Different neural pathways lead to journey-dependent and journey-independent place cell activity in an embodied model of hippocampus

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Rodent hippocampal place cell activity can be journey-dependent, firing in a location only when the animal takes a particular path leading to or from that location. Alternatively, place cell activity can be journey-independent, firing irrespective of the animal's path. We hypothesized that different neural pathways may drive journey-dependent and journey-independent place activity. To investigate this idea, we used a brain-based device, Darwin XI, that incorporated a detailed model of medial temporal neural architecture modulated by experience-dependent synaptic activity. Brain-based devices are neural simulations embodied in robotic devices that perform behavioral tasks while interacting with real-world environments. The brain-based device method allowed us to fully examine the entire simulated nervous system at all levels during behavior, something that is presently not possible in behaving animals. Darwin XI navigated in a plus maze in which it approached a goal arm from different start arms. In the task, a journey corresponded to the route from a particular starting point to a particular goal. During maze navigation, the device developed place field responses in its simulated hippocampus. Journey-dependent place fields were identified in the recordings of simulated *CA1* neuronal units. The journey-dependent responses were both retrospective, i.e. activity was elicited in the goal arm, and prospective, i.e. activity was elicited in the start arm. Journey-independent place fields were also identified in the simulated hippocampus, in approximately the same numbers as journey-dependent fields. We determined the functional anatomical pathways that led to place activity in a reference *CA1* neuronal unit by recursively tracing backwards though the simulation's history, examining the contribution of all anatomically connected neuronal units to that *CA1* unit. Such backtrace analyses revealed that many different neural pathways could lead to place activity in a *CA1* neuronal unit. In spite of the degeneracy of pathways leading to place activity, we identified a significant difference in the anatomy of pathways leading to journey-dependent and journey–independent activity. Journey-dependent activity was strongly influenced by neural pathways through hippocampus, including the tri-synaptic pathway, whereas journey-independent activity was predominantly driven via the perforant path from entorhinal cortex.