

ORIGINAL ARTICLE

Association of food location with biological cues in the macaque monkey

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(Received for publication on February 2, 2004)

Abstract. Many animal species including humans are endowed with the ability to use biological cues and can extract information by observing other individuals. This study explored whether the macaque monkey could use biological cue to find a hidden target. When the experimenter hid food in one hand and crossed and uncrossed hands quickly, the monkey had no difficulty in finding the food and correctly reached for the baited hand. However, when the food was hidden in one of two cups and the cups were shuffled, the monkey could correctly select the baited cup only at an equal level of luck. These results indicate that the macaque monkey could associate the location of food with a biological cue better than a non-biological cue and keep it in memory when the target was unseen. (Keio J Med 53 (2): 98–102, June 2004)

Key words: animate, inanimate, monkey, object permanence

Introduction

For most animal species, the visual perception of motion is a particularly crucial source of sensory input. The ability to pick out the motion of biological forms from other types of motion in the natural environment is essential to predict the actions of other individuals. An animal's survival depends on its ability to identify the movements of prey, predators, and mates, and to predict their future actions, the consequences of which differ radically and could in some cases be fatal. As social animals, humans behave largely on the basis of their interpretations of and predictions about the actions of others. The superior perception in humans of biological motion without interference from shape was first reported by Johansson.¹ He attached light sources to an actor's joints and recorded their movements in a dark environment. Naive participants, rapidly and effortlessly, recognized the moving dots as a person walking. A positron emission tomography study showed activation of the brain regions in the intraparietal sulcus and in the caudal part of the superior temporal sulcus (STS) when human subjects viewed a point light display of the act of reaching towards a glass, picking it up, and bringing it to the mouth.² Another positron emission

tomography study with human subjects examined the brain activation upon observing objects being grasped by an experimenter in an experimental condition, and observing static scenes of the experimenter holding the same objects in a control condition.³ Subtracting the activation produced by the control condition from that of the grasping condition yielded a portion of the STS region of the brain, suggesting that activation of the STS region was due to analysis of meaningful hand movement.

Macaque monkeys also have a neural system that has been implicated in the ability of the perceptual processing of the visual appearance of another individual's face and body (reviewed by).⁴ The cerebral cortex in the anterior section of the STS has neurons that respond preferentially to movements of the hand, *i.e.*, such cells respond as monkeys view an investigator making various types of hand movements.⁵ Only one neuron thus far in the STS that responds to arm movements has been found to distinguish between the movements of the left and right arms. The neuron responded to movements of the left arm to the left but did not respond to the right arm reaching in the same direction (to the left).⁶ With regard to the neural representation of the hand movements, there is another

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type of neurons called mirror neurons. Mirror neurons, found in the premotor cortex,⁷⁻⁸ and the parietal cortex,⁹ become active when the subject moves their hand or mouth and when the subject sees someone else doing the same movement. Their activities do not depend on which hand the performer has used for that action. It is not well known, however, how well the macaque monkey can take advantage of biological or animate cue and make use of them in its behavior, and whether the monkey could use the information on which hand of the performer is used. This study was thus designed to focus on these aspects.

Methods

Subject

We used a 5.7 kg male Japanese monkey (*Macaca fuscata*). He was housed in an isolation cage and was allowed water and monkey chow *ad libitum*. The Animal Care and Use Committee of Tokyo Medical and Dental University approved this study, and all husbandry and experimental procedures were in accordance with the Guidelines for Animal Experimentation at Tokyo Medical and Dental University.

Experimental setup

All experiments used for Fig. 1 were conducted in an experimental room outside of the room in which the housing cage was kept. The subject was well acclimated to the experimental room, sitting in a primate chair, and showed no hesitation to extend his arms to get food from the experimenter. We set the table to the height of the monkey's waist. An additional test was conducted in a corridor. The subject was allowed to sit on the floor until the experimenter started the test. The test was conducted as in the experimental room except that table was not used in this test. Pictures used in Fig. 2 were taken under this test condition.

Procedure

To see whether the subject could make use of a biological or animate cue better than a non-biological or inanimate cue, we used human hands as the biological cue and plastic cups as the non-biological cue. Each test session consisted of ten trials of the same condition described below. Conditions were intermingled on a session by session basis, and the order was assigned randomly. Where applicable, all choices, such as the starting and final hand, cup, or food position, and the number of times the hands were passed over each other, were pre-determined randomly.

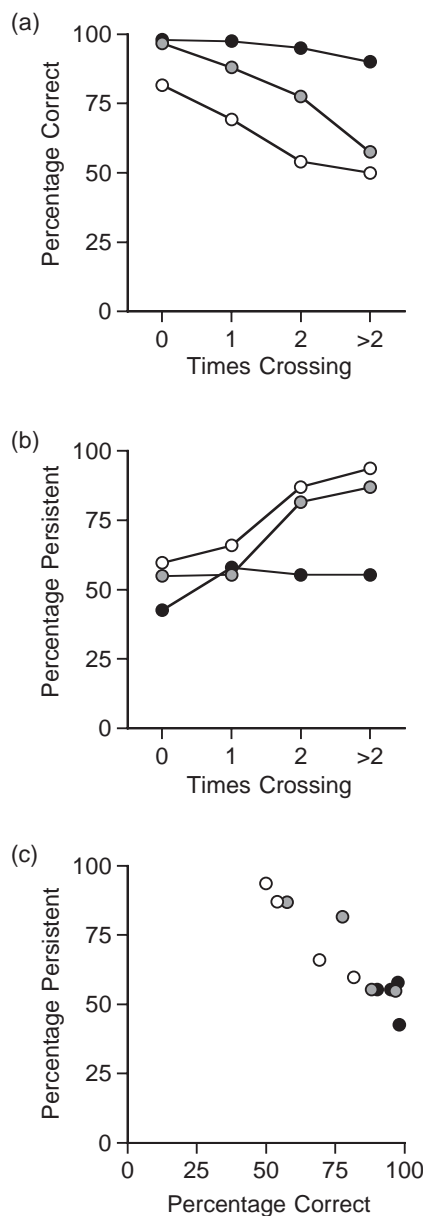


Fig. 1 Successful Use of Biological Cue. (a) The correct rate in each condition. It is higher when the food was hidden in the experimenter's hands than in the cups. (b) The percentage of the persistent trial. (c) The correlation between the correctness and the persistency. Filled circles: hands condition. Shaded circles: cups-hands condition. Open circles: cups condition.

Straight hands condition: an experimenter showed the subject both hands on one of which was placed a piece of food in the full view of the subject, closed both hands, and extended both hands toward the subject. *Hands crossed once condition:* an experimenter placed a piece of food on one hand, closed both hands, crossed arms once, and extended both hands toward the subject. *Hands crossed twice condition:* similar to the pre-

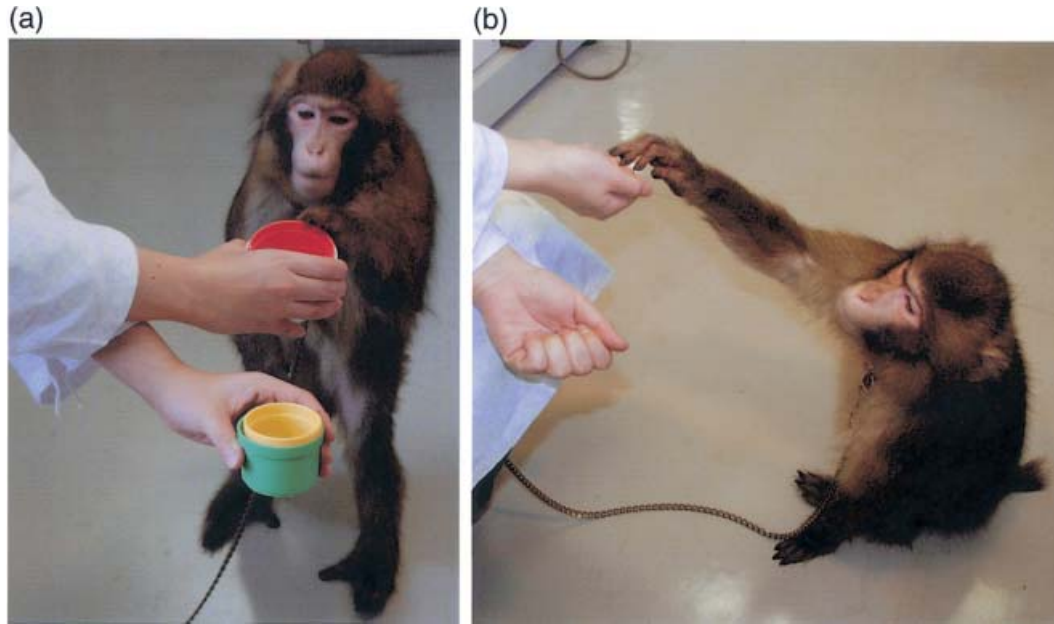


Fig. 2 Monkey's Typical Behaviour in the Choice Test. (a) Non-confident reaching after cup shuffling. After observing the shuffling of the cups, the monkey stood up and tried to look into the cups. (b) Confident reaching after hand shuffling. After observing the shuffling of the hands, the monkey reached out to the baited hand without standing.

vious condition except that the experimenter returned the crossed arms to their original location. *Shuffled hands condition*: the same as in the previous condition except that the experimenter crossed and uncrossed their arms twice or more. The final status, whether they would be crossed or not, was pre-determined randomly. In all conditions where the food was held in the experimenter's hand, the subject solved the task by correctly selecting the hand which held the food at the beginning of the trial.

Straight cups condition: an experimenter placed a piece of food on a table in the full view of the subject, placed a green cup and a red cup upside down to cover and hide the food, released cups, withdrew both hands for about 10 cm. The experimenter, then, moved the cups, each cup with one hand, toward the subject. *Cups crossed once condition*: an experimenter placed cups to hide the food on the table, moved them around to exchange their locations, released the cups, uncrossed arms, and pushed both cups toward the subject. *Cups crossed twice condition*: the same as in the previous condition except that the exchange of the cup locations was made twice. *Shuffled Cups condition*: the same as in the previous condition except that the cup locations were exchanged 3 or more times. In these conditions, the locations of the experimenter's hands when presented did not give any cue and the subject solved the task by correctly selecting the cup which covered the food at the beginning of the trial.

Straight cups-hands condition: an experimenter placed a piece of food in one of two cups that were placed on the table in the full view of the subject, picked up the cups, and moved the cups straight toward the subject. *Cups-hands crossed once condition*: the same as in the previous condition except that after picking up the cups the experimenter crossed arms and moved the crossed arms toward the subject. *Cups-hands crossed twice condition*: the same as in previous condition except that the experimenter uncrossed arms before moving the cups to the subject. *Shuffled Cups-hands condition*: the same as in the previous condition except that the experimenter crossed and uncrossed arms 3 or more time before extending them to the subject. In these conditions, the subject solved the task by correctly selecting either which hand held or which cup contained the food at the beginning of the trial.

For all shuffle conditions, the experimenter quickly moved hands and arms to prevent the subject from following the motion. The times taken to hold the food in the hand, to hide the food with the cup, and in the presentation of the hands, cups, or cups with hands were approximately matched across the corresponding conditions, *i.e.*, 1.5 sec for straight, 2 sec for crossed once, 2.5 sec for crossed twice, and 4 sec for the shuffled condition.

Analysis

The trials in which the subject did not reach out to the hands or cups were omitted from the analysis. We

calculated the persistent rate as the rate of the trials in which the subject responded to the same side as in the previous trial. We used this parameter as a measure of the subject's status, whether he would be attempting to solve or giving up the trial. Since monkeys typically respond successively to the same side regardless of the stimulus if they cannot use any cues to solve the choice task, we expect high rate of persistency under such conditions.

Results

The response in each trial did not seem to differ among the conditions. In some trials throughout all conditions, the subject looked somewhere else during the trial and did not reach out to the hands or cups, especially when the correct rate was low. In other trials, the subject kept looking at the experimenter or cups, although he did not seem to gaze at a particular target.

In all hand conditions where the food was hidden in the experimenter's hands, the monkey chose the baited hand consistently. The correct rate was higher than the equal chance level, *i.e.* 50%, even when hands were shuffled (90%, 36/40) (Fig. 1a). Consistent with the good performance, the rate of trials showing persistent response was near the chance level (Fig. 1b). In the straight-cups condition, the monkey quickly reached for the cup from the first trial, and the correct rate was 82% (49/60) that was higher than the chance level, indicating that the monkey was not afraid of the cups and that he knew that hidden food should lie under the cup placed over the food pellet at the beginning of each trial. However, the correct rate dropped as the number of the cup relocations increased: 69% (97/140) when crossed once, 54% (27/50) when crossed twice, and 50% (25/50) when shuffled. Consistent with the deterioration in performance, the persistent response increased. In cup-hand conditions, the performance was in between the hand condition and cup condition.

Across all conditions, the percentage of the persistency trial was inversely correlated with the correct rate (Fig. 1c), suggesting that the subject chose the same side as in the previous trial when he did not know which hand or cup was baited, and thus strengthens the conclusion that the monkey could correctly choose which hand was baited but could not make a correct choice when the food was hidden in the cup.

Making use of biological cues was observed also in the condition where the monkey could choose under a more natural test condition. The monkey stood up as if he were trying to see the inside of the cups in the cups condition (Fig. 2a) but remained sitting in the hand condition (Fig. 2b) and reached out for the baited hand.

Discussion

In the cups-hands conditions, the subject could solve the task by retrieving the memory of either which hand had held or which cup had contained the food in the beginning of the trial. Contrary to our expectation that the performance would be better than hands alone and cups alone conditions, it was worse than hands alone conditions. Two simple possible mechanisms are that hands hidden by the cups gave less visual information than hands alone, and that cups interfered the information of hands as a cue. Another mechanism, and one we think quite probable, is that the scene of the actor's holding food in the palm has more biological and perceptual meaning than the scene of the actor's placing food into the cup – the monkey could no longer associate the food location with the hand in the latter case, since the human and monkey neural systems are endowed with processing meaningful motion, *e.g.*, some neurons in the STS respond when the subject observes an actor's hand manipulating an object but not when observing a hand and an object moving but spatially separate.⁵

The experimenter quickly moved hands and arms in all shuffle conditions to prevent the subject from following the motion. There still is a possibility that under the shuffle conditions the subject could visually follow the motion of the hand better than that of the cup. Although we could not estimate the relative contribution of the memory and visual motion following, it could not be solely attributed to the latter factor since the performance differed between the biological hands condition and the non-biological cups condition even in the straight conditions. Thus, there must be at least some contribution from the nature of monkeys to associate the food location with the right or left hand and to keep the association in memory.

When the subject's attention was diverted somewhere else during the trial, sometimes by a momentary environmental noise, he did not typically reach out to the hands or cups. This happened throughout all conditions, suggesting that the memory of the food location with the aid of the biological cue was not retained after an external disturbance and was limited within the capacity of the working memory.

This study offers the first convincing evidence of the use of biological cues in monkeys to relate to the location of food and keep it in memory. Our monkey associated the location of the food with the experimenter's hand whether it was the right or left, and kept it in memory to solve the behavioural task. We used only one monkey in the present study, and whether the findings in our single animal could be generalized to this animal species thus remains to be examined with larger number of animals. We can however conclude at

least that the above behavioural characteristics do exist in this animal species.

Acknowledgments: This study was supported by a Grant-in-aid and by Support of Young Researchers With a Term from Ministry of Education, Culture, Sports, Science and Technology (MEXT) of Japan.

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