Hippocampus Structure and Functions

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The distinction and consistency of the Dorsal and Ventral Hippocampus's functions.

"What is the name of the mythical creature with the upper body of a horse and the lower body of a fish that came with Poseidon?"
"It is Hippokampos!"

In Greek mythology, Hippokampos means seahorse, and it was later morphed into the English word hippocampus. Hippocampus, a part of the brain, gets its name because of its shape.

Figure 1. Comparison of the human hippocampus and seahorse

The hippocampus is a small seahorse-shaped structure located in the medial temporal lobe of the brain. As part of the limbic system, it is well known for its function of declarative memory formation, consolidation, and retrieval (Squire, 1992). Damage or dysfunction of the hippocampus can lead to a variety of memory impairments, such as amnesia (Zola-Morgan et al., 1986). The hippocampus is a highly intricate and multifaceted brain region that is not limited to memory processing, but also encompasses a range of other important human functions, including emotional regulation.

Let's go back to the structure of the hippocampus. According to the analysis by Moser and Moser (1998), the hippocampus may not be a single entity, but rather, the dorsal and ventral regions may have different roles. Dorsal and ventral are anatomical terms used to describe the relative positions of structures in the body or brain. Dorsal refers to the upper or back side, while ventral refers to the lower or front side. In the hippocampus, the dorsal portion is the septal pole, which is closer to the top of the brain, while the ventral portion is the temporal pole, which is closer to the bottom (Moser & Moser, 1998). Moreover, previous studies of anatomy revealed that the input and output connections of the dorsal hippocampus and ventral hippocampus are different (Swanson & Cowan, 1977).

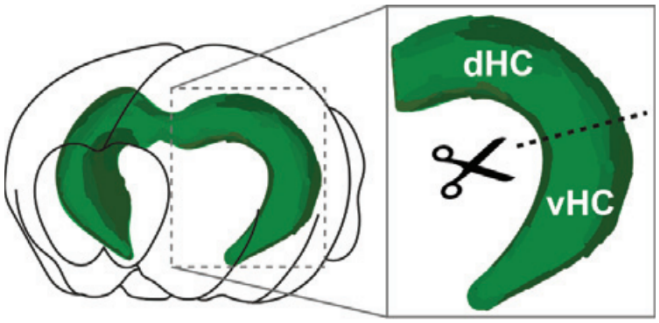

Figure 2. The diagram of the hippocampus. The hippocampus is divided in the middle into dorsal hippocampus and ventral hippocampus.

The dorsal hippocampus is associated with episodic memory and spatial navigation. In a study by Maguire et al. (1997), taxi drivers recalling complex routes through the city showed different activation patterns in the right posterior hippocampus compared to the anterior hippocampus, while language materials preferentially activated the human posterior hippocampus over the anterior hippocampus, with greater activation in the left side (Greicius et al., 2003). Anatomically, the dorsal CA1 is linked to the postpressive and anterior cingulate cortex (Cenquizca & Swanson, 2007; Vogt & Miller, 1983), two cortical regions primarily involved in cognitive processing of visuospatial information and memory, and environmental exploration (Maguire et al., 2006; Spiers & Maguire, 2006). Overall, the dorsal region of the hippocampus is more associated with cognitive processes.

The ventral hippocampus is responsible for emotions, such as anxiety and fear. Kjelstrup et al. (2002) found that lesions to the most ventral quarter of the rats‘ hippocampus led to reduced defecation in brightly lit chambers, indicating a reduction in anxiety. Additionally, studies indicate that animals with the ventral hippocampus removed tend to disregard cues associated with fear (Koh et al., 2009). In human research, the ventral hippocampus is involved across conditions of threat, safety, and conditioned inhibition, using the pairing of threat and safety cue (Meyer et al., 2019) . In terms of neuronal connectivity of the ventral hippocampus, it communicates bidirectionally with the amygdala via glutamate signaling, projecting responses to fear cues (Jimenez et al., 2018). Due to this anatomical feature, the ventral hippocampus is more associated with emotions.

Although the dorsal hippocampus is thought to be more important for spatial processing and memory, and the ventral hippocampus is primarily responsible for fear and anxious behavior, anatomical connections suggest a flow of information between the dorsal and ventral regions (Lee et al. 2019). It was found that in spatial performance, the dorsal hippocampus was mainly involved in the formation of spatial maps, while the ventral hippocampus was involved in spatial flexibility and the ability to update spatial maps (Lee et al. 2019). When dealing with fear, the dorsal CA3 results in the formation of a generalized fear response; the ventral CA3 leads to fear discrimination between the fear-inducing and safe contexts (Besnard et al.,2020). In practice, the dorsal and ventral hippocampus function as a single integrated structure.

In summary, both the dorsal and ventral regions of the hippocampus, which are "the head and tail" of the hippocampus, work separately and together to facilitate various cognitive functions to enhance quality of life.

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