Learning rules for spike timing-dependent plasticity depend on dendritic synapse location

Johannes J. Letzkus, Björn M. Kampa* and Greg J. Stuart#

Supplementary Figures 1 to 5.

Supplementary Fig. 1. Computer simulations of the influence of dendritic synapse location on somatic EPSP rise time.

A) Model morphology with colour-coded location of synaptic inputs (left). Somatic (centre) and dendritic (right) EPSP voltage waveforms for the different synaptic locations. **B)** Somatic EPSP peak plotted against distance of the synapse from the soma. Note the strong correlation of synaptic distance and somatic amplitude. **C)** The EPSP rise time at the soma for different synaptic distances in the model (colour coded circles with linear fit) overlaps with visualised layer 2/3 to layer 5 connections (filled squares). Simulations used the same model as Fig. 8.

Supplementary Fig. 2. Synapses from layer 2/3 pyramidal neurons impinge onto the apical dendritic domain of layer 5 pyramidal neurons.

A) The experimental set-up (left) consisted of a paired somatic recording between synaptically connected layer 2/3 (grey pipette) and layer 5 (blue pipette) pyramidal neurons combined with a dendritic recording (red pipette; 429 ± 13 µm from the soma). In this configuration a presynaptic AP (grey) elicited a uEPSP which was recorded both in the dendrite (red) and the soma (blue). **B)** uEPSPs in the dendrite had a significantly faster rise time than at the soma (left, $p<0.001$, $n=16$). In addition, their amplitude was greater in the apical dendrite (right, $p<0.01$, $n=16$). Together, these data suggest that layer 2/3 synapses are located on the apical dendrite of layer 5 neurons.

Supplementary Fig. 3. I_h normalises uEPSP half-width, but does not compromise the relationship between rise time and synapse location.

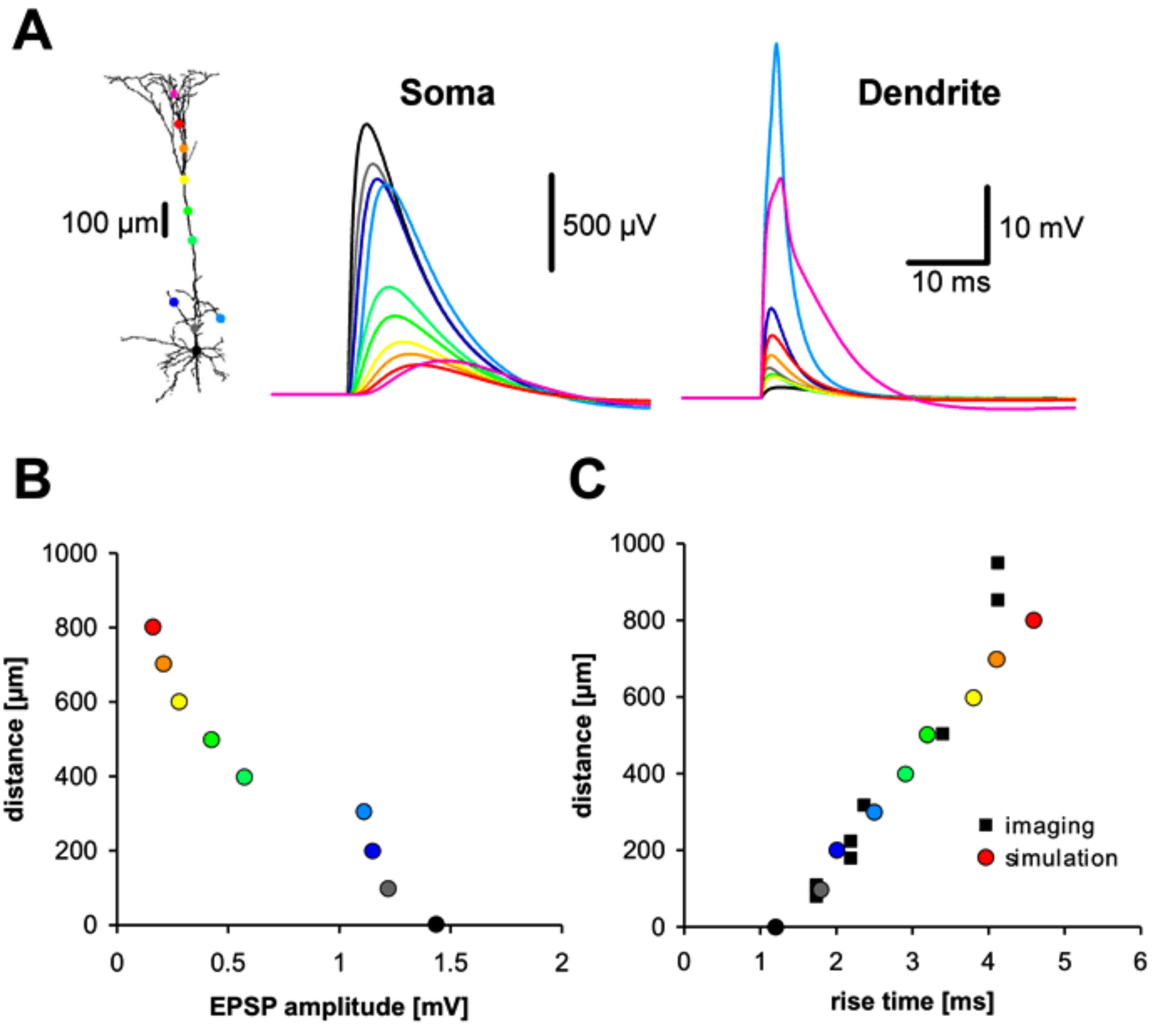
A) In control uEPSP half-width does not correlate with rise time (r=0.10, p>0.05, n=82). **B)** Upon block of I_h by ZD7288 (50 µM) a clear correlation between uEPSP half-width and rise time is observed (r=0.75, p<0.001, n=34), as expected for passive filtering of uEPSPs located at different distances from the soma. In this situation rise time can be used as a measure of the electrotonic distance of the synapse from the soma. **C)** uEPSP rise time in control and ZD7288 are strongly correlated (r=0.79, p<0.001, n=34), indicating that rise time in control is a good indicator of synapse location despite the impact of I_h on EPSP time course. **D)** Example uEPSP in control and after application of ZD7288 (averages of 100 sweeps). Note the marked increase in half-width and amplitude.

Supplementary Fig. 4. 100 µM $NiCl_2$ does not block NMDA responses in layer 5 pyramidal neurons.

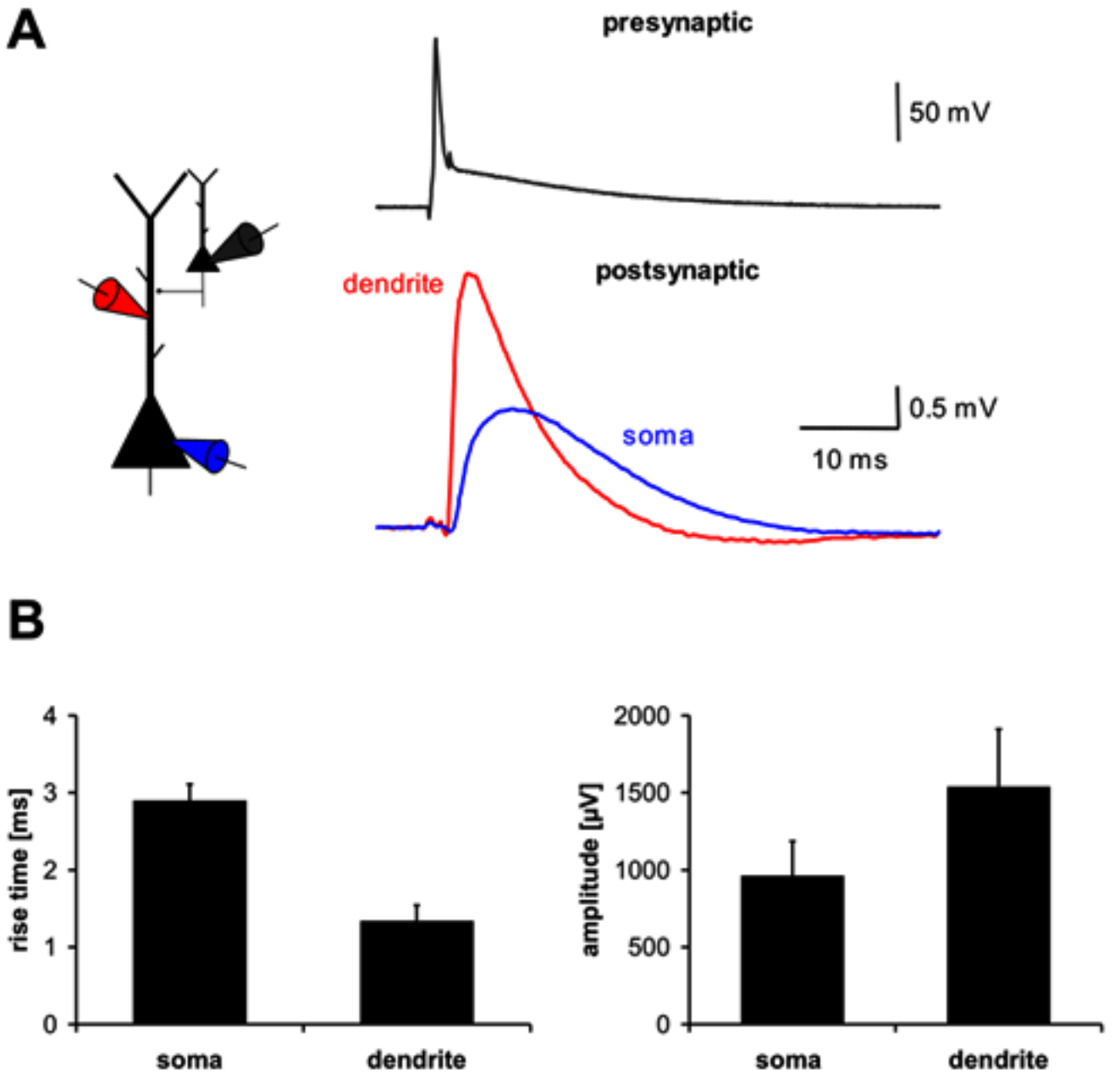
NMDA (100 µM) was applied by brief (5 to 10 ms) pressure ejection from a patch pipette at proximal dendritic locations. After a baseline period of 10 minutes, 100 µM $NiCl_2$ was bath-applied (red bar) for 15 minutes and then washed out. $NiCl_2$ had no effect on NMDA response amplitude (p>0.05, n=4). Top traces are average NMDA responses of all experiments before, during and after application of $NiCl_2$.

Supplementary Fig. 5. Calculation of NMDA receptor-dependent synaptic plasticity.

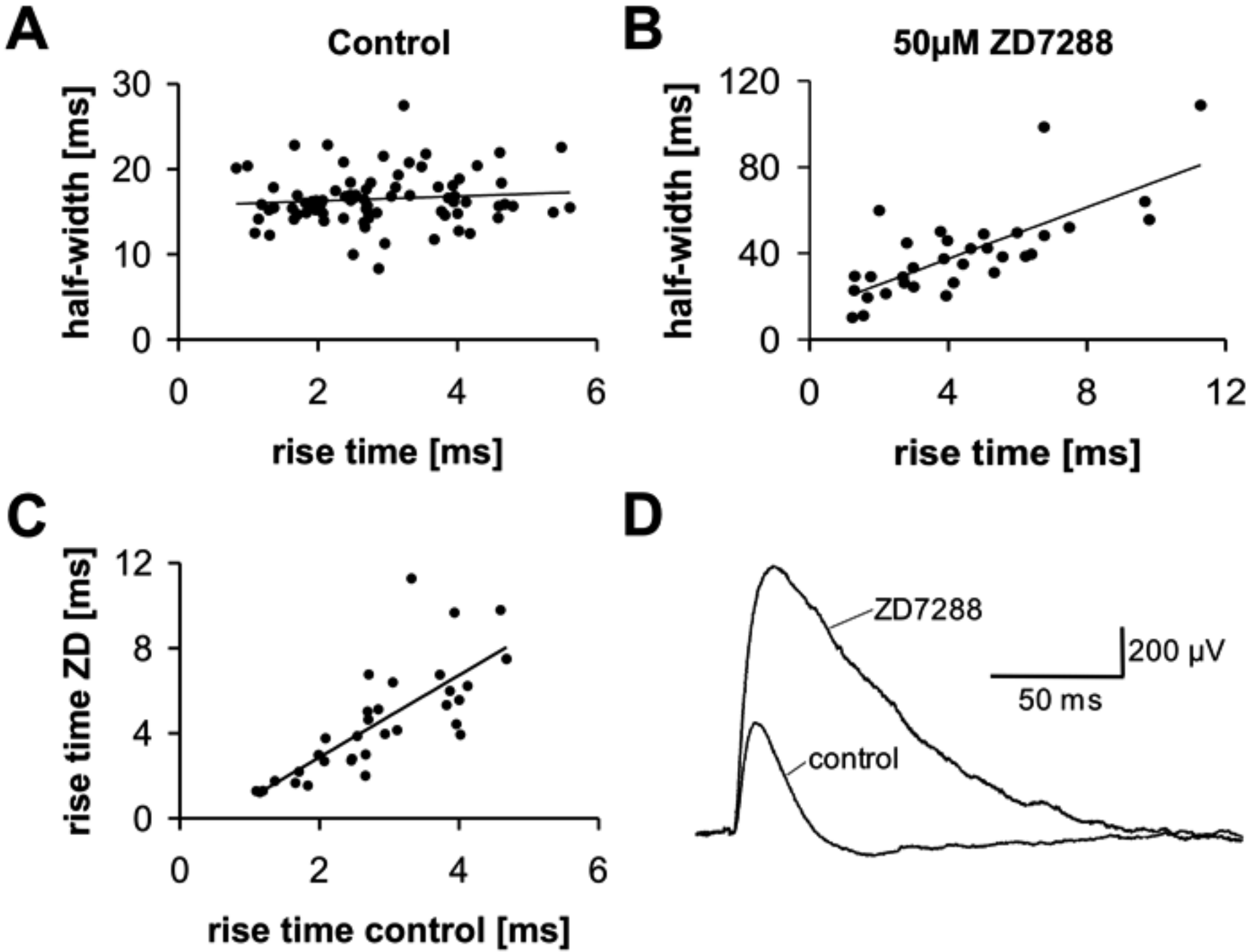
Plot of the relationship between normalised, integrated NMDA receptor conductance (NMDA activation) and STDP (see Experimental Procedures). High levels of NMDA receptor activation (>80%) lead to LTP (STDP >100%), moderate levels (<80%) lead to LTD (STDP <100%) and low levels (<55%) cause no change in synaptic weight. Circles indicate the threshold for induction of LTD and LTP.



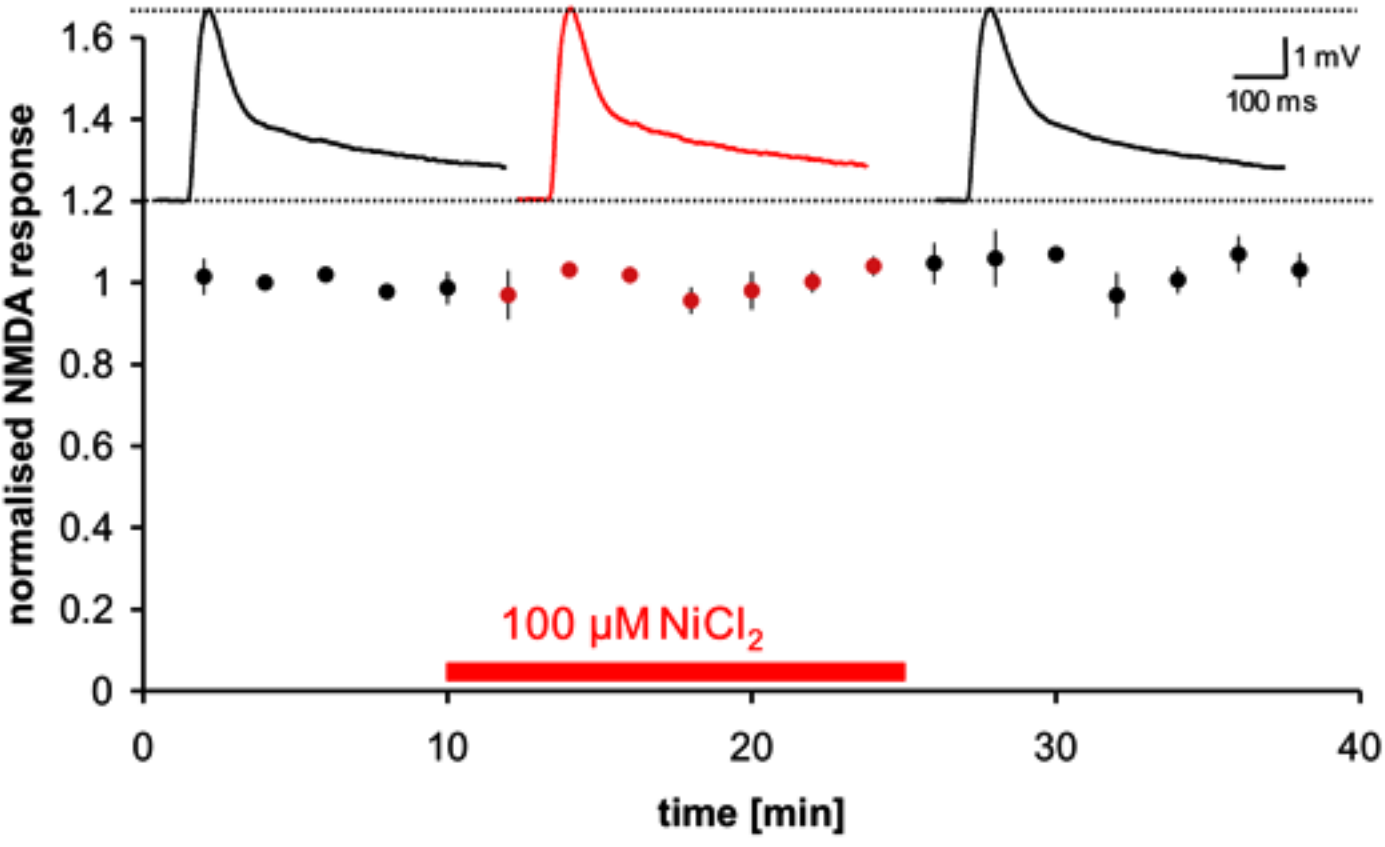
Supplementary Fig. 1 Letzkus et al.



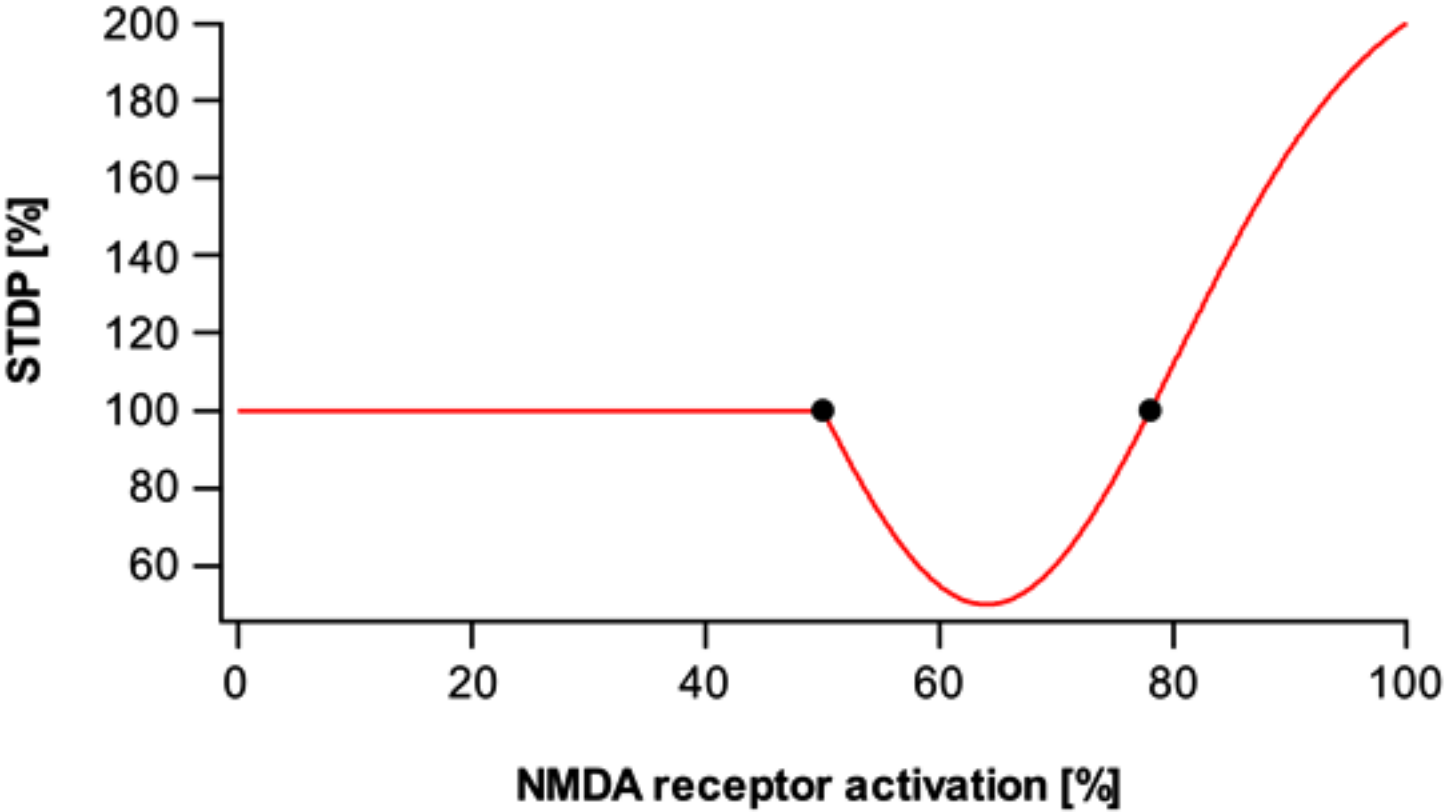
Supplementary Fig. 2 Letzkus et al.



Supplementary Fig. 3 Letzkus et al.



Supplementary Fig. 4 Letzkus et al.



Supplementary Fig. 5 Letzkus et al.