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Author(s)	Elliott, Mark
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DEFINING PERCEPTUAL SYNCHRONY

Mark A. Elliott

Department of Psychology
National University of Ireland, Galway, Ireland
mark.elliott@nuigalway.ie

Abstract

How does neuronal activity bring about the interpretation of visual space in terms of objects or complex perceptual events? If they group, simple visual features can bring about the integration of spikes from neurons responding to different features to within a few milliseconds. Considered as a potential solution to the binding problem it is suggested that neuronal synchronization is the glue for binding together different features of the same object. This idea receives some support from correlated- and periodic-stimulus motion paradigms, both of which suggest that the segregation of a figure from ground is a direct result of the temporal correlation of visual signals. One could say that perception of a highly correlated visual structure permits space to be bound in time. However, on closer analysis the concept of perceptual synchrony is insufficient to explain the conditions under which events will be seen as simultaneous. Instead, the grouping effects ascribed to perceptual synchrony are better explained in terms of the intervals of time over which stimulus events integrate and seem to occur simultaneously.

Our ability to extract structure from the mosaic of ambient visual information raises an as yet unresolved question for perceptual neuroscience. Known as the ‘binding problem’ this question asks how neuronal activity can bring about the organization of visual space into definable subregions resolvable as objects or as complex perceptual events. Physiological studies have shown that simple visual features can bring about the temporal alignment of spikes from a number of neurons to within a few milliseconds of one another, if those features group. A number of psychophysical paradigms have attempted to corroborate the physiological binding hypothesis, and seem to have enjoyed some success: The first of these approaches involves *periodic motion* or the alternate presentation of sets of display elements in different phases of a global presentation frequency (Fahle, 1993; Leonards, Singer & Fahle, 1996). Using this technique it has been shown that the global orientation of elements in a target presentation frame may be judged with greater than chance probability as a function of the onset asynchrony between the target and a second frame containing background elements. A second technique, referred to in terms of *stochastic* (or *correlated*) motion, involves presentation of a field of Gabor patches which individually and seemingly at random reverse in phase, thereby effecting a form of apparent motion similar to that of a running machine. The critical modification in this paradigm involves the temporal correlation of phase reversals which can bring about perception of a figural region consisting of those elements which change phase at the same time (Alais, Blake & Lee, 1998; Lee & Blake, 1999).

At first glance the use of periodic and correlated motion appear to support the idea that synchrony can bring about the organization of visual space: On the one hand, a figural region emerges with the desynchronization of figural elements from their background, while figural regions appear to emerge solely as a function of the correlated motion of their elements. In fact, in the case of periodic motion, a direct link between psychophysical binding and physiological timing seems particularly promising when it is considered that a figural region emerges when the onset of figure and ground are desynchronized by intervals of as little as 7

ms (Fahle, 1993). by a reversal of logic this permits temporal integration to operate within windows close to a limit of around 10 ms, which is around the maximum separation in time between synchronized spikes. In the case of correlated motion, perception of a figural region seems to come about as a result of perfectly correlated phase reversals. Both lines of evidence lay very strong emphasis on the idea that the segmentation or emergence of figural subregions comes about as a function of the temporal synchrony/asynchrony of figure and ground. In fact, this outcome has been explicitly equated with the temporal synchronization of neurons responding to the presence of simple visual features that group (Alais et al., 1998). Nevertheless and in spite of these claims, figure-ground separation akin to that demonstrated by Lee and Blake (1999) has been shown to arise by virtue of temporal bandpass filtering. A physiologically plausible temporal bandpass filter has been shown to convert the different pattern in phase reversals between figure and background elements into a classic spatiotemporal contrast cue. This can signal the figural subregion irrespective to the synchrony or otherwise of the motion reversals (Adelson & Farid, 1999) and clearly questions the *necessity* of a mechanism sensitive to temporal synchrony (Farid, 2002).

Our concern in this paper is connected with a problem of induction, so fundamental that it obliges rejection of perceived synchrony as *sufficient* an explanation for the effects of either correlated or periodic motion. The problem is founded on the fairly common observation that events may be perceived as synchronous (or simultaneous) beyond the case where the two events occur at precisely the same time. In fact and depending upon stimulus conditions, perceptual simultaneity may be experienced between stimulus events separated by intervals of between zero milliseconds (true simultaneity) to a few tens, if not over a hundred milliseconds while there may be little or no difference between perceptions of synchrony following presentation of physically simultaneous events and perceptions that follow presentation of non-simultaneous events. So why is this problematic for perceptual synchrony? The synchrony or *simultaneity problem* proper arises when we ask the question “to what extent can we claim to have *experienced events as simultaneous*?” At the crux of the problem are events that are non-simultaneous but which we see as simultaneous and it might be considered an acceptable claim that, irrespective of the actual simultaneity of two events, in perception events can be considered simultaneous if that is how they seem to the observer (Kelly, 2005¹). However the following logic modifies this consideration:

Take any two events A_1 and A_2 that appear to the observer to occur simultaneously, in spite of which they are separated by some interval. Take then some third event that occurs at some time later than both A_1 and A_2 but is experienced as simultaneous with each. Using this method a series of events from sets $\{A_1, A_n\}$ may be experienced as simultaneous although the point may be reached at which A_1 and A_n come to be experienced as non-simultaneous. Perceived simultaneity is thus *non-transitive* (i.e. $A_1 = A_2$ & $A_2 = A_3$ but $A_1 \neq A_3$) and non transitivity should, in principle, preclude a definition that includes *simultaneity* because simultaneity cannot be both *non-transitive* and an *equivalence* relation. It seems an obvious solution to circumvent the problem of transitivity two events may be defined as perceptually simultaneous if (and only if) they appear to be simultaneous and if (and only if) there is no third event with which one event appears to be simultaneous while the other does not. Indeed this counter argument might be valid if it were not for the following corollary: Although two events might *appear to be simultaneous* it is nonetheless impossible for the observer to conclude that they have *experienced them to be simultaneous* without reference to the third, non-simultaneous event. This event thus marks both the limit of perceived simultaneity and indeed the maximum interval of time between which the two key events would have been perceived as simultaneous. On these grounds perceptual synchrony seems little more than a non sequitur which lacks construct

validity unless taken to refer to the *interval of time* over which two or more events are seen to occur at the same time.

This argument states that perceptual synchrony is not sufficient to describe the perceptual effects arising visual events that take place in very close temporal proximity. An alternative explanation is that the effects of periodic and correlated motion are a function of the interval of time over which two or more events are perceived to be in synchrony. On these grounds there is no basis for considering any current measures of perceptual synchrony as support for the common claim that neuronal synchrony is a means for the binding of perceptual features. But this is not to say that the information that appears to go together when presented within a given interval of time is not bound together, it is just to say that it cannot be claimed to be bound merely by virtue of its simultaneous appearance. Instead, and as a potential factor for inclusion into the calculus that links mind and brain it seems more promising to include the simultaneity threshold itself as a more parsimonious (and seemingly replicable) measure of when two or more events appear to the observer as if they occur in synchrony.

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1. ⁱ The logic is related to Goodman's new problem of induction (Goodman, 1951): Goodman introduced the notion of a color grue, which applies to all things which appear green when examined before a certain time *t* and which change to blue if examined after time *t*. If we examine emeralds before time *t* and find that emerald *a* is green, emerald *b* is green, and so forth, each will confirm the hypothesis that all emeralds are green but they also confirm the hypothesis that all emeralds are grue. For truly grue emeralds, the hypothesis that they are green is false, but this information only comes after time *t* has passed. The issue here is that for non-simultaneous events *a* and *b*, seeming to appear together, we might claim them to be simultaneous, because we lack any information about how they appear when separated in time (we say green because we see green, even though the events may be grue). In other words we speculate on their simultaneity because it seems to us to be the most likely possibility

given the information we have available to us, i.e. given we examine the relation a-b without awareness of their temporal separability, before Goodman's time t. Applied to the simultaneity problem this means that for asynchronous events we are constrained to come to the (very often) false conclusion that those events are synchronous. But we only make this error up until the point at which we are aware of their asynchrony. This entails, the only perception that we can claim with any degree of certainty is that of the asynchrony between a and b and this in turn entails the asynchrony to be the only valid and reliable variable available to us when examining the perceptual effects of periodic and correlated motion paradigms.