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Distinct relationships derived from dimensionality in Dentate Gyrus

In our daily lives, as new experiences arise, the capacity to retrieve relevant information to similar experiences while identifying the distinguishing unique characteristics to current circumstances enable employment of appropriate strategies in a task relevant manner. During learning, an organism must have a strategy for relating similar experiences while identifying their differences. The hippocampus has been identified as an integral region for learning new experiences. Former theories propose that the hippocampus creates a distinct code for similar experiences (*pattern separation*) and re-engages representations of former experiences from partial or noisy inputs (*pattern completion*). More recently, Cayco-Gajic proposed the concept of dimensionality to better describe the processes responsible for pattern separation within DG.

Dimensionality is a means of representing the population codes representing sensory information providing a framework for pattern separation, whose key components are: expansion, decorrelation, and sparse coding.[1] Expansion occurs between entorhinal cortex (EC), sending multisensory information downstream, and DG. A small population of EC projects onto a much larger population within DG.[1]This random mixing of various inputs recodes information by creating a greater number of distinct combinations to represent the same or similar inputs.[5] While CA3 recreates representations using partial inputs, DG creates distinct codes for stimuli to minimize interference through decorrelation. Decorrelation through thresholding scrambles input patterns by requiring a greater level of excitation to generate action potentials and removing any correlated fluctuations of subthreshold membrane potential in DG.[2] Sparse coding is described as a small population of active neurons relative to the population within a region, resulting in greater possible combinations of representations of the neural code.[1] Sparse coding in DG arises from the of high levels of feedforward and feedback inhibition on granule cells by inhibitory interneurons basket cells.[1,4] Feedforward inhibition decreases the active population of granule cells, while feedback inhibition creates rhythmicity in the region.[4]

DG's role in spatial pattern separation was exhibited in a lesion study by Gilbert et al. (2001) on a cheese board maze (Figure 1A). Subject rats were presented a target item during the study phase (Figure 1A) with a reward in the well below. In the test phase (Figure 1B) an identical target item was placed in the same location and a foil object was also placed on the maze at distances between 15-105cm.[3] Rats with DG lesions showed significant deficit in performance compared to control lesion rate.[3] We adapted the procedure to an electrophysiological study, using the same procedure on a 16-arm fan maze (Figure 1C), implanting a rat with a 96-channel hyperdrive. This enabled the capacity to collect LFP and single-spike data from DG during the task with the aims of characterizing spiking activity of DG interneurons & characterizing temporal coordination of spiking activity with respect to rhythms in DG LFP during spatial pattern separation task.

To characterize spiking activity a firing-rate analysis (Figure 2) was performed, which revealed a higher firing-rate in close conditions compared to far conditions indicative of greater DG recruitment during the task. However, the firing-rate was sustained more consistently during correct trials suggesting a greater level of inhibition present in DG. A spectral analysis of the local field potential revealed an increase in power in the theta range, 5-10 Hz, leading to explore the spike-phase relationship of this frequency range. The DG-DG spike-phase relationship on 5/23 (Figure 3A) revealed the most obvious shift in phase bias of trials within the close condition, with phase bias of 150-210° in correct trials and 330-0° phase bias in incorrect trials. However, more in depth analysis needs to be completed for distinctions of trials within the far condition. Similarly, in the beta frequency, 15-30 Hz, the most obvious shift in phase bias of

trials was within the close condition (Figure 3B), with a bimodal distribution during correct trials shifting to a unimodal distribution during incorrect trials. More in depth analysis needs to be completed for distinctions of trials within the far condition. The DG-DG spike-phase relationship on 5/08 did not reveal any obvious phase shift the in the theta frequency (Figure 4A), but it did in the beta frequency for trials within the close condition. In close correct trials there was a phase bias 90-150° that shifted to a less discriminable distribution in close incorrect trials (Figure 4B).

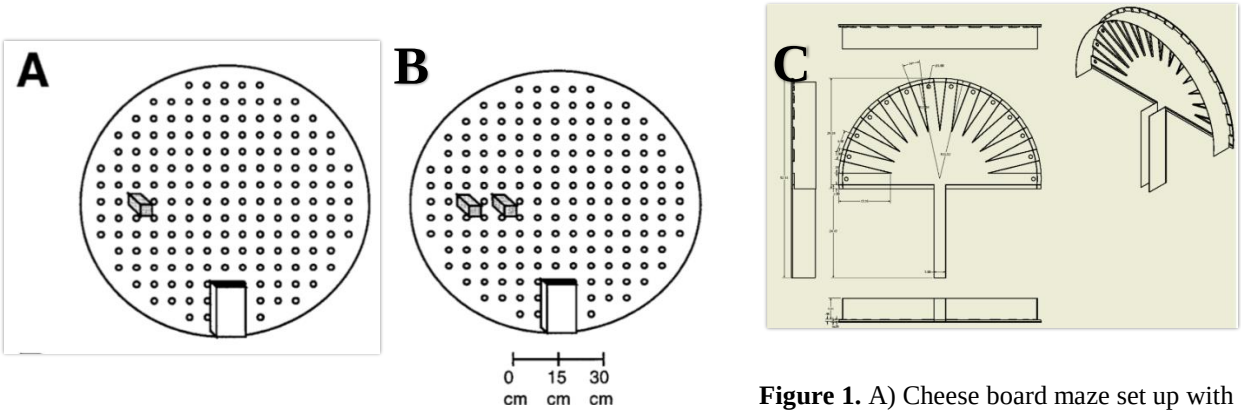


Figure 1. A) Cheese board maze set up with only target item during study phase of Gilbert et al. (2001) lesion study. B) Cheese board maze set up with target and foil items during test phase of Gilbert et al. (2001) lesion study. C) Fan maze used during electrophysiological recordings of current study.

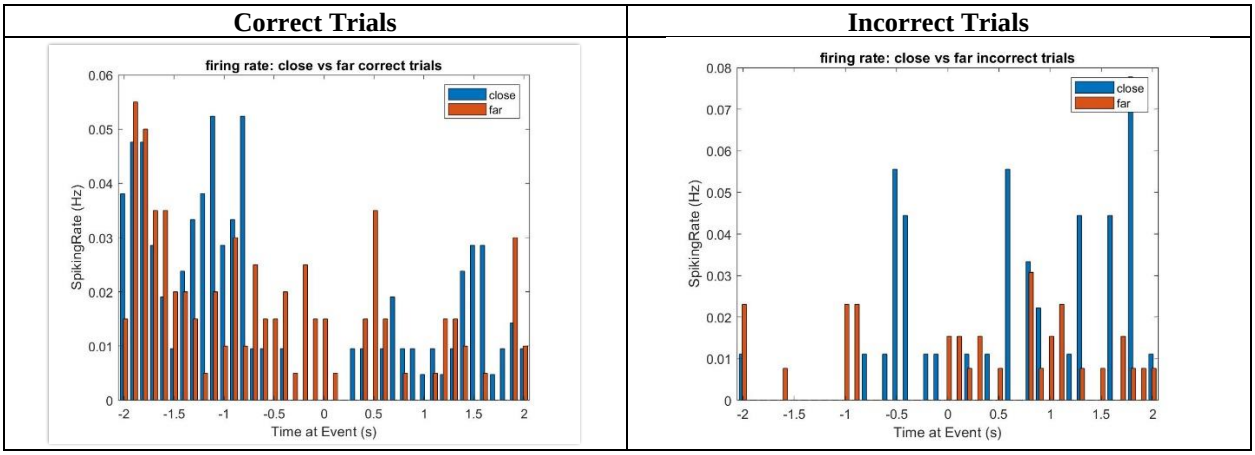


Figure 2. Firing rate histogram of DG interneuron during correct trials (left) and incorrect trials (right) of close (blue) or far (red) condition.

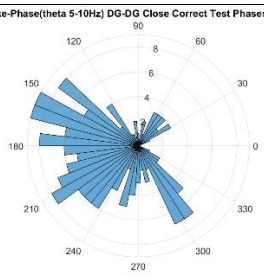
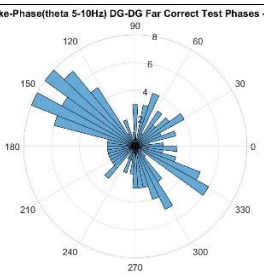
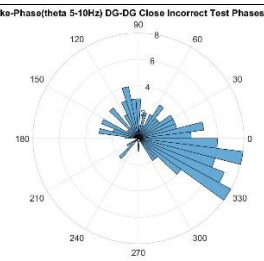
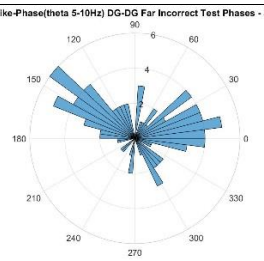
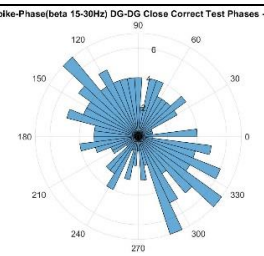
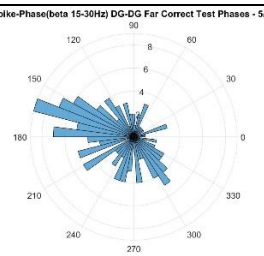
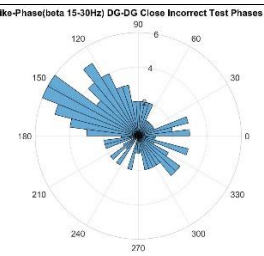
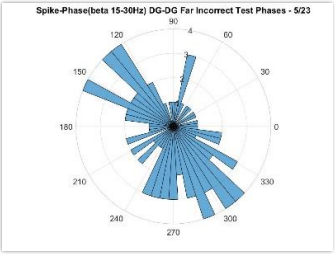
Theta (5-10 Hz)		
A	close	far
correct		
incorrect		
Beta (15-30 Hz)		
B	close	far
correct		
incorrect		

Figure 3. A) Circular histograms of DG spiking according to phase of DG LFP filtered for theta frequency (5-10 Hz) on 5/23. B) Circular histograms of DG spiking according to phase of DG LFP filtered for beta frequency (15-30 Hz) on 5/23.

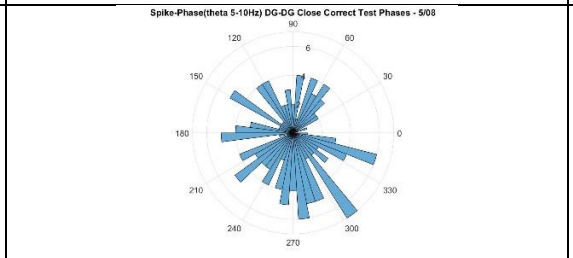
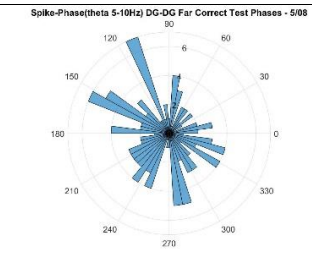
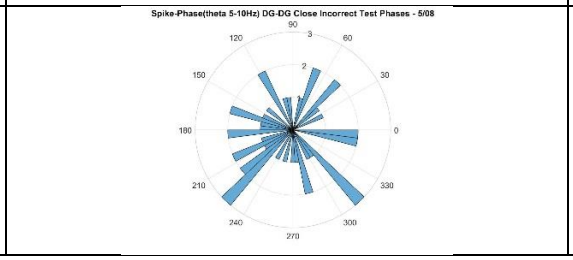
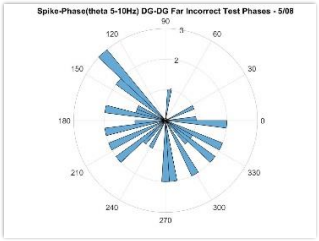
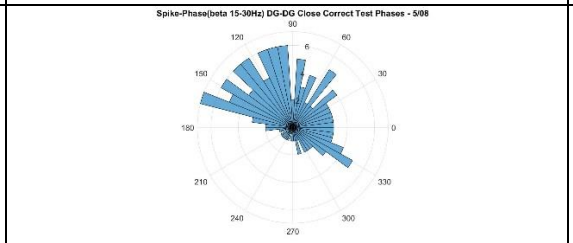
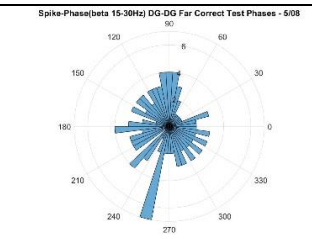
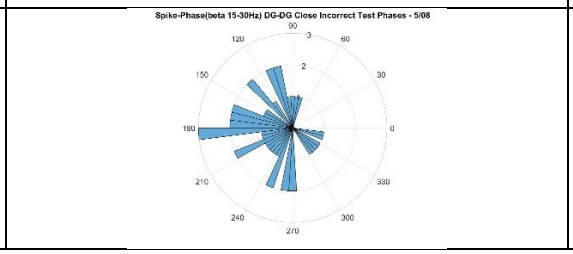
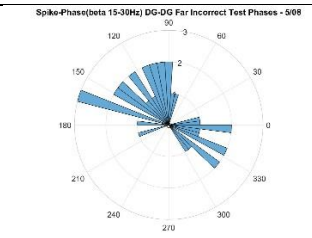
Theta (5-10 Hz)		
A	close	far
correct		
incorrect		
Beta (15-30 Hz)		
B	close	far
correct		
incorrect		

Figure 4. Figure 3. A) Circular histograms of DG spiking according to phase of DG LFP filtered for theta frequency (5-10 Hz) on 5/08. B) Circular histograms of DG spiking according to phase of DG LFP filtered for beta frequency (15-30 Hz) on 5/08.

References

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