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The Role of Feedback and Feed-Forward Perisomatic Inhibition in the Hippocampal Gamma Oscillations

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GABAergic interneurons play the crucial role in synchronizing the output of the pyramidal cells. To study the functional properties of the GABAergic interneurons in the oscillatory activity of the hippocampal network, we generated two genetically modified mouse lines in which the excitatory drive was selectively reduced mainly in parvalbumin-positive GABAergic interneurons. This was achieved either by deleting the GluR-D subunit of the AMPA receptors (GluR-$D^{-/-}$ mice), or by deleting the GluR-A subunit only in the parvalbumin-positive interneurons (GluR-$A^{PV\text{-}Cre\text{-}/\text{-}}$ mice). Our study showed that the excitatory drive onto the parvalbumin-positive interneurons is impaired. The impairment is reflected in a large reduction of amplitude of AMPA receptor mediated EPSCs. Moreover, the decay time kinetics of AMPA receptor mediated EPSCs is considerably slower in GluR-$D^{-/-}$ mice. However, deletion of the GluR-A subunit in parvalbumin-positive interneurons did not affect the kinetic properties of the recorded evoked EPSCs. The deletion of the GluR-D subunit leads to $GABA_A$ receptor dependent suppression of LTP. The reduction in the excitatory input onto the parvalbumin-positive GABAergic interneurons was reflected in an expected disruption of gamma frequency oscillations in both mutant mouse lines in comparison to the WT. Nevertheless, long-range synchrony (CA3-CA1) was reduced only in GluR-$D^{-/-}$ animals. Interestingly, synchrony between CA3 and CA1 regions in GluR-$A^{PV\text{-}Cre\text{-}/\text{-}}$ animals remained unaffected. In summary, our data suggest that the GluR-D containing synapses in distal parts of the parvalbumin-positive cells might be responsible for cross talk between the hippocampal regions and for long-range synchrony. Accordingly, the GluR-A containing synapses might be responsible for the local synchrony.