Letters

Untangling spatial from temporal illusions

The flash-lag effect (FLE) is a phenomenon in which a flash aligned with a moving object appears to spatially lag behind the stimulus. In their recent review of the FLE, Krekelberg and Lappe conclude that 'the influence of differential latencies on the perception of position of moving objects… is undeniable' [1]. They refer to the hypothesis that differences in physiological latencies might translate directly into perceptual time differences. This idea has enjoyed recent popularity as a proposed explanation for the flash-lag illusion [2–4]. However, this is inconsistent with evidence that timing judgements between flashes and moving objects are very accurate [5]. Recent research suggests that the FLE, as opposed to being a temporal illusion, is a consequence of spatial interpolation [5–7].

The appeal to differences in physiological latency to explain the FLE runs the risk of oversimplification, given the many shortcomings that hypothesis must contend with. First, the differential latency (DL) model predicts that the outcome of a 'race' between *de novo* movement and a flash can be changed, by giving the flash a head start; however, this hypothesis has been tested and disproved [6]. Second, the DL model predicts that the onset time of a flashed and moving object will be misperceived; this hypothesis has also been tested and disproved [8]. Third, the DL model runs into difficulties in the 'flash-initiated' paradigm, in which the flash and moving object appear simultaneously: the DL model predicts that the moving object will suffer the same delay as the flash, as it suddenly appears from nowhere. However, the continuous and flash-initiated conditions yield the same psychophysical result [6]. Fourth, skepticism about the DL explanation of the FLE is warranted by the conspicuous absence of physiological support. In fact, as Krekelberg and Lappe acknowledge, the available physiology in the medial temporal area (MT) speaks against the DL model. Thus, the differential latency hypothesis lacks a sufficient base of support, and any direct connection between the timing of neural signals and the timing of perception is cast into doubt by a critical analysis of the extant data.

Much of the confusion in the stormy world of flash-lag literature can be attributed to a single assumption that has not been critically assessed: the assumption that a measured *spatial* difference can be directly translated into a *temporal* difference. Having assumed such translation, almost all reports on the FLE measure a perceived spatial offset (e.g. 1° of visual angle), but report a putatively corresponding time difference (e.g. 70 ms).

Our alternative view, if correct, is fatal to this assumption: even while a moving object has a real-world time corresponding to each position, it could be that the pairing is no longer veridical, or even retained, in the representation of the stimulus in the nervous system. Given the distributed processing in the visual system, a logical possibility is that position information is not persistently represented, but instead is only computed when needed. In other words, when an observer is asked where a moving object was at a particular moment, a special (and possibly rare) computation is then performed. A smear of spatial positions must be evaluated (deblurred) into a single, unambiguous answer. The result of this computation can be non-veridical – that is, a smear of spatial activity across cortex can be evaluated at some intermediate position. In this view, time can be stamped with high fidelity, but the position associated with that time is the result of a deblurring process that interpolates over a smear of recent positions [5–7]. The observer is only able to report a perceived position after this computation is complete [9]. This framework naturally explains other illusions, such as the Fröhlich effect, in which a moving object that appears suddenly is not seen in its true starting position, but instead some distance into the trajectory [10]. This suggests that the FLE is another incarnation of the Fröhlich effect, one in which the spatial landmark takes on a temporal stamp as a result of being flashed instead of being static [6].

Spatial interpolation over occupied positions of the moving object offers an explanation for the FLE that has many advantages. First, it is consistent with other illusions (e.g. the Fröhlich effect). Second, it is consistent with subjects' ability to accurately judge temporal relationships between flashed and moving objects [5]. Third, it does not embed the assumption that a measured spatial judgement translates directly into a temporal illusion. Fourth, it accounts naturally for the rounding of the curve seen in Whitney and Murakami's reversal of the moving object, for which they were forced to appeal to an additional mechanism (neural delay variability or a separate spatiotemporal averaging filter) [3]. Thus, in contrast to Krekelberg and Lappe's statement that latency differences 'undeniably' influence perception, a spatial explanation could prove more parsimonious.

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