cues can be integrated for purposes of shape recognition to the extent that they are synchronously displayed, and coincidence in the millisecond and even submillisecond range is needed for effective encoding of image data.

Background

A cornerstone principle of neurophysiology is the idea that neurons are either intrinsically designed to be selective with respect to the stimuli to which they will respond, or through connections with other units, can be made to be selective [1-4].

A corollary is the concept of a "rate code," this being the notion that the strength or salience of the stimulus is reflected in the average rate at which the cell fires [5]. In this regard, it is assumed that the timing of individual spikes is random and must be averaged over some interval – generally thought to be in the 20–200 ms range.

This time interval seems consistent with various perceptual phenomena, such as the frequency at which one sees fusion of a flickering stimulus, that which provides for smooth motion in a rapid sequence of still images, and the duration of visible persistence resulting from a brief flash. The fact that an observer can combine partial shape cues over a hundred milliseconds or more to achieve object recognition also suggests that exact timing of the spike signal is not critical.