

Supplementary material
Perceived luminance depends on temporal context
David M. Eagleman, John E. Jacobson, and Terrence J. Sejnowski

A suggested model for the Temporal Context Effect

We suggest that a simple model (Fig S1) may explain our results: (1) the system commits to brightness values of objects in the scene, (2) these commitments hold even while neural responses adapt, (3) V1 neural activity encoding the brightness of two objects is compared, and the difference of activities produces a difference between assigned labels. Since the commitment to the first label is kept, that forces the second label to increase. Because the activities of neurons in primary visual cortex diminish, the TCE suggests that a different neuronal population (perhaps outside of V1) retains brightness labels. This second system could utilize, for example, the maintained level of activity in a downstream coalition of neurons. A coalition that wants to be adaptation-blind should stay high even as the input driving it adapts (hysteresis).

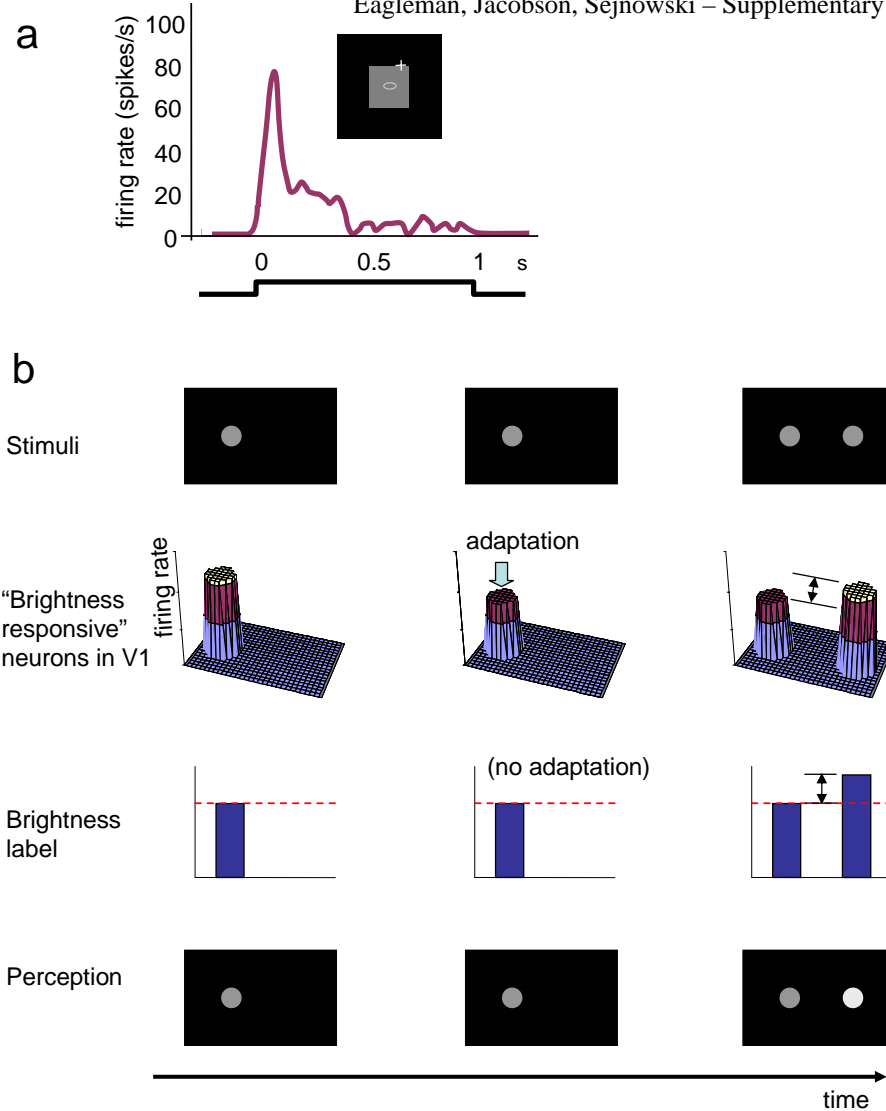
As a point of clarification: in our model, there is no *initial* V1 response difference for any of the flashes. The only thing that changes is the V1 response to the *long* flash, which decreases monotonically through time. (See arrow marked 'adaptation', Fig S1). The experimental justification for the adaptation of the V1 response to the long flash comes from Kinoshita & Komatsu (2001), who demonstrate the diminishing firing rate from the V1 brightness encoding cells when there is a dark background. (This diminishment is, of course, shown by essentially all neuron types). The activity generated by the brief flash (whether onset- or offset-aligned) will be compared against different activity levels of the long flash, depending on how long the latter has already been on.

As for *why* V1 activities are compared instead of the labels, we can only say that this hypothesis (comparison of V1 activities) gives us a parsimonious and consistent account of the data we have reported. The alternative hypothesis – a comparison between the labels – does not explain the brightness illusion. The illusion reported here is not, of course, the sole basis for the model. Instead, the observations leading us to the model are outlined in the first sentences of the abstract: understanding brightness encoding cells in the face of (1) neural adaptation, but (2) no perceptual adaptation. Combined with our results, we are led to propose that brightness labels are assigned to newly-appearing objects, but that brightness *comparisons* take place at a different level. The results of comparisons are combined with previous label commitments. Further accounting of the neural circuitry may help us to understand in the future why our proposed account matches the data. As a further point of clarification: while our hypothesis suggests that V1 activities are compared against one another, but this does not necessitate the comparison takes place *in* V1.

What happens when the two flashes are not simultaneously present?

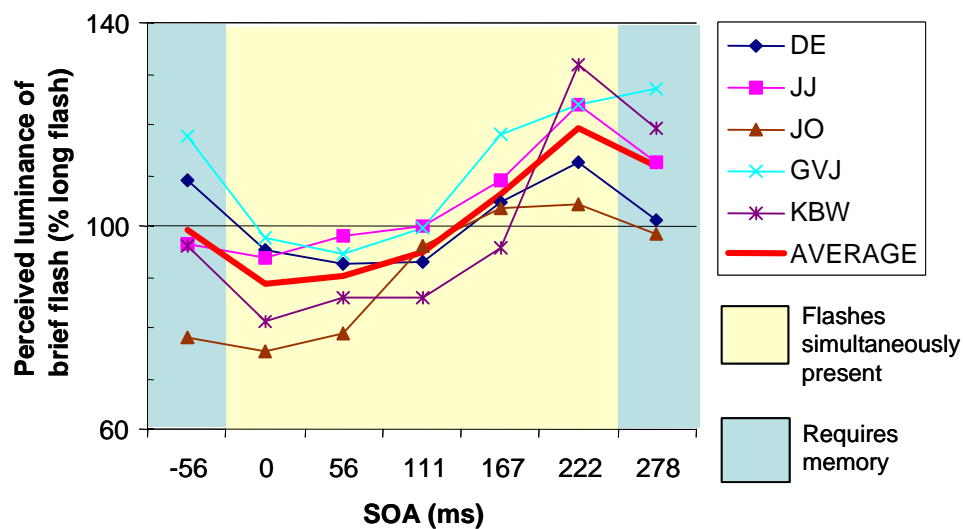
We have also performed experiments in which there is no temporal overlap between the two flashes. When the SOA is -56 msec, for example, or 278 msec, the perceived

luminance of the brief flash moves toward equivalence with the long flash (i.e., the 100% mark; Fig S2). In other words, at negative or long SOAs, two flashes of equivalent luminance will appear equivalent. We observed some interesting results in these parameter ranges, including the fact that the variance of observers' reports rises steeply when the flashes are not simultaneously present. We cannot presently speculate on this variance difference except to note that a very different kind of comparison might be occurring when (a) there are two flashes present (main manuscript) versus (b) a comparison between a flash and the *memory* of a second flash (Fig S2). We will analyze these 'non-simultaneous flash' results in a separate manuscript, since they address a different testing condition – i.e., one that requires *memory* of the flash.



Supplementary Figure S1. (a) Response of a brightness-responsive neuron in awake macaque primary visual cortex, figure adapted from Kinoshita & Komatsu, Fig 7B (2001). In response to a gray stimulus on a black background, the response of this neuron grows quickly but begins to diminish after 100 ms. (b) Hypothesized model. The top row shows the sequence of stimuli in the offset-aligned condition; the long and brief flashes have identical luminance. The 2nd row shows a cartoon of the corresponding neural activity of brightness-responsive neurons in V1 (Rossi & Paradiso, 1996; Rossi et al, 1999; Kinoshita & Komatsu, 2001). As the long flash remains on the screen, the associated neural activity diminishes. The eventual appearance of the brief flash generates an unadapted neural response. 3rd row: In contrast to the brightness-responsive cell activity, the brightness label assigned to the long flash does not diminish. When the brief flash appears at the end of the sequence, a difference in neural

activities is translated into a difference in brightness labels. Since the system has already committed to labeling the long flash at a certain brightness value, the brief flash's label will be promoted to something higher than that value. The perceptual correlate is illustrated in the bottom row: the long flash does not appear to change in brightness, and the brief flash appears much brighter.



Supplementary Figure S2. Brightness of the brief flash, including the non-simultaneous regime. The experimental paradigm is the same as the one shown in Fig 1b, but additionally showing results when the two flashes have no temporal overlap (blue region).