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Evolution of Intelligence: an Approach to Its Assessment

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Abstract. The goal was to suggest a meaningful approach to the assessment of intelligence which may be used, for example, in correlational studies with measures of encephalization. Suggesting, as others have done, that species comparisons based on quantitative differences inherently confound intellective with nonintellective abilities, the present approach described a hierarchy of 8 basic levels of qualitatively different intellective (learning) abilities. The levels range from habituation to complex concepts. Practical procedures and strategies which increase the precision of the scale were described.

This paper describes an approach to the comparative assessment of intelligence which results in a numerical index that meaningfully reflects an animal's general intelligence. Such an index might be correlated with brain indices to address questions about the evolution of the brain and intelligence. Useful brain indices have been proposed [e.g., *Jerison,* 1973, 1977; *Passingham,* 1975; *Riddell and Corl,* 1977], but behavioral measures currently in use are too limited or have questionable validity as indices of intelligence.

Intelligence: What Is It?

Intelligence is a hypothetical entity which does not exist as something which occupies space or which has isomorphic physical and chemical correlates. It is an entity the existence of which may only be inferred from an animal's responses to its enviroment. Strictly speaking, it is accepted that such an entity cannot be considered apart from an animal's 'biological equipment' and that any apparent dichotomy between intellective and nonintellective aspects (e.g., sensory, motor, motivational, etc.) of behavior will be a false one. However, there is an aspect of intelligence which is relatively independent of the sensory, motor, motivational, etc. aspects of behavior. This relatively independent aspect of intelligence is related to how an animal 'knows' and responds to its environment. In some species, apparently most of this aspect of intelligence is inherent. In others, apparently most of it is learned. It is the learning aspect of intelligence which is central to the present paper.

The relationship between learning ability and intelligence is widely accepted. For example, students of human intelligence such as *Zeaman and House* [1967] have observed that questions about the relationship between learning and intelligence are not concerned with the existence of a relationship but whether mental age, the intelligence quotient or both should be related to learning. *Zeaman and House* [p. 192] also noted one view, apparently widely held, which suggests that the mental age to chronological age ratio represents 'the slope of a life-time learning curve, characteristic of the organism and recoverable in new miniature learning situations' and that the intelligence quotient 'is the measure of present learning ability'.

Students of intelligence in nonhuman animals who have explicitly related learning abilities to intelligence (or some synonomous term such as 'higher mental functions' or 'higher nervous activity') include: *Bitterman* [1965]; *Corning et al.* [1976]; *Harlow* [1958]; *Hayes and Nissen* [1971]; *Jolly* [1972]; *Masterton and Skeen* [1972]; *Passingham* [1975]; *Razran* [1971]; *Rumbaugh and Gill* [1974]; *Viaud* [1960]. These and other references to be cited will attest that the measurement of intelligence in animals has usually been regarded to be synonomous with the measurement of learning ability.

Previous attempts to provide learning skills data which reflect comparative intelligence may be divided into those which emphasize *quantitative* differences and those which emphasize *qualitative* differences in performance. To be discussed in the next section, it may be impossible to provide valid assessments of species differences in intelligence which are based on quantitative differences. The principal problem associated with species comparisons of intelligence based on qualitative differences is one of being able to order those differences along a meaningful axis. The present work solves this problem by describing a meaningful *hierarchy* of qualitatively different learning (intellective) skills which is applicable to all species.

Quantitative versus Qualitative Measures of Learning (Intelligence)

The problems associated with the quantitative differences approach have been discussed previously [e.g., *Bitterman,* 1960, 1965; *Dewsbury,* 1978; *Hodos,* 1970; *Nissen,* 1951; *Warren,* 1974]. Specifically, the quantitative differences in performance which result from intellective differences and those which result from such 'nonintellective' differences as sensory, response-effector, motivational and other species differences are confounded. One species might not perform as well as another owing, for example, to sensory or motor disadvantage rather than any fundamental difference in intellective capacity for a given task.

Regarding a species' intellective ability to perform a particular task, it would seem to be more important to know whether it can perform the task successfully when conditions are suited to it. Quantitative differences in performance among species which are able to perform a task successfully may only reflect inequities in the 'nonintellective' conditions of the task. Establishing *suitable* testing conditions for a species should be relatively easy, but establishing *equitable* conditions, given all the possible interactions which might occur among the 'nonintellective' factors, might be impossible to achieve.

The assessment of qualitative differences among species has also been discussed previously. For example, *Bitterman* [1965] argued for this approach, and *Warren* [1965, 1974] searched for those abilities which distinguished primates from nonprimates. *Bitterman* [1965] reported qualitative differences among species (a) with respect to whether they showed progressive improvement in the performance of spatial and visual discrimination reversal learning and (b) with respect to differences in the kinds of strategies used to perform probability learning tasks. *Warren* [1974] observed that primates appeared to differ from nonprimates in their abilities to (a) generalize from the double alternation sequence, (b) develop and generalize transituationally valid response rules from one type of task to another, and (c) suppress transfer from one task to another when such suppression was appropriate. While the value of being able to identify such qualitative differences in learning is recognized, nevertheless the identification of them is of limited use. For example, there is no obvious relationship among these qualitative differences, that is, there is no apparent axis or dimension on which to compare them. Additionally, apparently none of the five examples cited could be used to distinguish among the primates.

A Hierarchy of Intellective (Learning) Abilities

Before describing the hierarchy in its present form, it should first be noted that although its merit will (it is hoped) be obvious and although the hierarchy is sufficiently developed to be immediately useful, nevertheless it must be regarded as a first approximation. There are unanswered (but relatively minor for present purposes) theoretical questions and there are insufficient data regarding certain empirical questions to permit the presentation of a fully developed hierarchy at this time. These questions will be acknowledged in their appropriate contexts during the presentation which follows.

Additionally, it may be noted that the hierarchy is sufficiently basic to permit all previous learning data to be reinterpreted, where necessary, to reflect the status of those data with regard to levels in the hierarchy. Furthermore, it is suggested that there is no *conceivable* learning measure which cannot be analyzed in terms of the basic features of the hierarchy.

Gagné's Learning Hierarchy

The starting point for the proposed hierarchy is the hierarchy of 8 learning types suggested by *Gagné* [e.g., 1970]. *Gagné*'s assumption that each type (with, as he noted, the possible exception of type 1 for type 2) is prerequisite to the next higher type is accepted. Whether type 1 (Signal Learning) is prerequisite to type 2 (Stimulus-Response Learning) is one of the unresolved questions noted earlier; for most species comparisons of interest (namely, among the vertebrates) this may make little difference, since as *Warren* [1965, p. 251] suggested, 'there is no systematic variation in capacity for simple classical or operant conditioning among the vertebrate species studied thus far'. The reader is referred to *Gagné* [e.g., 1970] for further explication of his hierarchy. The hierarchy proposed here uses only his types 1, 2, 3, and 5. Definitions for these types, from *Gagné,* will be provided in the following section.

A Hierarchy of Intellective Abilities

The hierarchy proposed here is summarized in table I. Table I includes one minor and two major departures from *Gagné*'s [1970] hierarchy of learning types. The omission of his type 4, Verbal Associations, is regarded as a minor change, because *Gagné* considered it to be parallel and functionally equivalent to type 3, Chaining. Verbal Associations is omitted, because it applies only to humans and, in some analogous form perhaps, a few chimpanzees.

The major changes are the addition of Habituation and the substitution of the hierarchy of logical operations (levels 6–8 in table I) for *Gagné*'s types 6–8. The addition of Habituation acknowledges it as a form of learning [e.g., see *Corning et al.,* 1976; *McConnell and Jacobson,* 1973; *Thompson and Spencer,* 1966] which may be within the capacity of some species for which conclusive demonstrations of other kinds of learning have yet to be shown. However, whether Habituation should be placed at the bottom of the hierarchy is an unresolved question; thus its placement there should only be considered tentative.

Using the basic logical operations to define the structures of concepts is well precedented in research on human concept learning [e.g., *Bourne,* 1970; *Haygood and Bourne,* 1965; *Millward,* 1971], and the practicality of using this approach with nonhuman animals has been demonstrated [*Thomas and Crosby,* 1977; *Thomas and Ingram,* 1979]. That the logical operations are hierarchically related is based on *Millward*'s [1971] organization of them (which he denoted as levels I, II, and III) based largely on *Neisser and Weene*'s [1962] observation that the higher levels are defined in terms of the lower levels. Empirically, however, *Bourne* [1970] has suggested a slightly different order, namely (read $<$ as denoting mean fewer trials to criterion) conjunction $<$ disjunction $<$ conditional $<$ biconditional, although the difference between conjunctive and disjunctive concept learning was not statistically significant. The generality of this order must await additional experimental confirmation. Meanwhile the order shown in table I which is based on higher levels being defined in terms of lower levels will be used.

The substitution of the hierarchy of logical operations for *Gagné*'s learning types 6–8 is justified as follows. (a) There is considerable overlap between *Gagné*'s description of Concept Learning (his type 6) and the kinds of concept learning described here as Affirmative Concepts. Yet the distinction here including the differentiation of Absolute and Relative Class (Affirmative) Concepts avoids some uncertainties raised by some of *Gagné*'s terminology (e.g., 'concrete' versus 'abstract' concepts together with some of his examples, such as, 'oddity' which he described as concrete). (b) *Gagné*'s explication of Rule Learning (type 7) and Problem Solving (type 8) depended upon examples intended for humans and for archy of learning types. The omission of his type 4, Verbal Associations, is regarded as a minor change, because *Gagné* considered it to be parallel and functionally equivalent to type 3, Chaining. Verbal Associations is omitted, because it applies only to humans and, in some analogous form perhaps, a few chimpanzees.

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At this point it is useful to define the abilities summarized in table I and to indicate sources of literature relevant to them.

Level 1: Habituation. Habituation is usually defined as a *decrement* in responding which is seen to a stimulus upon its repeated presentation. However, as *Thompson and Spencer* [1966] noted, the process involved must be distinguished from processes such as receptor adaptation or

Table I. A hierarchy of intellective (learning) abilities

	level 8:	Biconditional Concepts[1]
Relational concepts		
		Conditional Concepts[1]
	level 7:	Conjunctive Concepts[1]
		Disjunctive Concepts[1]
Class Concepts	level 6:	Affirmative Concepts[1]
		Absolute / Relative
	level 5:	Concurrent Discriminations
	level 4:	Chaining
	level 3:	Stimulus-Response Learning
	level 2:	Signal Learning
	level 1:	Habituation

[1] The complements of these logical operations apply also at their corresponding levels (namely, affirmation/negation, disjunction/joint denial, conjunction/alternative denial, conditional/exclusion, and biconditional/exclusive disjunction [*Millward,* 1971, p. 940] and appropriate tests of the complements might be used. However, the complements are excluded from further consideration in the present work.

effector fatigue which might also account for response decrements. *Thompson and Spencer* identified nine parametric characteristics of habituation which might be used as operational criteria to define it.

Level 2: Signal Learning. Gagné [1970, p. 63] defined signal learning as follows. 'The individual learns to make a general, diffuse response to a signal. This is the classical conditioned response of Pavlov (1972).' Most learning texts in psychology consider classical conditioning and provide pertinent references. A useful text for its comparisons of classical conditioning and instrumental learning (see Level 3) is *Kimble*'s [1961].

Level 3: Stimulus-Response Learning. 'The learner acquires a precise response to a discriminated stimulus. What is learned is a connection (Thorndike, 1898) or a discriminated operant (Skinner, 1938), sometimes called an instrumental response' [*Gagné,* 1970, p. 63]. Useful sources pertinent to this and level 4 are *Honig* [1966] and *Honig and Staddon* [1977].

Level 4: Chaining. 'What is acquired is a chain of two or more stimulus response connections' [*Gagné,* 1970, p. 63].

Level 5: Discrimination Learning. 'The individual learns to make *n* different identifying responses to as many different stimuli, which may resemble each other to a greater or lesser degree. Although the learning of each stimulus-response connection is a simple type 2 occurrence, the connections tend to interfere with each other's retention (Postman, 1961)' [*Gagné,* 1970, p. 63; *Gagné*'s type 2 in the quotation refers to level 3 here]. Another way to state this definition might be that discrimination learning refers to an animal's ability to perform multiple, concurrently learned discriminations. *Rensch* [1967] has reported multiple, concurrent pattern discrimination learning by fish, reptiles, birds and mammals.

Conceptual Behavior. Before proceeding to levels 6–8, a brief, general discussion of conceptual behavior will be useful. It will be appropriate first to provide a definition of conceptual behavior in an operational framework which is applicable to all animals. 'Conceptual behavior ... refers to selective responses to stimuli which are consistently correct in terms of predetermined and discoverable reinforcement contingencies but which do not depend upon prior experience with the specific stimuli presented on a given trial' [*Thomas and Kerr,* 1976, p. 335]. This definition distinguishes clearly between those experiments which may be regarded as having provided evidence for conceptual behavior and those experiments which should not be so regarded. Namely, it must not be possible for an animal to use specific cues which result from the specific properties of the stimuli or from the specific patterns formed by the stimuli. Many experiments have been reported as having demonstrated conceptual behavior in nonhuman animals which have failed to control against the animal's use of such specific (as opposed to conceptual) cues. The best that one may say about such experiments is that they are inconclusive. When a reader evaluates a claim of conceptual behavior in an animal, the first thing to be determined is whether the possibility existed or was likely that the animal may have used available specific cues.

Level 6: Affirmative or Class Concepts. Affirmative or Class Concepts involve only the logical operation, affirmation, or its complement negation. The synonym Class Concepts is used to distinguish concepts involving affirmation from concepts involving the *explicitly relational* logical operations seen at levels 7 and 8. In the present work, affirmation is restricted to those conceptual entities which may be affirmed by the senses. Typically here, the discussion will be in terms of visually detectable stimuli, although stimulus classes involving other sense modalities are appropriate (e.g., the acoustic class 'noise' versus the acoustic class 'pure tone').

Operationally, there are two kinds of class concepts, those for which the distinguishing feature is inherent in the stimulus and those for which the distinguishing feature is a relative one which may be affirmed only by comparing stimulus choices. The former are designated *absolute class concepts* and the latter are designated *relative class concepts.* Their operational distinction is that it is *not* necessary to compare stimulus choices in order to affirm an instance of an absolute class concept, but it *is* necessary to compare stimulus choices in order to affirm an instance of a relative class concept. The operational distinction says nothing about what an animal *might* do but what is or is not *necessary* for the animal to do.

Absolute class concepts may be based on a single dimension, such as color, form, size, or number. In these cases, potential cues from the irrelevant dimensions must be held constant or rendered ambiguous. As shown in table II, there are examples in the literature which correspond to color, form and number.

Alternatively, absolute class concepts might be based on multiple dimensions. For example, red-triangular objects of a particular size, say

Table II. Examples of animals' performances of class concepts

Absolute class concepts	Relative class concepts
Single-dimension concepts	
Color (red, blue): *Weinstein,* 1945	Relative color: *Bernstein,* 1961[1] *Strong et al.,* 1968[1]
Form (triangularity): *Andrew and Harlow,* 1948	Relative form: *Bernstein,* 1961 *Strong et al.,* 1968
Size (no known conclusive example: *Klüver,* 1933 (possibly)	Relative size: *Bernstein,* 1961 *Strong et al.,* 1968 *Thomas and Ingram,* 1979
Number (threeness): *Hicks,* 1956	Relative Number: *Dooley and Gill,* 1977
Multi-dimension concepts	
«People»: *Herrnstein and Loveland,* 1964 «Pigeon»: *Poole and Lander,* 1971 «Man-made» vs. «No man-made» objects: *Lubow,* 1974 «Tree», «Water,» «A person»: *Herrnstein et al.,* 1976 The letter «A»: *Morgan et al.,* 1976	Oddity:[2] *Levine and Harlow,* 1959 *Strong and Hedges,* 1966 *Thomas and Boyd,* 1973 Sameness-difference:[2] *Robinson,* 1955, 1960 *King,* 1973 *King and Fobes,* 1975 *Smith et al.,* 1975

[1] These authors investigated the abilities of apes and monkeys to perform 'dimension-abstracted oddity' where color, form or size might be the relevant oddity cue on a particular trial.
[2] Oddity and sameness-difference are appropriate examples in those experiments where the relevant cue might be determined by more than one or combinations of dimensions.

10 cm^2, might be conceptualized by a subject as a stimulus which could be designated as a member of the class, 'red-10 cm^2 – triangles', that is, the subject might cue on the combination of dimensions rather than any of the single dimensions. This discussion is significant, because it provides a means of classifying such concepts affirmed by pigeons as 'tree', 'water', and 'a person' [*Herrnstein et al.,* 1976]; see related examples in table II. Stated differently, the class 'tree' is comprised of stimulus 'com-

pounds' which are comprised of single-dimension 'elements'. That such compounds may have stimulus properties which are independent of their elements is suggested by the work of *Rescorla* [1973]. That no single element may be essential to the recognition of a compound is suggested by the work of *Morgan et al.* [1976]. For further discussion of this line of reasoning, see *Thomas and Crosby* [1977].

Relative class concepts *require* the subject to compare stimulus choices before it affirms the example of the concept. The well-known 'oddity' problem, when properly constructed, is an example of a relative class concept. Any of the *single dimensions* of color, form, size, and number may be rendered relative class concepts when they provide the relevant cue (the others being held constant or rendered ambiguous) in the 'dimension-abstracted oddity' task [*Bernstein,* 1961]. Size (e.g., 'large' or 'small') and number (e.g., 'more' or 'fewer') may be presented as relative class concepts independently of dimension-abstracted oddity. Table II cites examples of relative class concepts.

It might be pertinent to note that, apparently, there are no conclusive studies of a nonprimate animal's having performed a relative class concept. There have been numerous reports of nonprimate animals performing the oddity problem [e.g., *Wodinsky and Bitterman*'s rats, 1953; *Pastore*'s canaries, 1954, 1955; *Warren*'s cat, 1960]; however, these studies are inconclusive on the grounds noted earlier, namely that it was possible (though, perhaps, unlikely) that the animals used specific as opposed to conceptual cues. It is not suggested, however, that nonprimate animals are incapable of performing relative class concepts but that no studies have been conducted with nonprimate animals which used conclusive experimental designs.

Level 7: Conjunctive, Disjunctive, and Conditional Concepts. Concepts here and at level 8 involve logical operations which determine relationships among affirmative concepts or affirmative concepts and nonconceptual stimuli. Apparently, only *Wells and Defenbacher*'s [1967] study has used animals and considered conjunctive and disjunctive concepts. However, that study is inconclusive, because their squirrel monkeys might have learned the *specific* stimuli which were associated with reinforcement. Conditional concepts (e.g.: *if* A, *then* B where A, B, or both are affirmative concepts) have been demonstrated in monkeys [e.g., *Riopelle and Copelan,* 1954; *Thomas and Kerr,* 1976] and apes [e.g., *Premack,* 1976; *Rumbaugh,* 1976]. *Thomas and Ingram* [1979] demonstrated the squirrel monkey's ability to perform three conditionals concurrently.

To illustrate practical designs for assessing conjunctive and disjunctive concepts the following affirmative concepts are used. (a) 'Curvilinear' which may be presented as stimuli which have only curvilinear borders will be symbolized here as 'C'. (b) 'Linear' which may be presented as stimuli which have only linear borders will be symbolized here as 'L'. (c) 'Same' which may be presented as two adjacent identical stimuli will be symbolized by lower case letters such as 'aa'. (d) 'Different' which may be presented as two adjacent nonidentical stimuli will be symbolized by lower case letters such as 'cd'.

The conjunctive may be tested simply by presenting, in random positions, examples of three of the aforementioned concepts on each trial. If, for example, the conjunctive 'linear *and* different' was correct and the animal was shown ...

aa L cd

..., it would be reinforced only for responding to both 'L' *and* 'cd'. It is necessary to include examples of the concepts 'same' and 'curvilinear' to provide the animal with meaningful response alternatives.

The disjunctive (e.g., 'L *or* cd') could not be tested as simply, because the animal might respond to the two concepts independently and there would be no means of establishing its awareness of the disjunctive relationship between them. A suggested solution is to combine the disjunctive and conjunctive with conditionals.

For example, *if* the stimuli are presented on a white background, *then* 'L *and* cd' is correct, but *if* they are presented on a black background, *then* 'L *or* cd' is correct. By responding conditionally and differentially to the same affirmative concepts, the animal would appear to show its awareness of the distinction between conjunctive and disjunctive relationships. In the final stages of training at least, the order of presentation of the conjunctive and disjunctive conditions should be random. To preclude an animal's fixation on one of the affirmative concepts, one-third of the trials in the disjunctive condition should omit the 'L' stimulus, one-third should omit the 'different' stimulus, but the remaining one-third should include both.

Level 8: Biconditional Concepts. The biconditional is usually expressed 'A *if and only if* B' and involves two conditionals; *if* A, *then* B and *if* B, *then* A. To be a conceptual biconditional A, B, or both must involve class concepts. Apparently, there has been no attempt to determine whether animals can perform biconditional concepts. A problem is to be able to argue that the animal had not merely learned the two conditionals independently and that it was aware of their biconditional relationship. The following design should be suitable to demonstrate the use of biconditional concepts.

The example will be in terms of the 'linear', 'curvilinear', 'same', and 'different' concepts described in the preceding section and symbolized, respectively, 'L', 'C', and lower case letters such as 'aa' and 'cd'. The animal will be trained on a master panel consisting of nine smaller stimulus panels in a 3 × 3 matrix. A trial will consist of a two-step presentation of stimuli; the animal must respond correctly to both steps. In the present example the animal performs two biconditionals concurrently, namely, 'same if and only if linear' and 'different if and only if curvilinear'. The animal will have been trained to take its initial cue from the center panel. A typical first step of a trial in the final phase of training might be ...

Blank Panel	Blank Panel	Blank Panel
aa	L	cd
Blank Panel	Blank Panel	Blank Panel

..., and it would be reinforced for responding to 'aa'. If correct, immediately upon responding, the stimuli will change to ...

L	ee	C
Blank	Blank	Blank
C	fg	L

..., and reinforcement will follow a response to 'L' in the top row. Correct responding should suggest that the animal was aware of the biconditional relationships between the stimuli in steps 1 and 2. It is necessary to have two biconditionals in this case to provide meaningful response alternatives. Stimuli should be changed on every step. Which of the four class concepts appears initially in the center panel as well as the top-bottom and left-right position alternatives should be determined randomly.

Increasing the Precision of the Hierarchy

To this point, it is possible only to assign whole numbers from 1 to 8 to indicate an animal's index of intelligence. As noted earlier, fish, reptiles, birds, and mammals (amphibia were not tested) have performed successfully on tasks which represent level 5 [*Rensch,* 1967]. The available data suggest that New World monkeys (e.g., squirrel), Old World monkeys (e.g., rhesus), and apes (e.g., chimpanzee) have performed successfully at level 7. It is reasonable to believe that these primates, like humans, will also perform successfully at level 8. Therefore, it is desirable to consider ways to increase the precision of the scale of measurement.

Levels 1–3. For now it is not considered to be meaningful to increase the precision of measurement at levels 1–3. That an animal may be capable of more than one type of habituation, signal learning, or stimulus-response learning might only reflect the diversity of its sensory and motor structures rather than the degree or flexibility of its intellect. However, it is meaningful to increase the precision of measurement at higher levels.

Levels 4 and 5: Chaining and Discrimination Learning. Chaining is concerned with the number of stimulus-response (S-R) units an animal can perform successively, and Discrimination Learning is concerned with the number of S-R units an animal can perform concurrently. The number of S-R units that an animal can learn under either condition might reflect its intellective ability. It should be emphasized, however, that one would not be concerned with the number of S-R units an animal can chain (level 4) if it is capable of learning two or more units concurrently (level 5). An animal which can perform at level 5 presumably has greater intellective ability than an animal which cannot perform at level 5 even though the latter might learn relatively long chains of S-R units.

Thus, for animals which are compared at level 4 because they appear to be incapable of performing at level 5 or, comparably, for animals which are compared at level 5 because they appear to be incapable of level 6, the number of S-R units is relevant. The indices for such animals may be expressed in terms of the appropriate decimal increment. For example, if three species were able to chain 8, 12, and 21 S-R units, respectively, their comparative intellective indices would be 4.08, 4.12, and 4.21. If a fourth species were tested and found to be able to chain in excess of 100, or say 108, the scores would have to be redesignated as 4.008, 4.012, 4.021, and 4.108. Similar scoring would apply for species which are compared at level 5. Despite the precision which may be implied by such decimal numbers, nothing more than ordinal measurement is intended, and the use of such numbers should be limited to the appropriate statistical measures [*Stevens,* 1968].

Level 6: Affirmative or Class Concepts. Using logical criteria there is more than one way to increase the precision of measurement at this level.

The burden will be on the investigator who compares species to be consistent in the way pecision is increased. A score of 6.3 determined via one approach night not be equivalent to a score of 6.3 determined via another approach. It must be noted also that empirical results may not always reflect logical increases in precision. Since few, if any, relevant empirical data exist, the logical increases in precision to be suggested below must be regarded as tentative.

The following example applied to the oddity problem suggests how level 6 concepts may be increased in difficulty by varying the relevant, constant, and irrelevant (or ambiguous) cues. Let O represent oddity and N represent nonoddity, each together with a number which denotes the number of *shared* dimensions (e.g., color, form, and size). For example, O1-N2 means that nonodd stimuli and the odd stimulus share one dimension and the nonodd stimuli share two dimensions including the one shared with oddity. This also means that one dimension is constant between the odd and nonodd stimuli, one is relevant, and one is irrelevant. With three dimensions and two categories there are nine possible combinations. However, three of these (O1-N1, O2-N1, and O2-N2) will not result in oddity discriminations. Among the remaining six, the following order of difficulty from 1 (presumably easiest) to 6 (most difficult) in discrimination is suggested, partly from the analyses indicated and partly from judging sketched examples.

1. O0-N3 3 relevant cues
2. O1-N3 2 relevant cues, 1 constant cue
3. O2-N3 1 relevant cue, 2 constant cues
4. O0-N2 2 relevant cues, 1 ambiguous cue
5. O1-N2 1 relevant cue, 1 constant cue, 1 ambiguous cue
6. O0-N1 1 relevant cue, 2 ambiguous cues

Briefly, it may be useful to note the following. (a) The dimensions may not be equally salient for a species; therefore, random variations of the dimensions at each level should be used. (b) Beginning with 4, the task becomes that of 'dimension-abstracted oddity'; see *Bernstein* [1961]. (c) Other dimensions may be added, see *Bernstein* for examples, to further increase the levels of difficulty. (d) Other concepts, e.g., 'same' vs. 'different', may be varied analogously; for a somewhat related example see *Smith et al.* [1975].

Levels 7 and 8: Relational Concepts. There are two principal, overlapping ways to increase the precision of measurement at levels 7 and 8.

Table III. Sublevels of level 7 concepts

7.0	1 relationship: 1 concept[1]
	Conjunction: A *and* B
	Disjunction: A *or* B
	Conditional: *if* A, *then* B
7.1	1 relationship: 2 concepts
7.2	2 relationship: 1 concept
	Conjunctive + Conditional: *if* (A *and* B), *then* C
	Conjunctive + Disjunctive: (A *and* B) *or* C
	Conditional + Disjunctive: *if* (A *or* B), *then* C
7.3	2 relationships: 2 concepts
7.4	2 relationships: 3 concepts
7.5	3 relationships: 1 concept
	Conjunctive + Disjunctive + Conditional: *if* (A *and* B) *or* C, *then* D
	Conjunctive + Conjunctive + Disjunctive: (A *and* B) *or* (C *and* D)
	etc.
7.6	3 relationships: 2 concepts
7.7	3 relationships: 3 concepts
etc.	etc.

[1] Here and in succeeding examples the capital letters either represent class concepts or specific stimuli as indicated.

One is to increase the precision or difficulty of the class concepts (as suggested in the preceding section) involved in the relational operations. The other way is to increase the number and vary the kind of conceptual relations which an animal must consider before making a single judgment (response choice). There is an essentially unlimited number of tasks which might be constructed. The burden will be on the investigator who compares species to be consistent in the ways that they are compared.

Tables III and IV summarize an approach to the construction of a logical order of tasks of increasing complexity at levels 7 and 8, respectively. At present, it is not considered to be appropriate to compare animals on tasks of increasing difficulty at level 7 if they are capable of performing even the easiest task at level 8, although it is likely that complex tasks at level 7 might be failed by animals which can perform at level 8. Animals which can perform at level 7, but presumably not 8, should be compared on higher sublevels of 7. Animals which can perform at level 8 should be compared on higher sublevels of 8.

Table IV. Sublevels of level 8 concepts

8.0	1 Biconditional: 1 concept[1] A *if and only if* B
8.1	1 Biconditional: 2 concepts
8.2	1 Biconditional + 1 level 7 relationship: 1 concept Biconditional + Conjunctive: A *if and only if* (B *and* C) Biconditional + Disjunctive: A *if and only if* (B *or* C) Biconditional + Conditional: (*if* A, *then* B) *if and only if* C
8.3	1 Biconditional + 1 level 7 relationship: 2 concepts
8.4	1 Biconditional + 1 level 7 relationship: 3 concepts
8.5	1 Biconditional + 2 level 7 relationship: 1 concept Biconditional + Conjunctive + Disjunctive: (A *and* B) *if and only if* (C *or* D) etc.
etc.	etc.

[1] Here and in succeeding examples the capital letters either represent class concepts or specific stimuli as indicated.

Concluding Remarks

It is appropriate to reiterate that any task designed to assess qualitative differences, such as the levels or sublevels of the proposed intellective hierarchy, should be adapted to the sensory, motor, motivational, etc. capacities of the species involved. The intellective test should be one of an animal's ability to use its known capacities in increasingly complex ways. The choices of stimuli, response-modes, incentives, etc. should be such that it may be argued that an animal's failure to perform a task successfully was not likely due to those factors but was due to intellective inabilities.

Particularly in view of the preceding section, it is realized that the approach to the measurement of animal intelligence suggested here may appear somewhat fanciful. However, the alternative of continuing to compare species on the basis of the kind of quantitative measures which have been used traditionally appears to be completely unjustifiable.

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