Thomas, R.K. (2016). Intelligence, Evolution of. In H L. Miller (Ed.). *Encyclopedia of Theory in Psychology* (pp. 454-456). Thousand Oaks, CA: Sage Publications.

Introduction

Seemingly, no two investigators agree on what intelligence means or includes, but presumably all would agree that learning ability and memory are substantially involved. Most investigations of animal intelligence have used learning tasks or tasks that depended heavily on learning ability. Approaches to the study of the evolution of intelligence vary widely among investigators but two common approaches are (a) studying nonhuman primate intelligence as it might bear on human intelligence and (b) determining which species appear capable of performing tasks that were previously deemed to be uniquely human, such as, language, tool use, self-awareness, and having a "theory of mind." Little if any effort is being made to study the evolution of intelligence in a broader context. For example, there appears to be little interest in determining what might be learned by comparing representative species of fish, amphibians, reptiles, birds, and mammals, not to overlook the importance of invertebrate animals. The theoretical and methodological approach described here is one that can be applied to all animals, including humans.

The idea of a theory of evolution can be found in the writings of Anaximander (c. 610-585 BC), and a *scala naturae* wherein animals were hierarchically organized from lowest to highest and where intelligence was an important consideration as described by Aristotle (384-322 BC). However, if there is a pioneer in the modern study of the evolution of intelligence, he was George John Romanes (1848-1894). A native of Canada, Romanes lived all but the first year of his life in England. His books *Animal Intelligence* (1882), *Mental Evolution in Animals* (1883), and *Mental Evolution in Man* (1887) remain today as having provided the most systematic theoretical approach to the study of evolution of intelligence. Unfortunately, soon after Romanes's death notable psychologists including Wilhelm Wundt began to ridicule Romanes's use of anecdotal data, which were almost the only relevant data about animal intelligence available to him. It has been well documented that most of the criticism was unjustified; nevertheless, it resulted in Romanes' theoretical work never having been considered seriously by those who study the evolution of intelligence.

A Theoretical-Methodological Approach to Investigate the Evolution of Intelligence

As summarized below, there are eight fundamental types of learning that rank from lowest to highest because lower levels, generally, are prerequisites for higher levels. The principal uncertainty is whether Signal Learning at Level 2 is a prerequisite for Stimulus-Response Learning at Level 3 or whether they are parallel levels. The lowest form of learning, Habituation, has been shown to be within the capability of relatively simple invertebrates; whereas, evidence for the highest level, Concept Learning involving Biconditional Processing, has been limited to humans. Any example of learning, no matter how complex, can be analyzed in terms of these eight fundamental types. This theory of learning is inseparable from a theory of intelligence, because an animal's intelligence is determined by and limited by the highest level of learning of which it is capable. In view of this inseparability, the hierarchy to be described below will be referred to as a Learning Intelligence Hierarchy or LIH.

The Learning Intelligence Hierarchy (LIH)

Drawing from work by Robert M. Gagné and Lyle E. Bourne, Jr., I synthesized a hierarchy of learning abilities. I also proposed a methodological approach to assess those learning abilities as fairly as possible for any and all species.

The LIH is summarized as follows:

Level 1 Habituation and its complement, Sensitization,

Level 2 Signal Learning (also known as Classical Conditioning),

Level 3 Stimulus-Response Learning (also known as Operant Conditioning),

Level 4 Chaining, learning a series of units from Level 3,

Level 5 Multiple Discrimination Learning including (a) Concurrent Discrimination Learning and (b) Learning Set Formation,

Level 6 Absolute and Relative Class Concept Learning,

Level 7 Relational Concept Learning involving Conjunctive, Disjunctive, or Conditional Processing,

Level 8 Relational Concept Learning involving Biconditional Processing.

Levels 6, 7, and 8 also have applicable complementary processes. When learning a complex task, an animal might use several levels of learning ability concurrently or serially. Increasingly complex tasks can be constructed systematically using multiple levels of learning, especially at Levels 6-8, and these can be used to differentiate among the intelligence of humans. Alternatively, any complex learning task can be reduced to or analyzed in terms of the levels of learning ability involved.

Applying the LIH Fairly to All Species

Fundamental to comparing species fairly in any learning experiment is that confounding contextual variables (e.g., sensory, effector, motivational, and environmental differences) that might influence *performance* and obscure learning ability must be neutralized to the extent possible. Species' sensory and motor differences must be taken into account, and motivational incentives appropriate for each species must be used. Environmental variables such as illumination, temperature, humidity, etc. must be rendered optimal for each species. In brief, the emphasis is on the level of learning to be assessed, and the task used to assess it must be adapted optimally for each species.

Quantitative performance differences should not be used to compare species. If an animal can master a task representative of a given level in the LIH, it should not matter how many trials were required or how many errors were made; quantitative differences might be due to shortcomings in achieving fairness in testing conditions. On the other hand, for example, if the contextual variables are the same for tasks at two levels, for example, Level 5 Learning Set Formation versus Level 6 Class Concept Learning, and success at the lower level is followed by failure at the higher level, it is reasonable to attribute that failure to learning ability at Level 6 and not to the contextual variables.

It has been shown that fish, reptiles, birds and mammals (amphibians were not tested) are capable of some success at Level 5 on Concurrent Discrimination Learning tasks. It seems reasonable to conclude that had amphibians been tested, they would have shown some success at Level 5. Thus, all vertebrates appear to be capable of some success at Level 5, although which species may or may not be able to form learning sets has not been determined. Comparing the intelligence of species that fail to succeed at Level 6 can be based on the *number* of Concurrent Discrimination problems (Level 5) the animal can learn or whether it can or cannot form learning sets. The LIH can be applied to invertebrates as well. No matter at what level of the LIH a species can succeed, its intelligence will be limited to what it can accomplish with its learning abilities up to and including that level.

It appears that differentiation among birds and mammals on learning ability and intelligence will be determined by the degree to which they can learn to use concepts. To demonstrate an animal's use of a concept, it must succeed on trial-unique or first-trial presentations of the discriminanda that embody the concept; correct responses to subsequent presentations of the discriminanda are subject to being explained as rote learning. "Discriminanda" is a better term to use than "objects" or "stimuli," because objects have many discriminable properties such as color, shape, size, weight, texture, etc., and one may not know which properties served as the discriminable stimulus or stimuli for a particular species or individual animal. Additionally, discriminanda may not be in the form of objects; rather, they may be sounds, odors, flavors, or discriminanda associated with other sensory modalities.

Absolute class concept learning involves discriminanda whose inherent features manifest the concept. For example, the properties enabling the concept of "bird" are embodied in each bird although individual species of birds may differ widely. In absolute class concept learning, the possibility of stimulus generalization must be minimized if not eliminated. For example, two discriminanda which are perceptually distinguishable may appear so similar to the animal that it may fail to discriminate one from the other. Stimulus generalization is a complicated issue that requires greater consideration than can be given here.

Stimulus generalization is not an issue in relative class concept learning, as the discriminanda which manifest the concept involve a relative property such as oddity. The most used relative class concept task with nonhuman animals has been the oddity task. Typically the animal is presented with three discriminanda, two identical (or highly similar) and one distinctly different; the latter manifests the oddity concept. On later trials, a discriminandum that was odd at one time may now be one of the nonodd discriminanda; hence, the animal cannot rely on inherent properties of the discriminanda but must rely on their relative properties.

Relational Concepts are concepts that include one or more class concepts being used in conjunctive, disjunctive, or conditional relationships (Level 7) or biconditional relationships (Level 8). Although relatively few studies have been conducted that meet the trial-unique (or first trials only) testing requirement, those which have been done generally indicate that at least some avian, perhaps all, and likely most if not all mammalian species are capable of learning absolute class concepts. Although relatively few investigators have acknowledged the LIH, fortunately it can be applied retroactively to determine how any learning task used in the past fits within it.

The findings are not as clear for relative class concept learning, but among nonhuman animals the more convincing studies have been done using primates. The best-controlled examples of relational concept learning using animals have confounded conjunctive with conditional processing. Nevertheless Level 7 learning has been shown in some nonhuman animals. To be best of my knowledge, no one has designed a conclusive test of conditional or biconditional processing that can be used with nonhuman animals.

The Evolution of the Brain and Intelligence

A potentially important use of the LIH is in correlational studies with indices of brain evolution. Perhaps the best known contemporary index of brain evolution is Harry Jerison's "encephalization quotient" or EQ. It is an empirically-determined measure of how much brain an animal has compared to members of an appropriate comparison group with the same body size. For example, compared to the average mammal having an average human's body weight, humans have an EQ of about 7.56 which suggests that humans have 7.56 times as much brain as needed to function as a mammal of that size. However, the EQ may have flaws. For example, according to Jerison, a *Cebus albifrons* monkey had an EQ of 4.79 and a squirrel monkey an EQ of 2.81, but four chimpanzees' EQs ranged between 1.63 and 2.48. Few would agree that squirrel monkeys and Cebus monkeys are more intelligent than chimpanzees; however, that is an empirical question that has yet to be investigated fully.

Finally and unfortunately for the LIH, Jerison endorsed Euan Macphail's view that the fundamentals of learning are similar in all vertebrate species that have been studied. Macphail identified four types of learning: Habituation, Classical Conditioning, Operant Conditioning, and Complex Learning. Had he considered the LIH which was available to him, Macphail might have understood that "complex learning" reduces to components of levels 4-8 as described here and that it is highly unlikely that all vertebrate species are equally capable of learning at the higher levels.

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See also Classical Conditioning, Cognitive Evolution, Evolutionary Psychology. Intelligence Testing, Measurement of Intelligence, Operant Conditioning, Problem Solving

Recommended Readings

Bourne, L. E., Jr. (1970). Knowing and using concepts. *Psychological Review, 77*, 546-556.

Reznikova, Z. (2007). *Animal intelligence: From individual to social cognition.* Cambridge, UK: Cambridge University Press.

Sternberg, R. J. & Kaufman, J. C. (Eds.). (2012). *The evolution of intelligence*. New York, NY: Psychology Press.\

Thomas, R. K. (2012a). Learning set formation and conceptualization. In Norbert Seel (Ed.) *Encyclopedia of the sciences of learning*: Part 12 (pp. 1966-1968). New York, NY: Springer-Verlag.

Thomas, R. K. (2012b). Conditional reasoning by nonhuman animals. In Norbert Seel (Ed.) *Encyclopedia of the sciences of learning: Part 3* (pp. 742-745). New York, NY: Springer-Verlag.