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Oxytocin Enhances Social Recognition by Modulating Cortical Control of Early Olfactory Processing

Highlights

- Oxytocin in the olfactory system is required for social recognition
- Oxytocin activates cortical top-down inputs to olfactory bulb interneurons
- Top-down inputs generate states of high signal-to-noise in odor coding

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In Brief

Oettl et al. found that oxytocin transforms sensory channels for optimized processing of cues through cortical top-down recruitment of interneurons. These novel oxytocin actions are required for social recognition and may be of relevance to sensory perception deficits in autism.

Oettl et al., 2016, Neuron *90*, 609–621
May 4, 2016
http://dx.doi.org/10.1016/j.neuron.2016.03.033

CellPress

Neuron
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Oxytocin Enhances Social Recognition by Modulating Cortical Control of Early Olfactory Processing

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http://dx.doi.org/10.1016/j.neuron.2016.03.033

SUMMARY

Oxytocin promotes social interactions and recognition of conspecifics that rely on olfaction in most species. The circuit mechanisms through which oxytocin modifies olfactory processing are incompletely understood. Here, we observed that optogenetically induced oxytocin release enhanced olfactory exploration and same-sex recognition of adult rats. Consistent with oxytocin's function in the anterior olfactory cortex, particularly in social cue processing, region-selective receptor deletion impaired social recognition but left odor discrimination and recognition intact outside a social context. Oxytocin transiently increased the drive of the anterior olfactory cortex projecting to olfactory bulb interneurons. Cortical top-down recruitment of interneurons dynamically enhanced the inhibitory input to olfactory bulb projection neurons and increased the signal-to-noise of their output. In summary, oxytocin generates states for optimized information extraction in an early cortical top-down network that is required for social interactions with potential implications for sensory processing deficits in autism spectrum disorders.

INTRODUCTION

Efficient extraction of sensory information from conspecifics is critical to social recognition across perceptual boundaries throughout evolution, from olfaction in rodents and other animals to vision in humans (Brennan and Kendrick, 2006). Social recognition has been classically studied in rodents and other mammals (Fleming et al., 1979; Sanchez-Andrade and Kendrick, 2009; Wiesner and Sheard, 1933). Information on the identity of the conspecific comes from olfactory cues in urine or secretions from skin, reproductive tract, or specialized scent glands (Mykytowycz and Goodrich, 1974; Natynczuk and Macdonald, 1994; Stopka et al., 2007). The recognition of social olfactory cues is dependent on an intact main olfactory system since lesions of the main olfactory bulb (MOB) or chemically induced anosmia impair individual recognition in rodents (Dantzer et al., 1990; Popik et al., 1991; Sanchez-Andrade and Kendrick, 2009).

Odor information from the olfactory sensory neurons is first processed in MOB projection neurons, i.e., mitral and tufted cells (M/TCs), which convey sensory inputs directly to the olfactory cortex. Odor coding in M/TCs is modulated by interneuron networks. The most abundant interneurons are granule cells (GCs). GCs receive massive cortical top-down inputs primarily from the anterior olfactory nucleus (AON), which is the most anterior portion of the olfactory cortex (Balu et al., 2007; Brunjes et al., 2005; Cajal, 1911; de Olmos et al., 1978; Haberly and Price, 1978; Kerr and Hagbarth, 1955; Luskin and Price, 1983; Shipley and Adamek, 1984). These top-down inputs are transiently active in a brain-state-dependent manner (Boyd et al., 2015; Otazu et al., 2015; Rothermel and Wachowiak, 2014) and increase GC firing, thereby modulating inhibition on M/TCs (Balu et al., 2007; Boyd et al., 2012; Markopoulos et al., 2012). It is not known whether and how top-down inputs control odor coding relevant to social interactions.

The oxytocin (OXT) system is a critical modulator to social perception and behaviors (Lee et al., 2009). OXT release to the forebrain originates from neurons in the paraventricular nucleus (PVN) of the hypothalamus. The mechanisms have not been resolved through which OXT acts on olfactory circuits (Insel, 2010; Kendrick et al., 1992; Numan and Insel, 2003; Yu et al., 1996). The rat MOB itself contains few OXT terminals and OXT receptors (OXTRs), with the least dense expression in the GC layer (Numan and Insel, 2003; Vaccari et al., 1998). Interestingly, the AON is among the brain regions with highest OXTR expression (Freund-Mercier et al., 1987; Tribollet et al., 1988; Vaccari et al., 1998; Yoshimura et al., 1993) and receives dense innervation from OXT neurons of the PVN (Knobloch et al., 2012).