

Recursion in Language and Beyond: A Bilingual Perspective

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The issues of domain general functions of the hippocampus and basal ganglia have been addressed from both clinical and evolutionary perspectives (Shi & Zhang 2020; Zhang & Shi 2021). In line with insights of these studies, we suggest that the functions of the hippocampus and basal ganglia in categorical perception and recursive processing in cross-modality systems pave the way for recursion observed in language.

Recursion, the abstract linguistic computational system, has been assumed to be core part of the faculty of language, which gives rise to discrete expression (Chomsky, 1995). It is also assumed that recursion is independent of the other systems with which it interacts and interfaces though the mechanisms possibly shared with other cognitive domains (Chomsky & Berwick, 2016). From the evolutionary perspective, due to lack of detection of analogs in animal communication and other domains recursion is assumed to be uniquely human (Hauser, Chomsky & Fitch 2002). However, from the neurocognitive perspective, we propose categorical perception (CP) forms the basis for discreteness which provides the premise for recursion in language. CP is a widespread phenomenon detected across species, and seems a combination of nature and nurture (Zhang, Lei & Gong, in press). From the comparative perspective, CP has been found in nonhuman animals and prelinguistic infants. For instance, field crickets were reported to discriminate attractive and repulsive sounds (Wytenbach et al., 1996). Songbirds are able to discriminate not only their calls but also human speech sounds (e.g. Dooling et al., 1987; Hienz et al., 1981). Rodents can also discriminate the continuum of speech sounds. As for prelinguistic infants, as early as 3 to 4 months old infants can categorically discriminate cues of place of articulation. Infants before 6 months old are capable of discriminating speech phonemes in all languages (Kuhl et al., 2006). These data suggest that, contrary to Sapir-Whorf hypothesis, language is not indispensable for categorical perception. Meanwhile, we emphasize that the nurture part of CP is realized by statistical learning during critical period across species, which plays a crucial role in both development and evolution. Concerning recursion itself, by reviewing comparative evidence in auditory and visual perception (Gentner et al., 2006; Van Heijningen et al., 2009; Rey et al., 2012; Abe & Watanabe, 2011), and also motor production in nonhuman animals (Johnson-Pynn et al., 1999; Herman et al., 1984), we argue that in cross-modality sensorimotor systems, recursion has appeared without the existence of language.

At the brain level, the hippocampus and basal ganglia are both evolutionarily conserved subcortical structures. Both are involved in domain-general functions which could be used in the domain of language. The hippocampus plays a key role in statistical learning and lexical learning (Covington et al., 2018; Ullman, 2004), whereas the basal ganglia underlie implicit recursive processing and learning (Ullman, 2004; Progovic et al., 2018). Studies also implied the

cooperative and competitive relation between statistical and implicit learning, supported by the hippocampus and basal ganglia respectively (Batterink et al., 2019). Hence, from both theoretical and empirical perspectives, recursion is not unique to human language faculty (Hauser et al. 2002). Instead, we argue that recursion could have already emerged without language.

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