A METHOD FOR THE OBJECTIVE STUDY OF TOOL-USING BEHAVIOR¹

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Key pecking for food was shaped in four crows within a conventional operant-conditioning test chamber. When pecking stabilized, a metal screen with openings 2.5 cm high by 1.0 cm wide, was placed over the response key, so that the crow could still see but could no longer peck the key. At the same time, several dozen wooden matchsticks, which could be used to operate the key, were placed in the test chamber. The crows made no use of these during 50 to 75 hr of exposure to this condition. Subsequently, the behavior of two crows was shaped so that they approached the matchsticks, picked one up in their beaks, approached the response key with the matchstick in their beak, and finally operated the response key by poking the matchstick through the screen. This shaping procedure was ineffective with the two other crows. However, these birds were successfully trained through positional fading of the tool. This involved suspending a metal rod from the ceiling so that it hung directly in front of the response key, and the crow had only to peck it to operate the key. Then, the rod was gradually lowered by lengthening its tether until it eventually rested on the floor of the test chamber. The principal advantage of this methodology is the automatic recording of the terminal (tool-using) behavior under study.

Key words: tool-using behavior, shaping, crows

It has been reasoned that the development of tool-using behavior was one of the most significant events in human evolution, and until fairly recently it was believed that this type of behavior was the exclusive province of man (Alcock, 1968, 1972; Washburn, 1959). However, numerous reports within the past several decades have documented the occurrence of tool-use in nonhuman species, particularly birds (Thorpe, 1956) and primates (Menzer, Davenport, and Rogers, 1971; Washburn, 1967). To psychologists, the best-known example is the research of Kohler (1925) involving tool-use in chimpanzees, which purportedly involved the question of insight *versus* trial-and-error learning.

Definitions of tool-use typically contain two points; (1) the tool is viewed as an external object that is not part of the organism's morphology, (2) the use of the object (tool) must in some manner extend the range and/or efficiency of the organism's behavior. Some authors have argued for the inclusion of a third point, which stresses that use of the tool must occur through insight rather than trial-

and-error learning (Thorpe, 1945). This latter criterion seems difficult to sustain, since this distinction appears arbitrary and not subject to operational specification. Beyond this is the point that Thorpe himself makes in a later publication (1956)—that the origins of tool-use have not been established in the case of any wild species. This statement still holds true, so we have no basis, other than speculation, to decide how tool-use develops in a particular species.

Despite the apparent biological significance of tool-use, and the many reports of its occurrence in recent years, there has been little effort to analyze this behavior under controlled conditions. The research that provided a direct impetus for the present undertaking was reported by Jones and Kamil (1973), who observed that captive blue jays would tear pieces from newspapers under their cages and utilize the pieces to rake in food pellets that were otherwise beyond reach. The authors observed that a number of birds in their colony developed this behavior. They speculated that one bird probably acquired the behavior initially through a type of trial-and-error learning, and that other birds then acquired it through observational learning or imitation. Our primary aim was to develop a more ob-

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jective method for the study of tool-using behavior, a method in which measurement of the terminal behavior would be automated.

The common crow was chosen as the subject because, in the course of other studies with the crow, we have informally observed these birds to have high operant levels of manipulatory and investigatory behaviors. Crow and blue jays are members of the same family, the *Corvidae*.

We have found only one report of tool-use by crows in the wild. Homberg (1957), a Finnish ornithologist, observed a crow that had learned to pull in the lines of ice fishermen. The bird would first hold the line in its bill while walking backward. Then, it would walk on the line to the hole in the ice, grasp the line again, and walk backward. This continued until the fish was dragged onto the ice.

METHOD

Subjects

Training has so far been undertaken with four adult common crows (*Corvus brachyrhynchos*), which were maintained at approximately 85% of their free-feeding weights. The birds were housed in individual cages with free access to water and grit during the experiment.

Apparatus

A Lehigh Valley Electronics large-bird test chamber (model #132-06) was used. This test chamber has three response keys, but only the center key was used; the outside keys were covered. Top Choice, a processed dog food, served as the reinforcer, and reinforcement time was 2.0 sec.

Procedure

Preliminary training. Key pecking was shaped in each crow and training continued with every response being reinforced until responding was stable over three sessions. These training sessions were 1 hr in duration, so that satiation acted as the limiting factor upon responding. Then, a lattice-type metal screen was placed over the response key to prevent the crow from directly pecking the key. The critical dimensions of the screen were 7.3 cm high by 6.1 cm wide; the openings were 2.5 cm high by 1.0 cm wide.

At the same time that the screen was placed over the key, several dozen standard kitchen

matches (5.0 cm long by 0.3 cm diameter) were placed in a metal container on the floor of the test chamber. Thus, the crow could operate the response key only by picking up a matchstick and poking it through the screen. This did not occur during 50 to 75 hr of exposure to this condition, so the following procedures were employed to instate the tool-using response.

Shaping by successive approximation. This procedure was attempted with each of the four crows and was successful in two cases (C-4, C-45). It involved a succession of steps in which the crows were given food for approaching the matchstick, moving the beak toward the matchstick, touching the matchstick with the beak, grasping the matchstick in the beak and raising it off the floor, moving successively closer to the key with the matchstick in the beak, and finally poking the matchstick through the screen until the microswitch was activated. One crow that was not successfully trained through shaping (C-13) picked up the matchsticks and tossed them around the chamber; the behavior appeared to be aggressive in form. The other crow (C-14) could not be induced to grasp the matchstick in its beak.

Shaping through positional fading of the tool. The two crows whose stick-holding responses were not successfully shaped (C-13, 14) received subsequent training with a T-bar suspended from the ceiling of the test chamber, as shown in Figure 1. This was positioned so that the crow had only to strike the horizontal metal rod and propel it a distance of 0.4 cm in order to activate the response key. It was necessary to shape the behavior of both crows to get them to approach and peck at the rod. When this behavior was established, the response criterion was changed so that the crow had to grasp the rod in its beak and push it into the response key in order to receive food. After this behavior became stable, the T-bar was removed and a metal rod 7.2 cm long by 0.35 cm diameter was suspended from the ceiling by monofilament nylon. During the early sessions with this arrangement, one end of the rod was positioned so that it protruded through the screen at the start of the session. However, it rarely remained in this position long when manipulated by the animal. Thus, the crows had to aim the rod correctly, and propel it a sufficient distance in order to obtain the reinforcer. When this task was mas-

Fig. 1. A side view of the intelligence panel, showing the T-bar suspended from the ceiling of the test chamber. The small platform to the right of the screen has been used to hold matchsticks, but it was not in place during the training of the birds described here.

tered, the nylon "tether" was gradually lengthened during successive sessions in 0.5- to 1.0-cm increments until the rod eventually rested on the floor of the test chamber. Finally, the nylon was removed so that the crow had to pick the rod off the floor and use it to operate the response key. Both birds developed reliable tool-use as a result of this training.

RESULTS AND DISCUSSION

Reliable tool-using behavior was engendered in each of the four crows used. The amount of training time and asymptotic levels of performance are shown in Table 1. Acquisition of the response through positional fading of the tool required lengthy training, including several "retracings" for each crow. That is, as the tool was gradually lowered by lengthening the tether, the behavior would sometimes break down, so that the crow received no fur-

ther reinforcements. Re-instatement of effective responding was accomplished only by elevating the tool to a position considerably closer to the response key. The terminal performance of each bird was quite efficient: the number of reinforcements obtained in 1 hr was not substantially different from that ob-

Table 1

The total training time and terminal rates of reinforcement for each crow. Reinforcement rates are based upon the mean performance over five consecutive 1-hr sessions.

Subject	Training Hours		Reinforcement Rate (reinf./hr)
	Shaping	Positional Fading	
C4	9		108
C13	10	68	80
C14	10	80	74
C45	8		76

tained by crows key pecking under a continuous reinforcement schedule (Powell, 1973). The present crows typically ceased responding approximately halfway through the 1-hr sessions, as shown in Figure 2, suggesting that satiation was the factor limiting responding. Crows ingest a smaller total amount of food in a 1-hr period than do pigeons (Powell, 1973).

Once the tool-using response was established, it readily generalized to similar objects. Crows 13 and 14, which were trained with the metal rod, used matchsticks when they were made available and the rod was removed. Other objects successfully used by the crows ranged in size from standard paper clips 3.0 cm long, to wooden sticks 20.0 cm long by 0.5 cm diameter. Figure 3 shows a picture of Crow 4 using a coffee stirrer that was painted black to operate the response key.

In the course of this research, we observed that each of the four crows repeatedly used the tool as a lever to operate the response key. That is, each crow worked to wedge the tool (matchstick or metal rod) between the edge of the intelligence panel and the plastic key itself, with the tool being supported by the metal screen. When it was wedged in this position, the bird had only to peck the end of the rod in order to receive food. This was clearly more efficient than the tool-using response envisioned by the experimenters, which necessitated dropping the tool after each response in order to eat, and then picking it up to make the next response. This behavior did

not appear "accidental" because it occurred repeatedly for each crow, and in the process of wedging the tool in place, the crows would ignore presentations of reinforcers until they were successful. We eliminated this behavior in order to obtain the individual responses desired by moving the screen away from the response key. This prevented the crow from wedging the tool in place and using it as a lever.

The present research demonstrated that the acquisition and maintenance of tool-using behavior can be brought into the laboratory and studied under controlled conditions. Some of the advantages in this approach are the utilization of conventional operant-conditioning apparatus and automatic recording of the terminal behavior being studied. This work again illustrates how responses that appear to be quite complex in nature can be built up through reinforcement of very simple behavior.

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Fig. 2. A cumulative record of responding for Crow 13 during one of the final tool-using sessions. The screen was positioned so that "wedging" the tool was not possible during these sessions (see text for details).

Fig. 3. Crow 4 using a coffee stirrer, which has been painted black, to operate the response key.