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Early Sharp Wave Synchronization along the Septo-Temporal Axis of the Neonatal Rat Hippocampus

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In the neonatal rat hippocampus, the first and predominant pattern of synchronized neuronal network activity is early sharp waves (eSPWs) occurring at a frequency of ~2–4 events per minute. However, how eSPWs are organized longitudinally along the septo-temporal hippocampal axis remains unknown. Using silicone probe recordings from the septal and intermediate segments of the CA1 hippocampus in neonatal rats in vivo we found that eSPWs are highly synchronized longitudinally. The amplitudes of eSPWs in the septal and intermediate segments of the hippocampus were also highly correlated. eSPWs also supported longitudinal synchronization of CA1 multiple unit activity. Spatial-temporal analysis revealed a septal-temporal gradient with more frequent initiation of eSPWs in the septal regions. The speed of eSPW longitudinal propagation attained ~ 250 mm/s. We suggest that longitudinal correlated activity supported by synchronized eSPWs emerges early during postnatal development and may participate in the formation of intrahippocampal connections in the developing hippocampus.

Keywords: hippocampus, neonate, sharp waves, synchronization.

Early Sharp Waves (eSPWs) are the earliest pattern of synchronized activity in the developing rodent hippocampus considered as a prototype of SPWs in adults [Karlsson et al., 2006; Leinekugel et al., 2002; Marguet et al., 2015; Mohns et al., 2007; Mohns, Blumberg, 2008; Valeeva et al., 2019a; Buzsaki, 2015]. Similarly to the SPW-ripple complexes in adults [Buzsaki, 2015; Csicsvari et al., 2000; Ylinen et al., 1995], eSPWs are associated with a short-lasting negative local field potential deflection below the CA1 pyramidal cell layer, massive activation of synaptic inputs and collective neuronal discharge in the hippocampal network [Karlsson et al., 2006; Leinekugel et al., 2002; Marguet et al., 2015; Mohns et al., 2007; Mohns, Blumberg, 2008; Valeeva et al., 2019a; Valeeva et al., 2019b]. Yet, despite the similarities in general electrographic phenotype, eSPWs display some unique features different from adult SPWs. For example, eSPWs lack the high-frequency ripple oscillations that are characteristic of adult SPWs [Buhl, Buzsaki, 2005]. Also, eSPWs are reliably triggered by myoclonic movements of neonatal animals, whereas in adults, SPWs, which mainly occur during sleep and periods of immobility, are not associated with movements of the animal [Buzsaki, 2015; Karlsson et al., 2006; Marguet et al., 2015; Valeeva et al., 2019a]. Generation of eSPWs involves activation of entorhinal inputs to the hippocampus suggesting that eSPWs are bottom-up network events embedded into large scale signaling by sensory feedback from neonatal movements [Valeeva et al., 2019a]. In contrast, adult SPWs are a typical top-down signal which is internally generated in the hippocampal network and which enable transfer of the time-compressed replay of neuronal sequences learned during exploration from the hippocampus to the neocortex where memories are consolidated [Buzsaki, 2015; Chrobak, Buzsaki, 1994; Ylinen et al., 1995].

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