

Tool-Making and Tool-Using in the Northern Blue Jay

Abstract. *Laboratory-raised Northern blue jays (Cyanocitta cristata) have been observed tearing pieces from pages of newspaper and utilizing them as tools to rake in food pellets which were otherwise out of reach. The frequency of this behavior was dependent upon the motivational state of the jay and the presence of food pellets.*

Tool utilization in animals may be defined as the use of physical objects other than the animal's own body or appendages as a means to extend the physical influence realized by the animal (1). Although it is possible that

many species can engage in such behavior, and although a number of cases of tool use by animals including birds have been reported, there are relatively few well-documented observations (2). We report one instance of tool use

which we have observed in the Northern blue jay (*Cyanocitta cristata*).

One adult blue jay raised in our laboratory colony was seen engaging in the following behavioral sequence. The jay ripped a piece of newspaper from the pages kept beneath its cage, manipulated the piece of paper, and then proceeded to thrust it back and forth between the wires of its cage, raking in food pellets too distant to be picked up directly with its beak.

This blue jay was brought into the laboratory at an estimated age of 7 to 10 days from a nest in the Amherst, Massachusetts, area 16 months before our observation of its tool use. It had been hand-raised and then maintained in a 45.7 by 45.7 by 61.0 cm wire cage that hung from the wall on pieces of 2 by 4 inch lumber; the wood made a small ledge on top of which food pellets often collected. Pages of newspaper were kept beneath the cage to catch droppings. Three different times during the 16-month interval, once for 2 weeks and twice for 5 weeks, the jay was maintained on a food-deprivation schedule that consisted of one feeding daily of a small food ration. It seems a fair conclusion that the jay somehow acquired its tool-using behavior while maintained under this combination of circumstances—a food-deprivation schedule, food pellets just out of reach on the ledge, and newspaper available under its cage. We know of no reports of tool use in the wild by blue jays (3).

After we observed the jay using a tool, we isolated it from the other jays in our colony in a cage modified by replacing the wire on one end with Plexiglas. We recorded the behavior on 16-mm film. Figure 1 shows eight photographs taken from frames of a single filmed sequence. These frames illustrate some typical components of the tool-using sequence. During filming sessions, we generally presented the blue jay with a 1.9 by 5.3 cm piece of paper. The most common response after taking the paper was to carry it to the perch and manipulate it. This manipulation could take a number of forms: (i) holding the paper between its feet and the perch and pecking at it, with the perch serving as an anvil; (ii) turning the paper a number of times by repeatedly grasping the paper in its beak and repositioning it between its feet and the perch; and (iii) holding the paper between its feet and the perch and twisting and turning it with its beak. The general results of these coordinated beak and feet manipulations was a crumpled

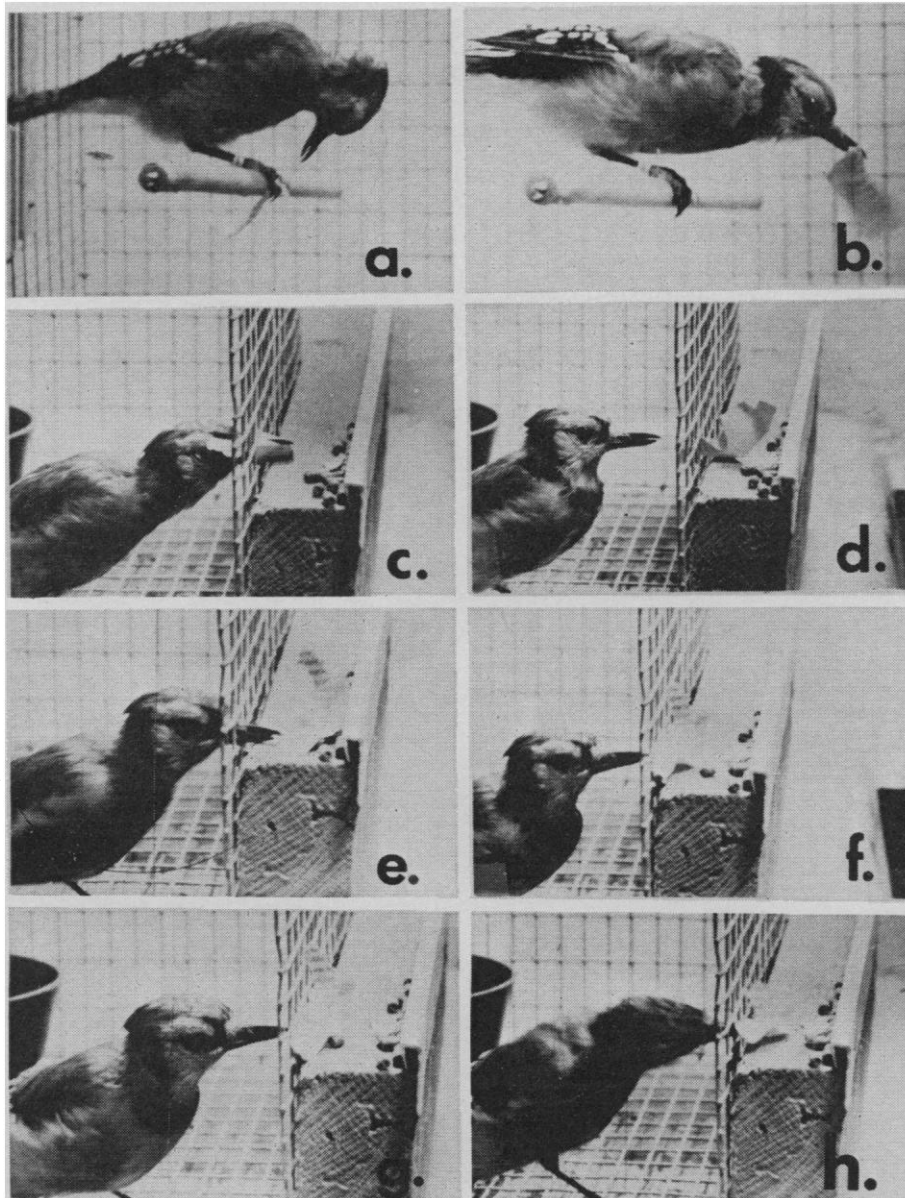


Fig. 1. Typical components of the tool-using behavior taken from a sequence filmed at 16 frames per second. (a) Frame 1. The bird is manipulating the paper on the perch. (b) Frame 13. The bird hops off the perch with paper in beak. (c) Frame 140. The paper is inserted through the wires of the cage. (d) Frame 156. The bird releases the paper and withdraws its beak. Between (d) and (e) the paper is swept from left to right with repeated grasping, moving, and releasing movements. (e) Frame 181. The paper is thrust forward and dropped on top of pellets. (f) Frame 183. The bird retracts the paper, setting a pellet in motion toward the wires of the cage. (g) Frame 189. The paper is released to rest on top of the pellet. (h) Frame 197. The bird retracts its beak after picking up the pellet, which is visible just under the edge of the paper in (g).

and irregularly shaped piece of paper. Next, the jay would sometimes place the paper in its water dish. Occasionally, especially when the interval since the last feeding had been long, these manipulatory stages were absent.

The jay would then take the paper and approach the side of the cage near the ledge and use the paper to rake in pellets we had placed there. Three patterns of this behavior were observed: (i) thrusting the paper through the wires and rapidly withdrawing it and flinging it away in a continuous motion; (ii) thrusting the paper through the wires and slowly withdrawing it, grasping it in the beak for a moment and then, in a separate discrete movement, throwing it to the floor; and (iii) thrusting the paper through the wires, releasing it and withdrawing the beak, and then thrusting and grasping the paper again. The behavior sequence illustrated in Fig. 1 exemplifies this third pattern. The blue jay positioned the paper on one side of the pellets and by repositioning its grip on the paper made successive sweeping movements of the paper to the opposite side of the pellets, thus sweeping pellets in an arc nearer a point where they could be reached with the beak from between the wires.

On different occasions we presented the blue jay with a feather, a 7.6- to 10.2-cm thistle, a piece of straw grass, a paper clip, and a plastic bag tie. In all cases the blue jay thrust the object between the wires and, except when using the thistle, was successful in raking in pellets.

In order to test whether this tool use was in fact a food-getting response influenced by food-related stimuli, we investigated the effects of food deprivation and presence of obtainable food pellets on this behavior. The blue jay was tested on six consecutive days. On days 1, 3, and 5, pellets were present on the ledge behind the cage, whereas no pellets were present on days 2, 4, or 6. Each day, the jay was observed for four 5-minute periods 2, 4, 6, and 24 hours since the last feeding. During each period, 1.9 by 5.3 cm pieces of paper were available, and frequencies were recorded for several behaviors: (i) manipulation of the paper with beak while holding the paper on the perch with the feet; (ii) actual tool use, defined as thrusting the paper between the wires of the cage near the pellets lying on the ledge; and (iii) the number of pellets obtained.

The frequency of tool use was virtually zero when pellets were not present,

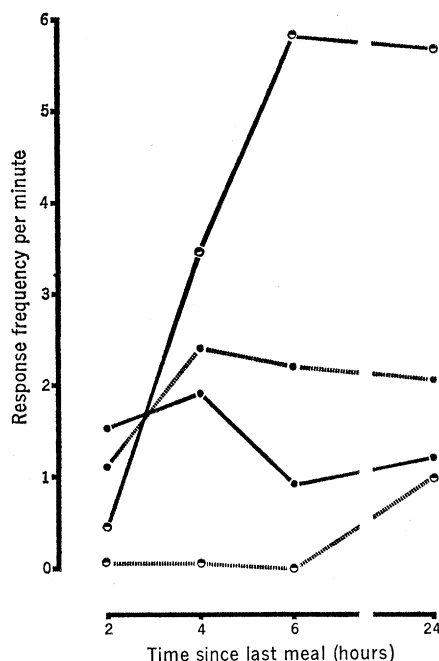


Fig. 2. The frequency of tool-using behavior as a function of time since feeding. The frequency of paper manipulation (solid circles) and of thrusting the paper between the wires of the cage (divided circles) is shown for days when pellets were present on the ledge (solid line) and for days when no pellets were present (dashed line).

and increased as a function of deprivation when they were present, reaching asymptotic levels within 6 hours of food deprivation (Fig. 2). These peak frequencies were quite high, about six per minute, and resulted in obtaining a pellet about once per minute. Some increase in frequency of tool use was also apparent under 24-hour deprivation when pellets were not present. However, of the 17 occurrences of tool use on days when pellets were absent, 14 were observed on the first such test day, 3 on the second day, and none on the third day; this suggests adaptation to the no-pellet condition. A relatively high level of manipulatory behavior was also observed, especially when pellets were not present and tool-using responses were therefore infrequent. Finally, another possible type of tool use was observed in the absence of pellets. The blue jay would occasionally take the paper, drop it in its water dish, and sweep it around the food cup, picking up food dust as if with a sponge. The jay would then either eat small pieces of dust off the paper or ingest the paper itself. This behavior was observed several times.

In an attempt to find some blue jays who had not acquired tool use in order to begin a study of acquisition of this

behavior, we tested a number of the blue jays in our colony. Of eight hand-raised birds tested, all more than 1 year of age, five showed definite tool use, two displayed some components of the behavior, and only one showed no sign of tool use at all. Even this single jay showed a high level of manipulation of the paper.

How the tool-using behavior first arose in our colony remains an important question. Although a definitive answer is not possible, we feel that the behavior was first acquired serendipitously by a single blue jay. We have often informally observed that blue jays will engage in a wide range of general exploratory behaviors, including manipulatory and probing movements, with any small object available. If, during such a sequence of apparently undirected behavior, a food pellet were accidentally obtained, this would probably result in an increase in the likelihood of repetition of the responses that immediately preceded obtaining the food pellet. These conditions would be sufficient to produce a kind of trial-and-error learning. The fact that to date we have found six jays in our colony demonstrating tool-using behavior is thought to be more likely the result of the spread of the behavior through observational learning or imitation than the result of the independent acquisition of this behavior by each of the six jays.

As Hall (1) correctly indicated, tool use in animals has received unwarranted attention because of its superficial similarity to human tool use. However, tool use is important as one of a number of indices of the type of behavioral adaptations characteristic of a species, even when observed in a laboratory setting. In the present case, it is clear that we have observed a learned behavioral sequence involving tool-making (in the tearing and alteration of paper) and tool use. This behavior is flexible with regard to the objects that can be successfully employed and has spread to a number of blue jays in our colony. Thus, the acquisition of tool use exhibited by blue jays, especially when taken together with other indices such as the performance of blue jays on learning-set tasks (4), may be indicative of a particular potential for behavioral adaptations typical of some species with highly generalized feeding behaviors, such as the Northern blue jay.

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Phanerozoic Taxonomic Diversity: A Test of Alternate Models

Although the fossil record forms our only direct evidence of the course of evolutionary and ecological history, it is notoriously incomplete (1). Many of our historical interpretations must be based on interpolations between scattered datum points; in effect we construct historical models that explain the data at hand and that are tested as new data appear. Two such models are available to describe the course of taxonomic diversity of marine biota during the Phanerozoic (2, 3). The purpose of this comment is to show that the fossil data are adequate to falsify one of them.

1) *Empirical model.* Although the processes of evolution and ecology operate chiefly on species, the fossil record of species is far too incomplete to serve as an adequate basis for the interpretation of many paleoecological patterns. Taxa in progressively higher categories, however, are represented by progressively more individuals over progressively broader geographical and temporal ranges and thus have increasingly better chances of being discovered in the record. For diversity estimation the family level is commonly employed. As diversity regulators apparently operate on species rather than directly on higher taxa, however, it is important to estimate the species diversities associated with the family data.

Figure 1 depicts the Phanerozoic diversity trends of well-skeletonized marine benthic phyla, classes, orders, and families as known from the fossil record (2); note that each category has a separate vertical scale. The diversity of taxa in increasingly lower categories is increasingly volatile. Below the phylum level, late lower Paleozoic to early middle Paleozoic diversity levels were high, but they declined in late Paleozoic to a low at the beginning of the Mesozoic. Classes have remained at this

low level, but orders increased somewhat during the Mesozoic and families underwent a great increase during the Mesozoic and Cenozoic. Genera of the best-known higher taxa that have contributed most to the post-Paleozoic rise in family diversity show an increase even more spectacular than that of the families. From such data it has been inferred that marine species diversity (Fig. 2B) rose to a mid-Paleozoic high, declined to a low at the close of the Paleozoic, and then underwent a Mesozoic-Cenozoic rise that raised species diversity by at least an order of magnitude over the early Mesozoic level (2, 4).

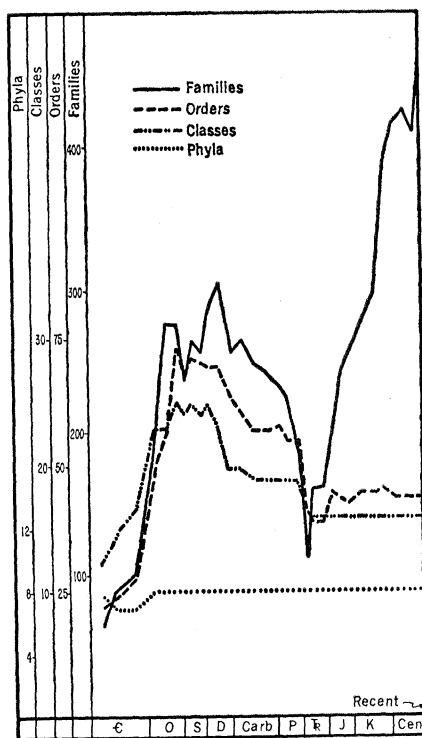


Fig. 1. Diversities of higher taxa of well-skeletonized benthic marine invertebrates as actually described from the Phanerozoic fossil record, plotted by period from Cambrian to Recent.

2) *Bias simulation model.* Our knowledge of diversity patterns and levels for living species far exceeds our knowledge of these factors for any time in the past. In general it is expected that preservation of ancient biotas would become successively poorer in successively older rocks, since the chances of destruction of fossils should increase with the time available. Raup (3) examined the main sources of bias in the fossil record in some detail, and while some of his points are arguable, it certainly seems clear that time-dependent biases do exist. Since higher taxa have a better chance of being recorded than lower taxa, higher categories should be proportionately better represented than lower ones at times when the record is poor. Therefore as the record improves through time the taxa in successively lower categories should display proportionately larger gains in diversity, even if diversities in all categories were temporally constant.

From such considerations, Raup (3) erected a model of Phanerozoic species diversity trends that is quite different from the empirical one (Fig. 2). He assumed an early species diversity maximum, presumably to correspond with the Ordovician to Devonian peaks in higher categories displayed in Fig. 1, and then a decrease to an intermediate species diversity plateau. He then employed a time-dependent bias to determine by computer simulation the diversities of genera and of species that would be registered in the fossil record. These resultant diversities rise toward the present, naturally, and the genera are proportionately better preserved than the species in progressively older rocks.

These two models imply radically different species diversity levels at certain times in the past (Fig. 2), so that if there were a way to obtain an estimate of actual diversity at one of these times it should be possible to falsify at least one of the models. In fact there is a way, and although it is indirect and does not involve actual species counting it nevertheless provides a strong test of these hypotheses.

The test revolves around our knowledge of how species diversity is accommodated in the marine biosphere at present. The regulators of diversity within habitats are still uncertain, though environmental stability is commonly considered to be a major factor. However, there is no question as to the way in which marine benthic diversity