

Fine-Scale Tracking of Gaze and Behavior in Large-Billed Crows: Methods and Applications for Cognitive Research

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Introduction

Corvids have emerged as a primary example of the convergent evolution of intelligence. Tracking gaze direction is a fundamental method used to investigate cognitive abilities in human infants and non-human animals. Despite the importance of investigating cognitive features in corvids, attempts to track their fine-scale gaze movements have been challenging due to the inherent difficulty of tracking their rapid head movements and their unique visual field configuration. Therefore, the primary goal of this research is to further investigate the visual processing of crows and determine how they adjust their behavioral responses.

Methods

Head movement tracking system

To track head movements in crows, a specialized facility equipped with infrared motion capture technology was constructed. An application was developed to calculate head orientation by estimating the positions of morphological key points (e.g., eyes and beak tip) based on the coordinates of markers attached to the crow's head.

Gaze tracking

A two-step approach was employed to estimate gaze direction from head orientation. First, the visual field configuration (including eye orientation and range of movement) of our study species large-billed crows (*Corvus macrorhynchos*) was measured. Second, presentation experiments were conducted to identify which specific regions of the visual field crows preferentially orient toward objects of interest.

Validation of cognitive paradigms

Using the established gaze tracking method, the applicability of three cognitive experimental paradigms—gaze following, anticipatory looking, and the violation of expectation (VoE) method—was tested to determine if looking duration could serve as a reliable index in crows.

Flexible use of social information

The validated gaze following paradigm was applied to investigate whether crows adjust their reliance on social information based on its value. The experiments compared the crows' responses in contexts after another a demonstrator directed its gaze toward either high-value information (food) or low-value information (object).

Results

Head movement tracking system

The developed system enabled the tracking of rapid and continuous head movements in crows with high precision, achieving a rotational error of less than one degree.

Gaze tracking

The results revealed that when attending to an object, crows preferentially orient specific regions of their visual field—namely, the area around the beak tip and the optic axis of the eyes—toward the target. This established a gaze tracking method from head orientation.

Validation of cognitive paradigms

All three paradigms (gaze following, anticipatory looking, and violation of expectation) function using the gaze tracking method to some extent. Furthermore, we found the need to account for technical limitations and the specific socio-cognitive traits of crows to conduct gaze tracking experiment using this system.

Flexible use of social information

Crows demonstrated the ability to flexibly modulate their use of social information depending on the value of the provided cues. They showed a high rate of gaze following after a demonstrator showed high-value information (food) but did not follow the gaze after a demonstrator showed low-value information (object). This suggests that crows strategically utilize social information by evaluating payoffs.

Discussion

Through a series of studies, we first developed a method to accurately track the head orientation of large-billed crows using an infrared motion capture system, which was confirmed to track head orientation with an error of less than one degree. We then constructed a pipeline for tracking the crows' gaze direction by associating the head orientation with a gaze model. This revealed that crows preferentially orient specific regions of their visual field toward a visual target. We subsequently investigated the applicability of this gaze tracking method in cognitive experiments: gaze following, anticipatory looking, and the violation of expectation (VoE). The results showed that all three experiments work to some extent. Although limitations of the gaze tracking method need to be considered, this system quantified a crow's looking duration as a reliable metric. Furthermore, we examined whether crows flexibly adjust their use of social information based on the value of the information. This study found that crows exhibit gaze following behavior when the information demonstrated by a conspecific is high-value, but not when it is low-value. The gaze-tracking method developed in this study broadens the possibilities for cognitive and behavioral research in corvids, including controlled cognitive experiments to investigations of ecological significance in natural settings.