Model derivation of equations 3-6 (main text)

Here we describe in more detail the mathematical steps for obtaining equations 3–6 of the model.

The receptive field of a neuron centred at $x_R$, width $\sigma_R$, and maximal firing rate of $A_R$ is defined as:

$$RF(x) = A_R \exp \left( -\frac{(x-x_R)^2}{2(\sigma_R)^2} \right).$$

The attentional spatial factor, centred at $x_{Att}$, width $\sigma_{Att}$, and attentional amplitude $A_{Att}$, is defined as:

$$A(x) = 1 + A_{Att} \exp \left( -\frac{(x-x_{Att})^2}{2(\sigma_{Att})^2} \right).$$

By multiplying the two terms one obtains:

$$RF^{attended}(x) = RF(x) + A_R \exp \left( -\frac{(x-x_R)^2}{2(\sigma_R)^2} \right) \times A_{Att} \exp \left( -\frac{(x-x_{Att})^2}{2(\sigma_{Att})^2} \right)$$

where the second term can be rewritten as:

$$A_R A_{Att} \exp \left( -\frac{(\sigma_{Att})^2(x-x_R)^2 + (\sigma_R)^2(x-x_{Att})^2}{2(\sigma_R)^2(\sigma_{Att})^2} \right).$$

The sum of the two second-order polynomials in the exponential can be rearranged such that only one second-order polynomial contains the variable spatial position ($x$). This gives the following expression:
The second exponential term is clearly independent of the spatial position $x$, and depends only on the relative distance between the initial receptive field center and the attentional center, and also on the initial receptive field and attentional sizes. Therefore, we can label it as one supplementary amplitude, $A_{\text{attended}}$. In the first Gaussian function, we can define a new width and a new center. Then one obtains equations (3-6).

**Normalization of receptive field profile volume: Shrinkage versus amplitude changes**

In the main text we state that the model does not make any prediction on the amplitude of the attention modulated receptive field profile. Here, we explain why the amplitude of the receptive field profile cannot be used as a measure of the influence of spatial attention.

The model prediction assumes that the attentional modulation of the receptive field profile can be only seen in the position and size parameters. The final maximal firing rate of the neuron (amplitude) cannot be used as a sensitive measure, because it is influenced by cortical normalization processes (e.g. Croner & Kaplan, 1995). These normalization processes tend to keep the total volume under the receptive field constant, which increases the amplitude when the receptive field is getting smaller (i.e. a negative correlation between shrinkage and change in amplitude (ratio attend-in / attend-out)). This prediction is supported by our data (Suppl. Fig. 1): With a decrease of receptive field size with attention (the ratio size $\text{RF}_{\text{in}}$ / size $\text{RF}_{\text{out}}$ below 100%; y-axis) the amplitude of the $\text{RF}_{\text{in}}$ profile tends to be higher than for the $\text{RF}_{\text{out}}$ profile (ratio amplitude $\text{RF}_{\text{in}}$ / amplitude $\text{RF}_{\text{out}}$ above 1.0; x-axis). This effect was statistically confirmed through a significant negative correlation of the two measures: in the analysis based on the receptive field parameters extracted from Gaussian fits (Suppl. Fig 1A; $r=-0.27$, $p<0.01$, $n=97$), as well as in the non-parametric analysis based on spline-interpolated receptive field profiles (Suppl. Fig. 1B; $r=-0.43$, $p<0.01$). Moreover, the amount of receptive field shift toward the attended position was not correlated to amplitude changes ($r=0.03$, n.s.,...
n=97) lending additional support that amplitude normalization follows and adapts to the RF input size change.

**Supplemental Figure 1**: Relation between size changes and amplitude changes of the receptive fields modulated by spatial attention. **A):** Receptive field size and amplitude changes extracted from the parametric analysis of the receptive fields (based on Gaussian-fitted receptive field profiles). Receptive field shrinkage is negatively correlated to the amplitude changes (r=-0.27, p<0.01, n=97). **B):** Receptive field size and maximum amplitude changes extracted from the non-parametric analysis (based on spline-interpolated receptive field profiles). Shrinkage and amplitude changes are significantly correlated (r=-0.43, p<0.01, n=97). In both panels, when spatial attention reduces receptive field size (y-axis values below 100%) the maximal firing rate of the neuron tends to increase (x-axis values above 1.0), which is expected from a normalization process that keeps the area under the receptive field constant. To illustrate this the black solid curve in each panel is the normalization prediction of keeping the volume under the receptive field profile constant, i.e. the amplitude is adjusted to take the receptive field size into account.