Measuring an Approximate g in Animals and People

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Abstract: A science of comparative cognition ultimately needs a measurement theory, allowing the comparison of performance in different species of animals, including humans. Current theories are often based on human performance only, and may not easily apply to other species. It is proposed that such a theory include a number of indexes: an index of the stage of development based on the order of hierarchical complexity of the tasks the species can perform; an index of horizontal complexity; and measures of g (for general intelligence) and related indexes. This article is an early-stage proposal of ways to conceive of g in animals and people. It responds to Geary's argument that domain-general mechanisms are essential for evolutionary psychologists. Existing research is used to enumerate domains, such as problem solving behavior in pursuit of food, or behaviors in pursuit of mates and/or reproduction, and itemize identifiable human social domains. How to construct g, across domains and within domains, is described.

Keywords: comparative cognition, domains, evolutionary psychology, hierarchical complexity, g, intelligence, IQ, measurement theory

Introduction

This article introduces a cross-species, cross-domain measurement theory of cognitive performance. Its proposal responds to the current lack of such a theory for the science of comparative cognition, and to evolutionary psychologists' needs for domain-general mechanisms (Geary, 2004). Even though current theories have generally not included this broader scope of intelligence, some of the very first studies of intelligence did address the issue as to whether or not animals could think (Romanes, 1988). Supporting the continuity of animal and human faculties, Darwin (1871) wrote, in concluding the fourth chapter of *Descent of Man,*

> Nevertheless the difference in mind between man and the higher animals, great as it is, certainly is one of degree and not of kind. We have seen that the senses and intuitions, the various emotions and faculties, such as love, memory, attention, curiosity, imitation, reason, etc., of which man boasts, may be found in an incipient, or even sometimes in a well-developed condition, in the lower animals. They are also capable of some inherited improvement as we see in the domestic dog compared with the wolf or jackal. If it could be proved that certain high mental powers, such as the formation of general concepts, self-consciousness, etc., were absolutely peculiar to man, which seems extremely doubtful, it is not improbable that these qualities are merely the incidental results of other highly-advanced intellectual faculties; and these again mainly the result of the continued use of a perfect language. At what age does the new-born infant possess the power of abstraction, or become self-conscious and reflect on its own existence?

Over the last century, part of this inquiry has developed into the field of evolutionary psychology. The concern in this field is for the adaptiveness of a wide variety of behaviors in multiple domains. In trying to address this issue, there has been an ongoing debate between modularity of intelligence (Cosmides & Tooby, 1994) versus general intelligence, mostly fought in the realm of human intelligence. In cognitive science, the modularity of mind refers to the idea that the mind is composed of independent, closed, domain-specific processing modules. Sperber (2002) states that Modularity is not just of the mind but of any biological mechanism. It can be envisaged at five levels:

1. At a morphological or architectural level, what is investigated is the structure and function of specific modules, and, more generally, the extent to which, and the manner in which the organism and its sub-parts, in particular the mind/brain, are an articulation of autonomous mechanisms.
2. At the developmental level, modules are approached as phenotypic expressions of genes in an environment. Cognitive modules in particular are hypothesized to explain why and how children develop competencies in specific domains in ways that could not be predicted on the basis of environmental inputs and general learning mechanisms alone.
3. At the neurological level, modules are typically seen as dedicated brain devices that subserve domain-specific cognitive functions and that can be selectively activated, or impaired.
4. At the genetic level, what is at stake are the pleiotropic effects among genes such that relatively autonomous "gene nets" (Bonner 1988) get expressed as distinct phenotypic modules. Genetic modularity is more and more seen as crucial to explaining on the one hand phenotypic modularity and on the other the evolution of specific modules (Wagner 1995, 1996; Wagner & Altenberg, 1996).
5. At the evolutionary level, hypotheses are being developed about the causes of the evolution of specific modules, and of genetic modularity in general. Understanding the causes of the evolution of modules helps explain the known features of known modules and also search for yet to be discovered features and modules.

In humans, the simplest operational definition proposed is that intelligence is whatever intelligence tests measure. In animal intelligence, the modularity view has generally dominated because most animals show no large degree of general intelligence (Locurto, 2004).

I will suggest that there should be some measure of general intelligence (g) (Jensen, 1998; Kanazawa, 2004) for animals. I will also present an alternative process and corresponding indexes that may be used along with traditional measures in humans such as IQ (Intelligence Quotient). This suggests another approach to human intelligence that more closely parallels the assessment of animal intelligence.

This approach will respect modularity and suggest that breadth of intelligence is a better way to summarize the generality of intelligence than the factorial approach of g so popular in academic approaches to human intelligence. Breadth will offer continuity with other animals and incorporate what has become known as the multiple intelligences of Gardner (1983/1993) and of Sternberg (1985). Breadth, which much of this paper leads to defining, will be carefully defined below and distinguished from traditional views of g.

Background of General Intelligence versus Modularity Studies

The concept of intelligence was the brain child of Sir Francis Galton (1869/1892/1962). Intelligence testing has been an empirically driven enterprise, with item selection based on very limited understanding of the domains of human endeavor. Charles Spearman (1904) found that grades of children in different subjects were positively correlated. These correlations seemed to be influenced by a dominant factor, g for "general" intelligence. He developed a model to account for the variation in intelligence test scores consisting of two factors. The first was g, a general factor that governs performance on all cognitive tasks. The second was the factor specific to an individual mental task: the individual abilities that would make a person more skilled at one cognitive task than another. Spearman's theory was too narrow. It did not consider other aspects of intelligence, for example, those corresponding to broad abilities such as spatial visualization, memory and verbal ability usually found through factor analysis.

In 1903-1905, Alfred Binet and Thophile Simon (Binet, 1903; Binet & Simon, 1905) worked on creating a practical way of assessing which children would not benefit from regular instruction for the French Ministry of Education. This was the Binet battery of tests. They did not suggest that that battery measured precisely any single faculty. This was because the battery was aimed at evaluating the child’s general mental development with a heterogeneous group of tasks. Binet had noted that children who had difficulty in school were very often late in developing skills in other fields easily acquired by most students of the same age.[1] In 1917, Robert Yerkes, who was President of American Psychological Association then, developed the Army Alpha and Beta Tests to measure intelligence in a group format. The tests were given to all new recruits in the U.S. military in 1918 onward.

At that time, there was almost no notion of animal intelligence. An exception was E. L. Thorndike, who did a great deal of work in both areas, coming up with the basic laws of learning. Thorndike's (1898, 1911) early studies with animal behavior produced his Law of Effect. That law states that responses to a situation that are followed by satisfying events are strengthened and responses that are followed by unpleasant ones are weakened.

Thorndike and his students began measuring intelligence as early as 1903 (Thorndike, 1904). When the United States entered World War I, Thorndike developed methods for measuring a wide variety of abilities and achievements. During the 1920's, Thorndike (1920, 1927) developed an intelligence test consisting of completion, arithmetic, vocabulary, and directions: the CAVD. This instrument was intended to measure intellectual level on an absolute scale. The logic underlying the test predicted elements of test design that eventually became the foundation of modern intelligence tests.

Thorndike distinguished three broad classes of intellectual functioning. Standard intelligence tests measured only abstract intelligence. The second class was mechanical intelligence: how well one visualizes relationships among objects and understands how the physical world worked. The third class was social intelligence: the ability to function successfully in interpersonal situations.

[1] Bergin and Cizek (2001) suggest that Binet’s work on measuring intelligence may have influenced Jean Piaget, (he worked for a time in the Alfred Binet Institute in Paris (Gruber & Vonèche, 1977), who later studied with Binet's collaborator Theodore Simon in 1920. But Piaget was more interested in the ways in which errors were made than the scores, leading his inquiry in other directions.

Thorndike proposed that there were four general dimensions of abstract intelligence:

- Altitude: the complexity or difficulty of tasks one can perform (most important).
- Width: the variety of tasks of a give difficulty.
- Area: a function of width and altitude.
- Speed: the number of tasks one can complete in a given time.

Factor Analysis

Factor analysis, a term introduced by Thurstone (1931), is a statistical procedure used to measure relationships among many variables. It allows numerous intercorrelated variables to be reduced to fewer dimensions, called factors. Factor analytic techniques are used to (a) reduce the number of variables and (b) detect structure in the relationships between variables, that is, to classify variables.

Thurstone administered 56 measures (15 hours' worth of tests) to 240 college students to try and determine the basic factors of intelligence. Without computers, it took him six months to compute the results. Thurstone found 12 factors to intelligence but only seven of these were clear enough to name. The one that persists today is g, the first factor.

Not too much has changed since Thorndike's and Thurstone's work. The determination of g from factor analysis takes only seconds now, and that determination is in most statistics programs. The same factors are found over and over, the main one being g, with many secondary factors also occurring. One can now do a Rasch Analysis on items from various intelligence measures, checking to see if they fall on a single dimension. But the scoring of item difficulty is such that items from very different domains will usually fall on a single dimension of difficulty in Rasch, without indicating the domain differences. A Rasch Analysis shows the degree of difficulty (Dattilio, Commons, Adams, Gutheil, & Sadoff, in press). It is a model that produces an objective, additive scale that is independent of the particular items used and of the particular participants tested (Wright & Linacre, 2001). Through the use of probabilistic equations, this model converts raw ratings of items into scales that have equal intervals. The Rasch Model was originally developed for large-scale achievement testing. Its use has since exploded in a variety of disciplines and for a wide range of topics, and it can be used to analyze a large variety of human sciences data (Linacre, 2003).

A scale is produced, on which each item (which is coded for and entered as a raw data point) is placed according to its Rasch "rating," or scaled score. Such a scale can then be used as a type of objective ruler against which to measure the data on items as to difficulty as well as on respondents-ratings. The ruler-like properties of the scaled numbers or Rasch scores that are produced provide some advantages over other scaling techniques. For example, the scale is made up of equally spaced, continuous intervals, that is, it provides a linear, interval measure against which items can be compared. As a result, a change of difficulty of 1 carries the same weight from 0 to 1 as it does from 2 to 3 in the same way that, on a ruler, a change in length of 1 inch, either from 0 inches to 1 inch, or 2 to 3 is the same. Furthermore, doubling on the Rasch scale means the same change in difficulty anywhere along its linear axis. Again, using the figurative ruler example, doubling the distance from 1 to 2 results in an equivalent *magnitude* of change as doubling the distance from 2" to 4." In the case of difficulty, a value of 2.3 is half as severe as a difficulty of 4.6.

The accumulation of "cognitive" testing data and improvements in analytical techniques have preserved g's central role and led to the modern conception of g (Carroll 1993). A hierarchy of factors, with g at its apex and group factors at successively lower levels, is presently the most widely accepted model of cognitive ability. Other models have also been proposed, and significant controversy attends g and its alternatives.

Toward a More Expansive Measure of g

But there have always been problems with these models. Somehow the animal intelligences and the human intelligences have not been systematically connected. Also, there was no known way of determining, without giving people independent items to do, how difficult the items were on an absolute scale.

There is also the problem in comparative psychology with the lack of a good way to compare "how smart" different animals are, and this is also true for people. A science of comparative cognition ultimately needs a measurement theory of how to compare the performances of different species of animals and different groups of people. Current theories are often based on human performances and human norms and may not easily apply to other species. Furthermore, there is also controversy about whether such theories and tests apply to other cultures or if they do, can group comparisons be made. I propose that a theory of comparative cognition needs to include multiple indices. This application is derived from my application of measurement theory to the problem of how smart something is (Commons, Trudeau, Stein, Richards, & Krause, 1998). An index would consist of a numerical scale used to compare variables with one another or with some reference number. In this article, I propose a way to conceive of g in animals and people.

There is controversy within the field of evolutionary psychology as to whether or not g is domain specific or domain general. One of the perspectives on modularity come from evolutionary psychology, particularly from the work of Leda Cosmides and John Tooby (1994). This perspective suggests that modules are units of mental processing that evolved in response to selection pressures. With this view, much modern human psychological activity is rooted in adaptations that occurred earlier in human evolution, when natural selection was forming the modern human species. In contrast to modular mental structure, some theories posit domain-general processing, in which mental activity is distributed across the brain and cannot be decomposed, even abstractly, into independent units. A staunch defender of this view is William Uttal, who argues in *The New Phrenology* (2003) that there are serious philosophical, theoretical, and methodological problems with the entire enterprise of trying to localize cognitive processes in the brain. Part of this argument is that a successful taxonomy of mental processes has yet to be developed. Skottke (March, 2006) argues that general intelligence, g, can be described as the ability of an individual to acquire and apply knowledge. Many studies have shown that g is at least 50 percent heritable and thus, can be passed down from generation to generation (DiLalla, 2000).

Evidence is overwhelmingly against generality. Such evidence is usually expressed in terms of the concept of modularity (e.g., Bonner, 1988). Miller (2000) argues that one of evolutionary psychology's most distinctive ideas is the expectation that the control of human activity is massively modular. The brain evolved so that it is composed of hundreds of distinct psychological adaptations that evolved to solve distinct ancestral problems of survival and reproduction. Cosmides & Tooby go on to state that the rationale for massive modularity has been the supposed trade-off between generality and efficiency:

> As a rule, when two adaptive problems have solutions that are incompatible or simply different, a single general solution will be inferior to two specialized solutions. In such cases, a jack of all trades is necessarily master of none, because generality can be achieved only by sacrificing effectiveness (1994, p. 89).

Modularity is obvious for morphology: animals have distinct limbs, senses, and organs to do different things. Psychological and behavioral control modularity has been less obvious to psychologists, but evolutionary considerations of functional efficiency suggest the brain and behavioral control should be at least as modular as the body.

Geary (2004) has argued that domain-general mechanisms are essential for evolutionary psychologists. Geary proposes that human motivational, affective, behavioral, and cognitive systems have evolved to process social and ecological information (e.g., facial expressions) that covaried with survival or reproductive options during human evolution. Further, he argues that the ultimate focus of all of these systems is to support our attempts to gain access to and control of resources—more specifically, the social (e.g., mates), biological (e.g., food), and physical (e.g., territory) resources that supported successful survival and reproduction over time. In this view, Darwin's conceptualization of natural selection as a "struggle for existence" becomes, for us, a struggle with other human beings for control of the available resources. This struggle provides a means of integrating modular brain and cognitive systems such as language with those brain and cognitive systems that support general intelligence. To support his arguments, Geary draws upon an impressive array of recent findings in cognitive science and neuroscience, as well as primatology, anthropology, and sociology. In addition, Chiappe & MacDonald (2005) argue the need for such a notion to understand human evolution. Note, this paper will *not* address current issues on the psychometric view of intelligence and only review part of the historical context.

Charles Locurto (2004) has been studying the structure of early acquisition of behavior and of stimulus control. He has focused on the structure of individual differences in mouse "cognition." There are specific mechanisms that are carried across at least some animals such as the structure of the eye and the nature of neural networks, but that does not equate to general intelligence. His findings with mice do not show a robust general factor (i.e., first principal component) that is typically found in human testing. Instead, he observed a more modular structure. The tasks he used in his batteries require a number of sessions to complete. Locurto cites a literature that says that clearer evidence of a general factor may be found if each task is run for only a few trials, thereby capturing early acquisition performance instead of performance following extended training. In response to this literature, Locurto developed a battery in which each task was designed to provide evidence of learning within a few trials. Moreover, each task was distinct in terms of motivation, sensory modality and/or behavior measured, thereby providing a strong test of the presence of a general factor. His results still did not indicate much of a general factor. This work led directly to what is presented here.

Modularity and Domains

Despite the theoretical debates, it is not an all or none proposition. Because values of g may have increased over evolutionary time as new organisms developed, there is a great need for defining g in a way that captures the issue of modularity versus generality in a systematic way.

Modules are similar to the notion of domains. These modules are thought to be related to brain function that is specialized for tasks in a given domain.

Although there are currently no standard ways to define domains, I take the strategy of relying upon existing research to enumerate domains. For example, many animals exhibit certain problem solving behaviors in pursuit of food, and different behaviors in pursuit of mates and/or reproduction. Animals also have different kinds of interaction behaviors with others of their own species. Some animals pair bond, some live in social groups, and some are loners, coming together only to mate.

Domains

In trying to measure g, or a general factor for animals, it would be good to have a list of domains and tasks within those domains that various animals can do. Domains are presently not on any scale. They are nominal. From the animal literature, the domains for most animals are discrete. The major ones I know are:

- Mate selection
- Attachment and caring
- Pecking order
- Prey defense
- Predator action
- Way finding
- Food sharing
- Migration
- Communication
- Social cohesion
- Recognition
- Food selection
- Choice in foraging

Hierarchical Complexity and Stage

The Model of Hierarchical Complexity (MHC) posits that tasks can be ordered as to their hierarchical complexity (Commons, Trudeau et al 1998). It belongs to the branch of mathematics called measurement theory. It formulates a measure of one major kind of task difficulty called *hierarchical complexity*. This measure is different from current measurement procedures in four major ways. First, hierarchical complexity of tasks forms an absolute scale rather than one based on norms, or content. Second, it is formulated in a manner similar to other measures from measurement theory (e.g., Krantz, Luce, Suppes, & Tversky, 1971). Third, it separates the empirical stage of *performance* from the largely analytic hierarchical complexity of tasks. Fourth, rather than basing stage on some inferred mental or logical operations; stage becomes the performances on tasks of a specified hierarchical complexity that are accomplished.

The Model of Hierarchical Complexity (Commons & Miller, 1998; Commons & Richards, 1984a, 1984b; Commons, Trudeau, et al., 1998) defines stage of performance on a task in terms of the order of the hierarchical complexity of the tasks that the performance successfully addresses. Formally, for a task to be more hierarchically complex than another, the new task must meet three requirements. First, a more hierarchically complex task and its required action is *defined* in terms of two or more less hierarchically complex tasks and their required task actions. Second, the more hierarchically complex task *organizes* or coordinates two or more less complex actions; that is, the more complex action specifies the way in which the less complex actions combine. Third, the coordination of actions that occurs has to be *non-arbitrary*; it cannot be just any chain of actions. Each new, task-required action in the hierarchy is one order more complex than the task-required actions upon which it is built (Commons, Trudeau, et al., 1998).

The MHC also may be used to measure the stages of animal or human behavior on this scale. It does so by taking the actions that animals and humans engage in, and ordering the hierarchical complexity of the tasks that those actions successfully address. Stage of performance has the same number and name as the corresponding order of hierarchical complexity of the task it correctly completes. The table below indicates how the MHC describes the orders or stages.

Table 1. Stages described in the Model of Hierarchical Complexity

Order or Stage	**Name**	**What they do**	**How they do it**	**End result**
0	calculatory	Exact–no generalization	Human made program manipulate 0, 1	None
1	sensory & motor	Discriminate in a rote fashion, stimuli generalization, move	Move limbs, lips, eyes, head View objects and movement	Discriminative and conditioned stimuli
2	circular sensory-motor	Form open-ended classes	Reach, touch, grab, shake objects, babble	Open ended classes
3	sensory-motor	Form concepts	Respond to stimuli in a class successfully	Concepts
4	nominal	Find relations among concepts Use designated concepts	Use names and other words as successful commands	Sequences of concepts, designated concepts
5	sentential	Imitate and acquire sequences Follows short sequential acts	Generalize match-dependent task actions. Chained designated concepts	Sequences of designated concepts
6	preoperational	Make simple deductions Follows lists of sequential acts Tell stories	Count random events and objects Combine numbers and simple propositions	Connectives: as, when, then, why, before; products of simple operations
7	primary	Simple logical deduction and empirical rules involving time sequence Simple arithmetic	Adds, subtracts, multiplies, divides, counts, proves, does series of tasks on own	Times, places, counts acts, actors, arithmetic outcome from calculation
8	concrete	Carry out full arithmetic, form cliques, plan deals	Does long division, follows complex social rules, takes and coordinates perspective of other and self	Interrelations, social events, what happened among others, reasonable deals,
9	abstract	Discriminate variables such as Stereotypes; logical quantification; (none, some, all)	Form variables out of finite classes Make and quantify propositions	Variable time, place, act, actor, state, type; quantifiers (all, none, some)

Order or Stage	**Name**	**What they do**	**How they do it**	**End result**
10	formal	Argue using empirical or logical evidence Logic is linear, 1 dimensional	Solve problems with one unknown using algebra, logic and empiricism	Relationships formed out of variables; words: linear, logical, one dimensional, if then, thus, therefore, because; correct scientific solutions
11	systematic	Construct multivariate systems and matrices	Coordinates more than one variable as input Consider relationships in contexts	Events and concepts situated in a multivariate context; systems are formed out of relations; systems: legal, societal, corporate, economic, national
12	metasystematic	Construct multi-systems and metasystems out of disparate systems	Create supersystems out of systems Compare systems and perspectives Name properties of systems: e.g. homomorphic, isomorphic, complete, consistent, commensurable	Supersystems and metasystems are formed out of systems of relationships
13	paradigmatic	Fit metasystems together to form new paradigms	Synthesize metasystems of	Paradigms are formed out of multiple metasystems
14	cross-paradigmatic	Fit paradigms together to form new fields	Form new fields by crossing paradigms	New fields are formed out of multiple paradigms

Measuring an Approximate g

Indexes to Measure g and Variants

Starting with the standard tasks within the standard domains, one can construct an analogue of g. There will be three types of measures: (a) the highest stage of performance attained in each domain (HS) including the highest stage in any domain (HHS); (b) a form of g that is somewhat akin to human g; (c) a derived measure of generality of performance, g breadth (gB).

Highest Stage of Performance Attained in Any Domain

An animal species may be characterized by the highest stage of performance observed with any amount of training on its best task series (HHS). Animals can perform up to the concrete stage, about what eight to ten year old children do. (Examples presented below show how the MHC can be used to compare how smart different animals are).

This first index requires some information as to what the domains are and what the tasks are within each domain. This is the most difficult part of the enterprise because we really do not know the domains well. We know what the tasks accomplish, but we do not have a systematic way to classify domains. Each task has a hierarchical complexity. The highest stage of performance (HS) is just the highest hierarchical complexity of the task that the organism in the species correctly addresses. Then one finds the domain and task in which the highest stage of performance (as determined by hierarchical complexity) occurs (HHS). Note that this falls on the stage scale that runs from 0 to 14. It is one such number.

The Index g

The second index, g, is the average of the highest stage numbers of performance in each domain (HS). This is somewhat akin to human g, but g would separate the highest stage from how broad g would be. The average has advantages of the total g, because the average is less sensitive to failing to include a domain or misidentifying a domain. Note that this average of highest stage falls on the stage scale that runs from 0 to 14.

The Index g-Breadth

The third index called g breadth (gB), measures how broad an organisms' capability is by using a scheme that uses a renormed g that removes the effects of the highest stage. This renorming does not refer to a sample but to the process of dividing the average of highest stage in each domain (g) by the top stage of the animal (HHS). This renorming takes away the effect of highest stage. Then we have three numbers, the highest stage (HS); the average stage across domains (g); and g breadth (gB).

Within Domain Smarts

Another form of "being smart" is within domains. This within-domain form is like the subtasks within the verbal IQ tasks. The within-domain form shows flexibility of stage of performance (fS) within each domain. One chooses the domain and task in which one wants to measure flexibility, then finds the highest stage of performance (HSdomain) on a wide variety of tasks that occur within that domain (as determined by hierarchical complexity). One then averages the stage numbers of the task performances within the domain. That is g-domain. That is divided by the Hsdomain. Again, this scale will consist of the rational numbers between 0 and 14. That gives gdomain Breadth.

Examples of Comparative Complexity in Selected Domains and Species

As an example of how this works, we can first compare human way-finding to pigeon way-finding, and then include fish, horses and rats. There is a great deal of variability in human way-finding. It may be that this is also true for other primates. Some people seem to always be getting lost, whereas others can go anywhere with the most minimal directions. Such people also may use the sun to find their way. Some orienteers even think they have a sense of north in their head. Pigeons are particularly good at way-finding. They follow features (as many people do) and seem to have a magnetic portion of their brain.

But most way-finding in animals is not as flexible as in humans or pigeons. While we do not understand migration very well in birds and fish, we do know that fish swim to and up the stream where they were born. But they are not particularly good perhaps at finding other places. Birds migrate pretty much along the same routes year after year. They can find their way back to their nests. But as humans, we can make and read maps. We can find our way in any weather. We do it differently and in a more hierarchically complex manner. Humans use maps that may show contours and features such as trails, roads, cliffs, junctions, etc. The differences in complexity of each of these tasks across species could be compared with this model, given some further work in specific areas.

Jay R. Feierman (personal communication) knows horses very well. He says that they are “absolutely dumb” at figuring out problems that were not present in their ancestral environment. The fact that on the open spaces they have a good sense for direction and can always find their way home is an example of a reasonably high stage of functioning in way-finding.[2] But on new problems, they are “terrible.” Feierman says a similar condition exists for rats, whose inborn abilities allow them to be so good at mazes. Maze-like problems were part of the ancestral world of rats. But horses do better across domains than rats. They acquire a much broader amount of information, and can be trained to do a wider variety of tasks.

A second set of examples is about comparing spiders and 11 year old humans. Spiders can build webs and they can wrap their prey, but that is about it. An 11 year old can also make a spider web with a syringe filled with a protein like that in a spider web. However, they can also do all sorts of tasks beyond that. Even though they both can build spider webs, and probably the spider’s is more elegant, the fact is that the human can do so many things spiders cannot.

A third set of examples compares African Grey Parrots, Crows, and other birds. Crows perform at the sentential stage 5 (see Table 1). They sequence nominal stage actions by planning to bend a wire to reach around a corner in a plastic tube to get food. Also at the sentential stage 5, African Grey Parrots sequence words and understand word sequences, distinguishing the difference between the passive voice and active voice. But the African Grey Parrots solve all sorts of problems beyond what Crows do at the sentential stage, such as saying letters and numbers in order, and counting small sets of objects systematically. At the nominal stage 4, pigeons can switch which key they use when a few examples from a class are switched. They form a large number of arbitrary concepts even including such abstract examples as inside and outside. Hence, at the concrete stage 3, their performances are quite broad. They are trained repletely to name classes such as fish (respond quickly) to non-fish (respond slowly). When a few examples are switched so that the class name has been switched from respond quickly to respond slowly, they switch their rate for all members of the class. Sparrows cannot do such things.

The foregoing examples indicate why it is useful to distinguish domains within species, and by describing tasks that are domain specific, they illustrate that similar task domains exist across species. They suggest that animals for the most part do not vary much in their stage of performance within species. This is not true within humans. It is easy to find adults ranging from primary to metasystematic stages. There are also great differences from person to person as to their relative stage of performance on tasks in different domains.

Human Domains

There are a number of issues in examining domains in the context of humans. For example, in the postformal stages (i.e., stages 11 through 14 in Table 1) that develop only in advanced adolescents and adults, there have been very few studies of domain (but see Demetriou, 1998;

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[2] Some primates, especially humans, have huge ranges. Other animals like elephants also have large ranges, and ranges are not linear as compared to migrations.

Demetriou & Kazi, 2001; Kail, 2004). There are at least two studies that measured postformal stages in a few different domains (Commons, Armon, Richards, & Schrader, 1989; King, Kitchener, Wood, & Davison, 1990). In both cases, the first factor was stage, with all the assessments but the Loevinger (1976) loading on it. It was more related to IQ. In each of these studies, a variety of tasks were administered. The Multisystems tasks asked people to compare four stories to each other that differed only in the way preferences or weights were ordered. In some stories, the ordering was transitive and in others that had identical structures, they were not. Table 2 indicates results from a factor analysis of how much each of the following measures loaded on the first "stage" domain.

Table 2. Factor loading on first "stage" factor of a multi-instrument study

Study	Factor Loading
Good-Life (Armon, 1984)	.85
Multisystems (Commons, Richards & Kuhn, 1982)	.75
Moral Judgment (Kohlberg, 1984)	.64
Ego (Loevinger, 1976)	.26

At one time, Piaget and Kohlberg did not think that there were domain specific developmental lags. But almost all the neo-Piagetians do. In developmental political psychology, one might consider the wide range of social domains. There has been a great deal of controversy about the nature of the social domain within the field of human development. Some researchers (e.g., Kegan, 1982; Kohlberg, 1984) held that development occurred roughly simultaneously in all domains and surely within the social domain. Fischer (1980) and many other neo-Piagetians did not think so. Armon (1984) proposed using Aristotle's classification of domains as follows: The True – Logical, Mathematical and Empirical, The Just – Fairness, The Good – Evaluative and Valuing, Beneficence – Caring, and The Beautiful. Here, Caring, Valuation and Justice are treated as all belonging to the social domain.

Social Domains and Subdomains

Each one of the subdomains of the Social Domain can be differentiated by finding people who can perform well in some of them but not others, even single others. What follows is a rough outline of the social subdomains and tasks within them.

Self

There are many bench marks in the development of the self. First, around 18 months, there is reflection on self, differentiation from others, and finally self recognition in a mirror (Bertenthal & Fischer, 1978). There are many disorders of the self, all having a different character. For example, with respect to self image, schizophrenics may think they lack a body. They may perceive the loudness of outside stimuli less than the inside voices. Anorexics may have a distorted body image and deficiency in detecting body aberrations. Narcissists perceive that what is important to them is almost always important to others. With attention deficit disorders, there is inattention to others.

Dyads

Intimacy has all the social perspective taking stages of Selman (1980) as modified by Commons and Rodriguez (1990). At the primary stage seven, one can take the perspective of oneself and one can take the perspective of others but not at the same time and not coordinated. At the concrete stage, decision making leads to agreement between two people based on each person understanding the perspective of the self and other at the same time. Intimacy develops finally at the metasystematic stage to the extent where people can become interdependent without giving up their own identity or dominating another.

Alliance and mutuality has a stage sequence also, paralleling the development of social perspective-taking. For example there is turn-taking in infancy at the beginning of the circular-sensory motor stage two. It has been observed that communicative interaction, as shown by eye glances that begin to take place from the first week, gradually develops into an interaction with sounds where the adult talks and the child is cooing and beginning to play peek-a-boo (Commons, 1973; Lobel, Miller, & Commons, 1981).

Lamb (1991) has show that the development of empathic responses at the beginning of the nominal stage 4 around 18 months is a precursor of moral development.

Triads

During the primary stage, one sees games involving groups of children. These can be small teams as in kick ball, dodge ball or jacks. This becomes the basis for small working groups or small committees. Decision making becomes an issue. Sometimes there is a consensus and the group stays together. Sometimes there is not and the group might split. At the concrete stage, the use of power becomes more apparent.

Committees

At the abstract stage 9, committees come into being. They consist of three or more people but not so large as to be an organization. There are social norms that play a significant role here.

Small Organizations

These can also be formed at the abstract stage 9. They may consist of single purpose large ad-hoc committees and simple non-differentiated organizations without departments. Roles are somewhat differentiated but also quite interchangeable. Such groups are governed by social norms and do not have to be face-to-face.

Small Markets

Small markets are an example of this level of social subdomain. For instance, in developing countries, there are usually open air markets with lots of vendors selling products. Many of the vendors sell the same products. There may be price, quality, and freshness competition. Flea markets are also of this sort.

Organizations

An organization is a group of persons organized for a particular purpose such as a political association or a business. Within organizations there are rules for cooperation as well as for competition among subunits of the organization as is the case with sports teams and candidates.

Public

This is a different kind of activity in which people have an imaginary audience or at least one they cannot see. This first happens at the formal stage 10. This is the lowest stage of performance for politicians, actors, musicians and writers among others who have a special sensitivity as to what works with the public. They are successful at communicating with the "everyman." We say they are successful if they are elected and if they are there more than one term or have more than one movie or album success. This is a domain unto its own. Think of higher stage purveyors like Ronald Reagan, William Clinton, Tom Hanks and the Beatles as exemplars.

Governments and Large Markets

See Sonnert and Commons (1994) for a discussion of the higher stages in the political process. Sara Ross (personal communication, January 2006) suggests one might look at the list of the often-used socio-political domains as shown above. One could relate them to socio-political structures at different stages of development. Then one could come up with stages of performance necessary in those domains to function well within those structures. One could design a semi-structured interview-scenario that included elements we think of as belonging in those domains (moral, interpersonal, etc.). We could use that to probe people's experience, attitudes, etc., in relation to how they think, react, function in regard to certain institutions and also other people who have roles in those institutions. Then one could come up with a score for each domain included in the interview's scenario. One might be able to predict where they could have problems and where they could benefit from further development.

One could conduct an experiment designed to improve performance in socio-political domains, by using Sara Ross's public issues process for example, and do the interview again, and score them. One could see if that intervention broadened them by increasing g, finding out which domains the intervention impacted, person by person. People could benefit personally and collectively, and the intervention could be revised and improved to target certain domains more specifically for more beneficial results.

Societies and Cultures

Some people, such as artists and scientists, have a great understanding of societies. They not only produce original works, but often understand how to market them to the society as a whole. For example of cultures as a whole, we speak of Western culture or Eastern culture.

Other Domains

There are other kinds of domains of knowledge in humans. People seem to vary in how well they do in them, so there might be some modularity associated with them also. A list of such domains includes:

- *Physical Science domains:* These include Physics, Chemistry, Organic Chemistry, Astronomy, Geology.
- *Biological Domains:* These include Biology, Biochemistry, Zoology, Botany, and their subdomains.
- *Analytical Domains:* These include Philosophy (which includes Epistemology, Morality and Ethics, Aesthetic, Logic, Metaphysics) and Mathematics (which includes such areas as Mathematics, Probability and Statistics, and Chaos Theory).
- *Experiential Domains:* There are two major experiential domains; Religion and Spirituality, and Art, Music, Performance, Communication and Persuasion.
- *Physical Skills:* These include sports, dance, military activity, equipment operation, playing instruments among other things.

Conclusion

The issues of modularity and generality in intelligence are not going to go away. This paper has presented one way to address the controversy, to keep modularity but measure general development across domains. Using such measures will help us understand the evolution of animals. It will also make clear that many of the problems people suffer from are not due to "bad' will, but due to deficits of development in given domains. Such unevenness in development seems to be associated with problems such as criminal activity, substance abuse, etc.

This theory of g may enhance the Model of Hierarchical Complexity's utility, as a formal theory now supports its development (Commons & Pekker, in press). It may also iterate a few of its key potential areas of value. There are clearly a number of challenges in fleshing out this theory in detail. One way to validate such a system of measurement could be to systematically compare a number of animals using the methods briefly described in this paper. However, it takes a great deal of time to test individual animals or humans on a large set of tasks. Therefore, at least with animals, it is probably best to analyze the tasks they do and how they do them. By determining the hierarchical complexity of the tasks, one can determine the stage of performance, which requires only scoring.

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