Supplementary Figure 1 - Does the organization of the cortico-thalamic feedback pathway mirror that of the feed-forward geniculo-cortical projection?

The orientation and receptive field “on” and “off” zones of layer 4 simple cells link to the spatial alignment and properties of the LGN cells providing their input. “On” center LGN cells (red) provide excitatory input to the central “on” subregion (red) of the cortical simple cell, “off” center LGN cells (blue) provide excitatory input to the flanking “off” subregions (blue) of the cortical cell. Are the “on” and “off” zones of the feedback simple cells spatially aligned with the “on” and “off” center LGN cells they influence and is there any specificity in the pattern of influence linked to this?
Supplementary Figure 2 - Schematic diagram summarizing the connectivity suggested by the data.

Left panel – The diagram shows the pattern of feedback made by two layer 6 cells to an on-center LGN relay cell. The receptive field of one feedback cell matches that of the LGN cell, in that it has a central "on" sub-region (red cell). The other has a central "off" sub-region (blue cell). All three receptive fields are centered on the same point in visual space. The cell with the matched field contacts the LGN cell through an inhibitory interneuron (black). Conversely, the cell with the mismatched field makes direct excitatory contact.

Right panel – Further schematic but showing suggested connectivity from layer 6 cells to layer 4 as well as those to the LGN. In this the connections to layer 4 are shown as the same phase. Thus we propose that the feedback to the LGN from layer 6 cells is phase reversed whilst that to layer 4 is phase aligned. See paper for discussion.
Supplementary Figure 3 - Reverse Hubel and Wiesel links in feedback from cortex to LGN.

Schematic diagrams summarizing the suggestions regarding the reciprocal relationships between layer 6 cortical simple cells and the LGN in the orientation and phase domains. (a) Arrangement for the phase aligned connections via inhibitory interneurons (drawn in black) and direct phase reversed connections to relay cells. (b) Receptive field types associated with phase aligned and phase reversed connections. Cortical cell is shown as having an “on” center. LGN cells with “+” centers are “on” center and “−” centers are “off” center.
Supplementary Methods

The degree of overlap was first assessed by superimposing the outline of the LGN receptive field center assessed from fitting the best single two-dimensional Gaussian to its spatial receptive field\(^1\) onto an outline of the best fitting Gabor function fitted to the cortical spatial receptive field\(^2\). Model Fitting was performed using \texttt{fmincon} (Matlab, Mathworks), minimizing the mean squared or mean fractional error\(^4\) between data and model. Cortical simple cells were fitted as Gabor functions (the product of an elliptical Gaussian and a sinusoidal term) using the equation:

\[
\cos(2 \pi \nu f + \phi) \exp\left[\frac{-(u-u_0)^2}{\sigma_1^2} + \frac{(v-v_0)^2}{\sigma_2^2}\right]
\]

where \(\sigma_1\) and \(\sigma_2\) = standard deviations of the major and minor axis of the Gaussian, \(f = \) spatial frequency of the sinusoid, \(\phi = \) phase of the sinusoid and \(u, v\) and \(w\) are the rotated spatial coordinates. The dimensions of a cortical sub region in the Gabor function were obtained from the curve defined by 20% of the peak value. The size and location of the center of the LGN RF was quantified by fitting the best single two-dimensional Gaussian to the spatial receptive field using the equation:

\[
dc + ae^{-\left(\frac{x^2+y^2}{\sigma^2}\right)}
\]

where the parameters are \(dc = \) spontaneous rate, \(a = \) amplitude, \(x\) and \(y\) = the coordinates of the Gaussian and \(\sigma = \) the standard deviation of the Gaussian. A circle drawn at 1.75 space constants (\(\sigma\), or standard deviations) from the peak of this best fitting Gaussian was then superimposed onto the cortical field and the degree of overlap measured. An example is shown in Fig. 2. We also checked LGN cell center size by fitting a Difference of Gaussian model to the data derived from spatial summation tuning curves.

The DOG model involved integrating the classical DOG equation over several diameters. Model parameters were:

\[
R = dc + ca \int_{-s/2}^{s/2} e^{-\left(x^2+y^2/\sigma_1^2\right)} - sa \int_{-s/2}^{s/2} e^{-\left(x^2+y^2/\sigma_2^2\right)}
\]

\(cs = \) Receptive Field Center Size
\(ca = \) Receptive Field Center Strength
\(ss = \) Receptive Field Surround Size
\(sa = \) Receptive Field Surround Strength
\(dc = \) Cell spontaneous

Goodness of fit was assessed using the mean fractional error (MFE\(^4\)). The model was constrained by making sure that the surround size was always larger than center size (or in some cases it was set to zero). Each of the other model parameters were constrained with upper and lower bounds.
If the center size assessed by this latter method was appreciably larger than that obtained from the former, we also computed the degree of overlap from this larger measure of the RF center size to check that this did not appreciably shift the degree of overlap.

References for Supplementary Methods