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Profiling nonhuman intelligence: An exercise in developing unbiased tools for describing other “types” of intelligence on earth ☆

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ABSTRACT

Intelligence has historically been studied by comparing nonhuman cognitive and language abilities with human abilities. Primate-like species, which show human-like anatomy and share evolutionary lineage, have been the most studied. However, when comparing animals of non-primate origins our abilities to profile the potential for intelligence remains inadequate. Historically our measures for nonhuman intelligence have included a variety of tools: (1) physical measurements – brain to body ratio, brain structure/convolution/neural density, presence of artifacts and physical tools, (2) observational and sensory measurements – sensory signals, complexity of signals, cross-modal abilities, social complexity, (3) data mining – information theory, signal/noise, pattern recognition, (4) experimentation – memory, cognition, language comprehension/use, theory of mind, (5) direct interfaces – one way and two way interfaces with primates, dolphins, birds and (6) accidental interactions – human/animal symbiosis, cross-species enculturation. Because humans tend to focus on “human-like” attributes and measures and scientists are often unwilling to consider other “types” of intelligence that may not be human equated, our abilities to profile “types” of intelligence that differ on a variety of scales is weak. Just as biologists stretch their definitions of life to look at extremophiles in unusual conditions, so must we stretch our descriptions of types of minds and begin profiling, rather than equating, other life forms we may encounter.

COMPLEX (*CO*mplexity of *M*arkers for *P*rofiling *L*ife in *EX*obiology) offers a new approach to profile a variety of organisms along multiple dimensions including *EQ – Encephalization Quotient*, *CS – Communication Signal complexity*, *IC – Individual Complexity*, *SC – Social Complexity* and *II – Interspecies Interaction.* Because Earth species are found along a variety of continuums, defining an intelligence profile along these different trajectories rather than comparing them only to human intelligence, may give us insight into a potential tool for quickly assessing unknown species. The application of profiling nonhuman species, out of world, will be both observational and potentially interactive in some way. Using profiles and indicators gleaned from Earth species to help us develop profiles and using pattern recognition, modeling and other data mining techniques could help jump start our understanding of other organisms and their potential for certain “types” of intelligence.

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1. Introduction

Measures of intelligence, based on human criteria such as language features, have previously been described for complex social mammals including primates, dolphins, vervet

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monkeys, prairie dogs, to name a few. Complex syntax, semantics and referential signal use has been found in many species. Studies of alarm calls in wild vervet monkeys [1], ground squirrels [2], and prairie dogs [3] have revealed elements of symbolic referential communication and competence. Similarly, laboratory studies of intra and inter-species referential communication and competence have revealed both semantic and syntactic understanding in common and pygmy chimpanzees [4] and bottlenose dolphins [5]. Dolphins, a non-terrestrial and most alien of social mammals, have the second largest encephalization quotient and complex cognitive abilities [6,7] and have a variety of mechanisms of information transfer [8] and teaching mechanisms [9].

Although human intelligence may be driven by complex social structure [10], non-mammals also show abilities that in some cases rival social mammals and include tool use and social skills (e.g. corvids (crows) [11]; ants, [12]). The social intelligence hypothesis has been challenged relative to other non-social forces that may also drive intelligence [13] suggesting a need for a non-human biased definition and measure of intelligence. This will be especially critical in our search for life beyond Earth and with alien species that have potentially evolved on other planets and under different environmental and social pressures. This will be relevant whether we decide to identify other "types" of intelligence to simply coexist with (ecologically), to interact with (symbiosis/mutual goals) or to potentially dialog with us (interaction/communication).

We currently propose to recognize signatures of life in Astrobiology on different scales including atomic, molecular, microfossils, macroscopic and planetary. How then will we recognize intelligence? Intelligence may be diverse in expression or different by type, degree, or scale. The Myers–Briggs psychology types (4 dimensions – Extrovert/Introvert, Sensing/Feeling, Thinking/Intuitive, Perceptive/Judgmental) ESIJ, EFIP, is an example of scaling on multiple dimensions and is utilized for typing complex human aspects.

This paper describes a multi-dimensional exercise to profile and assess different types of intelligence based on aspects of physical, social, and intellectual abilities.

2. Materials and methods

A Multi Dimensional exercise was developed called *COMPLEX*: *CO*mplexity of *M*arkers *for P*rofling *L*ife in *EX*obiology. Measures in five dimensions, from physical to global properties, were used including (1) *EQ – Encephalization Quotient* (neural complexity), (2) *CS – Communication Signals* (sensory modalities), (3) *IC – Individual Complexity* (personalities), (4) *SC – Social Complexity* (group/solitary living) and (5) *II – Interspecies Interaction* (external relationships).

Taxa used were based on categories established *by Dr. Lori Marino and Dr. Kathyrn Denning* on the Astrobiology website: *intelligence.seti.org/pages/*. These included *Vertebrates* (ex. Marine Mammal)-Cetaceans – DOLPHIN thought to have a high encephalization quotient, complex communication, associations, and big brains, *Invertebrates* (ex. Marine Invertebrate)-Cephalopods – OCTOPUS thought to have associative learning, tameness, exploratory behavior, *Invertebrates* (ex. Social Insect-Arthropods – BEE) thought to have collective intelligence, symbolic waggle dance, counting, learning, *Microbes* – (ex. Bacteria – GENERAL) thought to have complex behavioral responses w/o evolving complex brains, highly integrated, and *Machines* (ex. A.I. – GENERAL) demonstrated by neural networks, computational power, and algorithms.

Since most criteria for human intelligence emphasizes language, cognition and numerical competence, other dimensions of information processing were used to scale organisms in this exercise. Scoring of these criteria did not necessarily minimize anthropocentric bias for intelligence, but it did de-emphasize the sole importance of cognition or production of a language as the ultimate measure of intelligence as an attempt to broad our concept of "types" of intelligence. These scales address the importance of multiple features and skills, across multiple dimensions, which may be relevant to profile nonhuman types of intelligence.

Each category was scored by experts in the taxa, based on the own knowledge base, on four attributes on a scale of 1–10 (highest) and zero if no data were available. Experts scored zero or N/A if they did not feel qualified to score. Experts were then queried as to the difficulties of scoring

Table 1
Average scores generated from four attributes within five categories including: encephalization quotient, communication signal complexity, individual complexity, social complexity and interspecies interactions.

EQ=Encepahlization Quotient and other Physical Measures				
Brain/head/body ratio	**Neural density**	**Neural specializations**	**Convolution**	**Totals**
10	9	10	10	***EQ***=39
CS=Communication signals and their complexity				
Sensory modalities/cross-modal	**Natural repertoire**	**Information theory**	**Symbolic/synchrony/coordination**	
8	7	5	5	***CS***=25
IC=Individual complexity and the role of the one				
Personality/tendencies	**Role of individual**	**Leadership**	**Role flexibility**	
2	2	2	1	***IC***=7
SC=Social complexity of the group/society				
Group living	**Alliances/cooperation**	**Network variation**	**Culture/social learning**	
9	9	5	7	***SC***=30
II=Interspecies Interactions and Openness to other Species				
Natural interactions	**Cross-species altruism**	**Sensory gap to humans**	**Enculturation**	
8	6	8	6	***II***=28

attributes to attain a perspective on the development of future quantitative measures.

The category of *EQ – Encephalization Quotient* – was scored on brain to body ratio, neural density, neural complexity and degree of convolution (or equivalent). The category of *CS – Communication Signals* – was scored on sensory modalities, natural repertoires, information theory measures and symbolic aspects/synchrony. The category of *IC – Individual Complexity* – was scored on personalities/tendencies, role of individual, leadership, and role flexibility. The category of *SC – Social Complexity* – was scored on group living/solitary, alliances/cooperation, network variation, and culture/social learning. The category of *II – Interspecies Interaction* – was scored on natural external relationships, cross-species altruism, sensory gap from humans, and enculturation abilities.

Table 2
Comparable category scores for each taxon. Red boxes indicate interesting aspects of various taxa.

10 = low 20 = med 30 = high Perfect=40	EQ Encephalization Quotient+	CS Communication Signals	IC Individual Complexity	SC Social Complexity	II Interspecies Interaction
DOLPHIN	34	35	31	36	29
OCTOPUS	18	15	14	8	6
BEE	8	32	8	28	6
MICROBES	0	12	4	18	13
MACHINE	34	26	14	22	4

All four attributes were totaled for each category and a total score/category was generated.

3. Results

Table 1 shows an example of the five categories and how totals were scored for each attribute and then totaled for the category. Table 2 lists the taxon used for this exercise and their actual total scores per category. In this exercise dolphins scored high in most categories. Bees and Machines scored high in both the *Communication Signal* and *Social Complexity* categories. Finally, microbes scored relatively high in the *Interspecies Interaction* category.

The overlapping five dimensional profiles can be seen in Fig. 1. Each taxon generated a distinctive "shape" using these dimensions. A dolphin scored high to medium in all 5 dimensions, an octopus scored high in EQ and CS (chromatophores, polarized light) but low in IC (solitary, personality), SC (social structure), and II (external relations). A bee scored low in EQ but high in CS and SC (symbolic communication) and low in IC (solitary, personality) and II (external relations). Microbes scored high in SC and II (interactions and networks). Machines are skewed towards complex (parallel but non-living) networks with high abilities in EQ, CS and SC. Fig. 2 shows the shape of each profile individually with a description of its potential for types of interactions.

4. Discussion

Profiling species assumes we have access to appropriate data or information. Experts in this exercise extracted information from their knowledge of the literature and their own research studies. It is potentially easy to be taxa-biased so a larger pool of experts should be recruited for future exercises to average out scores for comparable taxa. Experts found

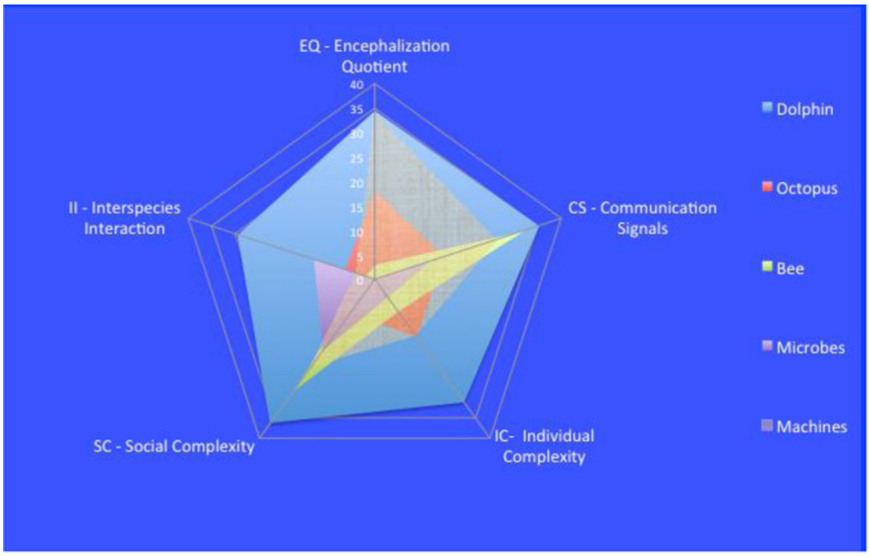

Fig. 1. The overlapping shapes for five types of nonhuman intelligence scored in five dimensions including: encephalization quotient, communication signal complexity, individual complexity, social complexity and interspecies interactions. A multidimensional overlapping view allows each taxon to be seen where its most powerful potential exists, in this case relative to other taxa.

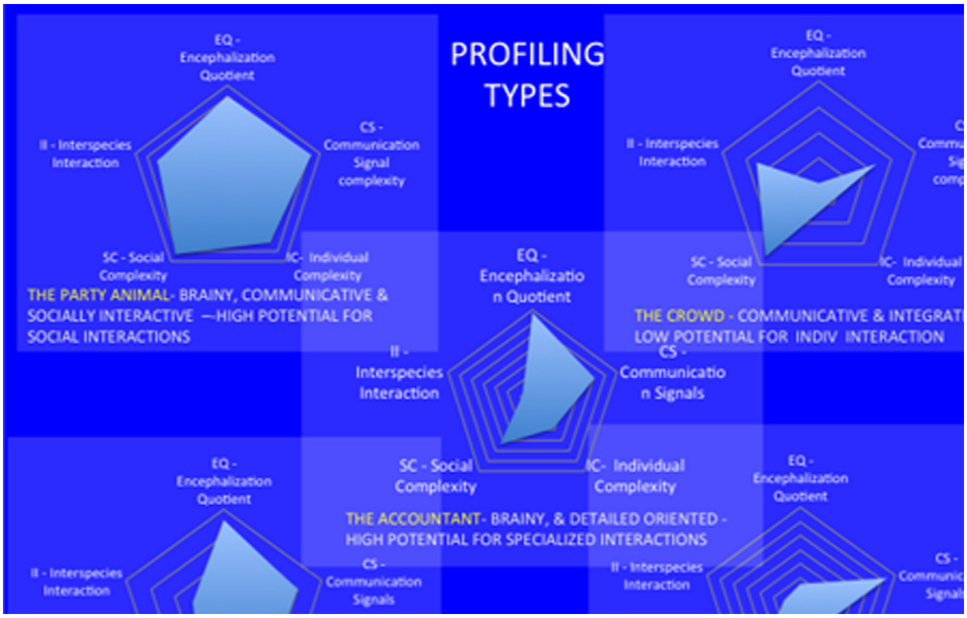

Fig. 2. Individual shapes of types of nonhuman intelligence generated for five taxa scored in five dimensions. Each taxon shows a unique and distinctive "shape". Each shape generated a description of a profile type and its potential in interaction and contact.

challenges of the work that included "equating" brains across taxa (i.e. brains = mushroom bodies in insects?) and determining if tests were "species appropriate" (i.e. Is a visual mirror test for an acoustic dolphin appropriate?). An empirical exercise with larger datasets would be useful to apply to the qualitative exercise presented here. Other techniques exist for processing and assessing cross- species information and interaction although they require real-time access to nonhuman cultures [4,14,15].

5. Conclusions

Convergent evolution suggests there are some aspects of universality of the emergence of cognition among social mammals, albeit with questions of functionality and mechanism debated [16]. Given that many species can comprehend artificial language (mammals, birds) and show numerical competence (mammals, birds, fish, amphibians) and that such abilities often predate language production or verbal language [17] but remain unmeasured in many species due to sensory gaps and techniques appropriate to species, it is possible that these abilities are more widespread than currently documented.

Earth based species provide a potential model for assessing nonhuman intelligence. If we can successfully use pattern recognition tools to profile "intelligent types" on Earth, could we then apply these tests to species outside our Earth? Could we develop pattern recognition tools and techniques that verify "types", for remote information gathering?

Based on our exploration of "extremophiles", we should expect an analogous diversity of types and manifestations of intelligence. However, some "types" of organisms may use multiple or even unknown sensory systems. An exercise in profiling other "types" of intelligence on Earth would be a good exercise for future Exobiology explorations.

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