T-type Ca^{2+} channels selectively enhance layer II medial entorhinal cortical ventral stellate cell excitability

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Neurons within the medial entorhinal cortex (mEC) fire action potentials in hexagonal arrays to encode for position within the environment (so-called 'grid cells'). The grid cell scale increases along the mEC dorsal ventral axis. This has, at least partly, been attributed to higher potassium and cation (HCN) channel density in dorsal mEC layer II stellate cells (SC) compared with ventral mEC layer II SC, resulting in significantly reduced dorsal neuron intrinsic excitability. However, we have shown that the subthreshold active T-type, $Ca_V3.2$, Ca^{2+} channels are also expressed throughout the mEC and modulate neuronal excitability. Their effects on dorsal and ventral SC excitability remain unknown. We have investigated this by making electrophysiological recordings from SC present in acute brain slices obtained from adult mice together with quantitative PCR (qPCR) and computational modelling. Whole-cell voltage-clamp recordings demonstrate that $Ca_V3.2$ currents are threefold larger in ventral SC compared with dorsal neurons. In agreement, qPCR indicated that $Ca_V3.2$ mRNA expression was significantly greater in ventral than dorsal mEC tissue. Genetic deletion or pharmacological inhibition of $Ca_V3.2$ channels in ventral SC resulted in significantly reduced input resistance when measured using depolarizing current pulses, decreased action potential firing and diminished excitatory postsynaptic potential summation compared with controls. In contrast, dorsal SC intrinsic and synaptic properties were similar in the absence and presence of $Ca_V3.2$ channel blockers or in $Ca_V3.2$ null and wildtype tissue. The effects of T-type Ca^{2+} channels on ventral SC intrinsic and resonance properties were further explored using computational modelling. Our results suggest that $Ca_v3.2$ channels selectively augment mEC ventral SC properties, thereby contributing to the intrinsic membrane gradient across the mEC dorsal-ventral axis. These findings also imply that increased $Ca_V3.2$ channel density in ventral mEC neurons might affect the grid scale in ventral mEC and thereby influence spatial coding.