Article

Current Biology

Visual Selective Attention in Mice

Highlights

- Mice can display effects of visual selective attention
- Accuracy is higher and reaction times are shorter on trials with valid spatial cues
- Spatial cueing improves perceptual sensitivity and lowers detection thresholds
- Mice can also use spatial cues to actively ignore irrelevant visual stimuli

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In Brief

Using three visual selective attention tasks adapted from work in primates, Wang and Krauzlis demonstrate that mice can exhibit spatial cueing effects on visual selective attention.

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Visual Selective Attention in Mice

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SUMMARY

Visual selective attention is a fundamental cognitive ability that allows us to process relevant visual stimuli while ignoring irrelevant distracters and has been extensively studied in human and non-human primate subjects. Mice have emerged as a powerful animal model for studying aspects of the visual system but have not yet been shown to exhibit visual selective attention. Differences in the organization of the visual systems of primates and mice raise the possibility that selective visual attention might not be present in mice, at least not in the forms that are well established in primates. Here, we tested for selective visual attention in mice by using three behavioral paradigms adapted from classic studies of attention. In a Posner-style cueing task, a spatial cue indicated the probable location of the relevant visual event, and we found that accuracy was higher and reaction times were shorter on validly cued trials. In a cue versus no-cue task, an informative spatial cue was provided on half the trials, and mice had higher accuracy and shorter reaction times with spatial cues and also lower detection thresholds measured from psychometric curves. In a filter task, the spatial cue indicated the location of the relevant visual event, and we found that mice could be trained to ignore irrelevant but otherwise identical visual events at uncued locations. Together, these results demonstrate that mice exhibit visual selective attention, paving the way to use classic attention paradigms in mice to study the genetic and neuronal circuit mechanisms of selective attention.

INTRODUCTION

Non-human primates are the primary animal model for studying the neuronal mechanisms of visual perception, due to their behavioral flexibility and the high degree of similarity between the organization of their visual system and that of humans. Over the past decade, mice have emerged as another valuable animal model for investigating the visual system, largely because of the unmatched arsenal of molecular and genetic tools they afford [1]. Mice can perform hundreds of trials in operant visual tasks similar to those used in primates and can generate comparable psychophysical data [2, 3]. Studies of visual function in mice can probe questions that are difficult, if not impossible, to address in primates, including how genetically defined neuronal populations in the visual system encode sensory signals [4, 5], and how these neuronal populations contribute causally to visual perception [6, 7].

Although mice have been gaining popularity to study early stages of visual processing [1], it remains unclear how useful they will be for studying higher-level aspects of vision—specifically, visual selective attention has not yet been demonstrated in mice. Visual selective attention refers to the ability to limit neural processing and behavior to the relevant subset of incoming visual signals, while actively ignoring other irrelevant and potentially distracting inputs and has been extensively studied in human and non-human primate subjects [8]. Visual selective attention has been characterized by localized changes in sensory processing in visual cortical areas that covary with behavioral changes in perceptual sensitivity, and regulated by circuits including cortical and subcortical brain regions [9]. In contrast, mice have a simpler cortical circuit organization compared to primates [10] and substantially lower spatial acuity [11–13]. The cortex of mice also seems to lack some of the frontal cortical areas implicated in the control of attention in primates; granular prefrontal cortical areas may have emerged as anthropoid specializations after the evolution of rodents and primates diverged 80–90 million years ago [14, 15]. These and other differences could mean that mice simply are not capable of the visual spatial selective attention found in primates.

In particular, the well-known benefits of spatial cues for visual perception in primates [8] have not been successfully demonstrated in mice, and there are only limited examples of cues affecting visually guided behaviors in mice overall. Mice can be trained to use visual stimuli to navigate through a virtual-reality environment [16, 17] and can also use an auditory cue in a cross-modal task to switch between making choices based on a visual versus an auditory stimulus [18, 19]. But testing whether mice can use spatial cues to control visual attention poses some specific challenges. First, task performance should be limited primarily by the ability of the mouse to extract the relevant visual signals, so that the perceptual benefits of providing spatial cues can be clearly measured. This criterion is difficult to achieve when the perceptual choice is trivial (e.g., simple on/off lights, no distracters), or when mice are freely moving, so that the retinotopic location of the stimuli is variable over time. Second, the task should distinguish cueing effects on the perceptual choice from biases in the motor response used to report the perceptual choice. If the choice is expressed by making a lateralized movement, such as orienting the body to the left