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ORIGINAL PAPER

Social signals increase monoamine levels in the tegmentum of juvenile Mexican spadefoot toads (*Spea multiplicata*)

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Abstract Monoamines are important neuromodulators that respond to social cues and that can, in turn, modify social responses. Yet we know very little about the ontogeny of monoaminergic systems and whether they contribute to the development of social behavior. Anurans are an excellent model for studying the development of social behavior because one of its primary components, phonotaxis, is expressed early in life. To examine the effect of social signals on monoamines early in ontogeny, we presented juvenile Mexican spadefoot toads (*Spea multiplicata*) with a male mating call or no sound and measured norepinephrine, epinephrine, dopamine, serotonin, and a serotonin metabolite, across the brain using high-pressure liquid chromatography. Our results demonstrate that adult-like monoaminergic systems are in place shortly after metamorphosis. Perhaps more interestingly, we found that mating calls increased the level of monoamines in the juvenile tegmentum, a midbrain region involved in sensory-motor integration and that contributes to brain arousal and attention. We saw no such increase in the auditory midbrain or in forebrain regions. We suggest that changes in monoamine levels in the juvenile tegmentum may reflect the effects of social signals on arousal state and could contribute to context-dependent modulation of social behavior.

Keywords Monoamines · Neuromodulator · Anuran · Acoustic communication · HPLC

Abbreviations

5-HIAA	5-Hydroxyindoleacetic acid
5-HT	5-Hydroxytryptamine (serotonin)
A-D di	Anterior-dorsal diencephalon
DA	Dopamine
DOPAC	3,4-Dihydroxyphenylacetic acid
E	Epinephrine
HVA	Homovanillic acid
ISO	Isoproterenol
MHPG	3-Methoxy-4-hydroxyphenylglycol
NE	Norepinephrine
P	Pallium
P-D di	Posterior-dorsal diencephalon
PoA	Preoptic area
P-V di	Posterior-ventral diencephalon
SC	Suprachiasmatic nucleus
SubP	Subpallium
Teg	Tegmentum
TS	Torus semicircularis

Introduction

Social behavior emerges from neural processing that translates sensory information deriving from social signals into meaningful behavioral responses. Although vertebrates may differ in their manifestations of social behavior, the principles of neural processing, as well as the neural and molecular mechanisms underlying social responses,

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