ROLE OF MIDBRAIN DOPAMINERGIC SYSTEM IN SOCIAL ENHANCEMENT OF VOCAL LEARNING IN SONGBIRD

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There are many similarities between avian vocal learning and human language learning, and in particular, social interaction is known to have a significant impact on vocal learning in both. For example, social interaction is known to facilitate language learning in humans (Kuhl, 2010). Similarly, social interactions between tutor and tutee are also known to enhance vocal learning in songbirds (Chen, Matheson, & Sakata, 2016; Eales, 1989). Juvenile birds learn to sing the same song by listening to the tutor song. In order to learn songs accurately, juvenile birds need to hear the songs directly from their tutor. On the other hand, they cannot learn to imitate songs well by passively listening to songs presented from a speaker. These behavioral studies highlight the importance of social interactions in vocal learning, but the neural mechanisms underlying the social enhancement of vocal learning remain unclear. In this study, we aim to understand the evolutionary origin of language learning by clarifying the neural basis of social enhancement of vocal learning in songbirds. We tested the hypothesis that direct listening to songs from the tutor bird enhances midbrain dopaminergic activity as a social reward for juvenile birds, leading to accurate song memory formation. We measured neural activity in the ventral tegmental area (VTA) and substantia nigra pars compacta (SNc) of freely behaving juvenile zebra finches. We

examined whether auditory responses to the tutor songs changed depending on the presence or absence of a live tutor bird. As a result, we found that a group of neurons in the VTA/SNc showed auditory responses to the tutor song presented from the speaker, and that these responses were markedly enhanced in the presence of the tutor. Moreover, similar enhanced auditory responses were observed when a juvenile listened to a song from a live tutor. These results suggest that midbrain dopaminergic system is involved in the process of juvenile birds learn songs from their tutor.

Next, we tried to find out where in the brain dopamine acts to enhance vocal learning. Previously, it has been suggested that memory of songs learned from a tutor bird is formed in the higher auditory cortex (NCM) (Gobes & Bolhuis, 2007; London & Clayton, 2008; Yanagihara & Yazaki-Sugiyama, 2016). In addition, dopamine receptors are abundant in the higher auditory cortex (Kubikova, Wada, & Jarvis, 2010). Thus, dopamine released in the brain when a juvenile bird hears the song from a tutor may enhance auditory responses in the higher auditory cortex. To test this, we examined whether dopamine modulates auditory responses in the higher auditory cortex. While measuring neural activity in the higher auditory cortex, we found that local administration of dopamine near the recording site markedly enhanced auditory responses to the songs presented from a speaker. These results suggest that dopamine is released into the higher auditory cortex by directly listening to the tutor song, which enhances the auditory responses in the higher auditory cortical neurons and leads to successful song memory formation. In conclusion, we show that dopamine is a key molecule for social enhancement of vocal learning in songbirds. This study provides a new research direction to explore the origin of language through social interaction and dopamine.

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