

A Neural Circuit for Auditory Dominance over Visual Perception

Highlights

- Audition dominates vision in mice perceiving audiovisual conflicts
- The VC and AC send converging inputs to the PTLp
- A neural circuit comprising the VC, AC, and PTLp computes auditory dominance
- PV+ interneurons mediate feedforward inhibition of visual inputs in the PTLp

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In Brief

Song et al. describe a neural circuit for the integration of cross-modal sensory conflicts. In head-fixed mice perceiving audiovisual conflicts, audition dominates vision via feedforward inhibition of visual inputs by auditory inputs as they converge in the posterior parietal cortex.

A Neural Circuit for Auditory Dominance over Visual Perception

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SUMMARY

When conflicts occur during integration of visual and auditory information, one modality often dominates the other, but the underlying neural circuit mechanism remains unclear. Using auditory-visual discrimination tasks for head-fixed mice, we found that audition dominates vision in a process mediated by interaction between inputs from the primary visual (VC) and auditory (AC) cortices in the posterior parietal cortex (PTLp). Co-activation of the VC and AC suppresses VC-induced PTLp responses, leaving AC-induced responses. Furthermore, parvalbumin-positive (PV+) interneurons in the PTLp mainly receive AC inputs, and muscimol inactivation of the PTLp or optogenetic inhibition of its PV+ neurons abolishes auditory dominance in the resolution of cross-modal sensory conflicts without affecting either sensory perception. Conversely, optogenetic activation of PV+ neurons in the PTLp enhances the auditory dominance. Thus, our results demonstrate that AC input-specific feedforward inhibition of VC inputs in the PTLp is responsible for the auditory dominance during cross-modal integration.

INTRODUCTION

Visual and auditory information is abundant in the environment. Different sensory channels detect auditory and visual stimuli, and distinct sensory areas of the brain process them. This modality-specific information must then be integrated in the brain for the animal to produce a coherent behavioral response (Ghazanfar and Schroeder, 2006; Jones and Powell, 1970; Kayser and Logothetis, 2007). When visual and auditory stimuli exhibit sufficient mismatch to generate cognitive conflicts, one sensory modality often dominates the other in the resolution of a conflict (Alais and Burr, 2004; McGurk and MacDonald, 1976; Pick et al., 1969; Shams et al., 2000).

The McGurk effect from human speech perception is a famous example of perceptual resolution of audiovisual conflict. In it, a

visual and auditory mismatch elicits the perception of an illusory phoneme (MacDonald and McGurk, 1978; McGurk and MacDonald, 1976). Some individuals, however, show complete auditory or visual dominance without any McGurk illusion (Giard and Peronnet, 1999; Nath and Beauchamp, 2012). This sort of simple dominance of one modality over another may be beneficial in certain circumstances. It can improve perceptual performance in response to sensory conflicts and help animals make quick decisions in a complex, ambiguous environment (Alais and Burr, 2004; Ernst and Banks, 2002; Ernst and Bühlhoff, 2004; Knill and Pouget, 2004; Witten and Knudsen, 2005). We do not yet fully understand the neural basis of the perceptual dominance that can occur during the integration of cross-modal sensory conflicts in behaving animals. The sensory integration may occur via neural modulation in the primary sensory cortices themselves (Bizley and King, 2009; Iurilli et al., 2012; Kayser et al., 2008; Lakatos et al., 2007; Molholm et al., 2002) or in higher-association areas (Avillac et al., 2007; Kolb and Walkey, 1987; Lim et al., 2012; Olcese et al., 2013; Raposo et al., 2014).

The way multimodal stimuli are integrated to form a single coherent percept also depends on the salience of each individual sensory stimulus. Saliency, in turn, depends both on stimulus intensity (Andersen et al., 2004; Meredith and Stein, 1983; Stein and Stanford, 2008; Takeshima and Gyoba, 2013) and top-down attention (Morís Fernández et al., 2015; Wimmer et al., 2015). According to the principle of inverse effectiveness, the strength of a multisensory interaction is inversely proportional to the effectiveness of each unimodal response (Stein and Stanford, 2008). This means reducing the salience of each sensory stimulus can generate larger effects during integration. The difficulty of matching stimulus salience across sensory modalities, however, makes the perception of cross-modal competition difficult to measure. To study the multisensory integration of conflicts, we must be able to present multimodal stimuli of varying, yet known salience to generate a fine-tuned, reproducible cross-modal sensory conflict.

It has been well known that artificial activation of a particular primary sensory cortex can elicit an artificial perception in a behaving animal (Houweling and Brecht, 2008; Romo et al., 1998; Salzman et al., 1990). Recently, it has even become possible to use a combination of behavioral experiments and optogenetic neuronal activation to ask trained animals about the salience of individual cortical activity (O'Connor et al., 2013;

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