The Development of Trisynaptic Pathway in the Hippocampus and the Milestone of Language Development

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1. Introduction

The hippocampus is involved in both episodic memory (Tulving and Markowitsch, 1998) and language processing (Duff and Brown-Schmidt, 2012). From evolutionary perspective, Zhang and Shi (2021) suggests that the hippocampus serves as the subcortical hub underlying displacement, which makes human language flexible in time and space. However, very few studies have explored the relation between the developmental trajectory of the hippocampus and flexibility of human language. In this study, by reviewing previous researches, we propose that the emergence of trisynaptic pathway in the hippocampus not only forms the basis for episodic memory but also serves as the milestone for the human language flexibility. We further suggest that the protracted development of such trisynaptic pathway serves as a channel for information exchange between episodic memory and language, and further forms the neurological basis for the domain-general mechanism between them.

2. Neurological structure of hippocampus

Within the hippocampus, there are two main pathways that connect the subfields of the hippocampus. The trisynaptic pathway (TSP) connects the entorhinal cortex, dentate gyrus, CA3 and CA1, and the monosynaptic pathway (MSP) connects entorhinal cortex and CA1 (Schapiro et al., 2016). MSP develops earlier than TSP. It has been shown that MSP is mainly related to statistical learning (Ellis et al., 2021) and associative learning which is not continuously maintained in the memory (Gómez and Edgin, 2016). The late emergence of trisynaptic pathway,

which occurs around 18-24 month, marks the developmental shift in the functions of the hippocampus to episodic memory. Before this period, even though infants can remember salient event in their lives, but details cannot be maintained (Peterson et al., 2011). While due to the emergence of TSP, learning becomes more flexible and the children can remember an object separate from its learning context (Robinson and Pascalis, 2004).

Beyond the domain of episodic memory. We propose that the emergence of the TSP also marks the milestone of human language flexibility. Studies on language acquisition have shown that during the same period (around 18-24 month) when TSP appears, children show a vocabulary spurt (Goldfield and Reznick, 1990) and grammatical developments (Maez, 1983). We suggest that the developmental transitions in both language and episodic memory is not a coincidence. The parallel of developmental trajectories in both domains implies a deep relation between the two domains subserved by a domain-general mechanism (Zhang and Shi, 2021).

3. Evidence from a Clinical Perspective

The relation between the function of the TSP in the hippocampus and linguistic ability is also implicated in the clinical studies. Dysfunctions in schizophrenic TSP have been reported in previous studies (Benes 1991, 1999). Further, Farmer et al. (2023) explores the ultrastructural organization of the TSP in schizophrenia and found excitatory and inhibitory imbalances in TSP. In Alzheimer's disease, trisynaptic pathway is also susceptible to premature degeneration (Llorens-Martín et al. 2014). In both schizophrenia and Alzheimer's disease, in addition to memory impairment, impairment of linguistic ability and reduced linguistic flexibility are also detected (Mckenna and Oh, 2005; Bickel et al., 2000).

4. Conclusion

We hypothesize that the emergence of TSP in the hippocampus gives rise the developmental transition in both memory and language, which captures the flexibility of both domains. This could be the neurological foundation for the generative nature of a domain-general mechanism.

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