From Cephalopods to Large Language Models: Conceptions of Intelligence and Reasoning

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Abstract

This paper explores convergences and contrasts between conceptions of intelligence and reasoning in three domains: cephalopods (principally octopus and cuttlefish), other marine animals (notably cetaceans), and contemporary large language models (LLMs). We use comparative biology and cognitive ethology to highlight different embodiments of information processing, problem-solving, and flexible behaviour, then draw instructive analogies for artificial intelligence research. We argue that cephalopods and other marine animals instantiate forms of intelligence that emphasize embodied, distributed, and context-sensitive problem solving; by contrast, current LLMs implement a disembodied, statistical-syntactic form of competence that nonetheless achieves surprising forms of emergent reasoning. Examining causal mechanisms, ecological pressures, and developmental trajectories that shape these intelligences reveals lessons for designing AI systems that are robust, adaptable, and socially situated. We suggest that reasoning and intelligence lie on a continuum from cephalopods to humans, and on to AI systems.

1 Introduction

How should we define intelligence and reasoning? Classical accounts emphasize problem solving, abstraction, and rule-based manipulation. Contemporary approaches in cognitive science emphasize adaptation to ecological niches, embodied sensorimotor loops, and the role of social interaction. Recently, engineered systems, especially large language models (LLMs), have challenged traditional demarcations by exhibiting capabilities (e.g., in-context learning, chain-of-thought-like behaviour) that are functionally similar to human reasoning in some tasks despite radical differences in substrate and training.

This paper juxtaposes three perspectives: cephalopods and other marine animals (as products of natural evolution and ecological pressures) and LLMs (as products of large-scale statistical optimization on text). We seek to (1) characterise the forms of reasoning manifested in each, (2) identify structural and functional parallels, and (3) propose a conceptual framework to guide future empirical and engineering work.

Current conceptions of intelligence, cognition and reasoning are very anthropocentric [1, 2].

Studying cognitive abilities between species can help AI researchers more accurately assess whether artificial systems possess, exceed, or lack cognitive capabilities [3]. *We suggest that reasoning and intelligence lie on a continuum from cephalopods to primates, and on to AI systems* [4].

Understanding cognition, intelligence and consciousness in understudied species and taxa such as cephalopods may also give us insights into how intelligence and correlates of intelligence (such as tool use) can evolve in diverse computational substrates such as potentially even large language models.

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2 Background: Three kinds of intelligence

2.1 Cephalopods and embodied cognition

Cephalopods, particularly octopuses, cuttlefish, and squid, display rich repertoire of flexible behaviour: problem solving (e.g., opening jars), tool use, camouflage and dynamic body patterning, and rapid reconfiguration of body morphology [5]. Anatomically, a large proportion of cephalopod neurons are located in peripheral ganglia (arms) rather than centralized in a single brain, producing a distributed architecture [6, 7].

2.2 Other marine animals: social and distributed cognition

Marine mammals such as dolphins and whales demonstrate social intelligence: cooperative hunting, cultural transmission of behavioural traditions, and complex vocal communication. These phenomena have been extensively reviewed by Rendell and Whitehead [8] and others.

2.3 Large language models: statistical and emergent reasoning

Large language models are trained by optimising predictive objectives over massive corpora. They lack direct sensorimotor embodiment (with exceptions in multi-modal agents) and are typically deployed as disembodied text-processing systems; nevertheless, LLMs achieve surprising capabilities such as coherent long-form generation, few-shot generalisation [9], and chain-of-thought style multi-step reasoning when prompted appropriately [10]. Critical reflections on the limits and risks of language models are provided by [11].

3 Comparative analysis

We compare domains across several axes: substrate and architecture, representation and memory, learning and development, embodied constraints, sociality, and ecological functions.

3.1 Substrate and architecture

Cephalopods: neural tissue distributed between central and peripheral ganglia; high parallelism and local autonomy (arms) [6].

Marine mammals: highly centralised brains, large social networks and long lifespans [8].

LLMs: artificial neural networks, typically transformer-based architectures that implement attention over token sequences [12].

3.2 Representation and memory

Biological systems encode memory across multiple timescales: synaptic modifications, neuromodulatory states, and behavioural traditions [13, 14]. Cephalopods exhibit rapid learning and contextual memory including local motor learning in arms [15].

LLMs store statistical associations in high-dimensional parameter space; short-term "working memory" is implemented by context windows. Persistent episodic memory is typically absent unless explicitly engineered (e.g., retrieval-augmented systems, memory-augmented agents) [9].

4 What counts as reasoning?

We propose a typology useful for cross-domain comparison: sensorimotor reasoning (fast perception–action loops), algorithmic/symbolic reasoning (abstract manipulation), social and cultural reasoning (prediction and manipulation of other agents), and statistical/associative reasoning (inductive generalisation from patterns). These classes overlap and co-exist in complex systems [14, 13].

5 Case studies

5.1 Octopus problem solving

Octopuses show flexible motor tactics to retrieve food from novel enclosures, exemplifying embodied problem solving where exploratory motor routines and local arm autonomy enable fast, context-sensitive solutions [15, 6].

5.2 Dolphin social coordination

Dolphins coordinate complex foraging strategies and transmit learned behaviour culturally, highlighting joint intention, shared attention, and long-term memory of social norms [8].

5.3 Emergent multi-step behaviour in LLMs

LLMs can be coaxed into multi-step reasoning via chain-of-thought prompting and in-context examples, though such behaviours can be brittle and prone to hallucination without grounding or external verification [10, 9, 11].

6 A synthetic framework: ecological competence

We propose *ecological competence* as a unifying lens: the degree to which a system achieves functional goals within a specific niche given its embodiment and resources. We outline a functional decomposition (perceptual front-end, short-term buffer, action generator, long-term store, social interface) that can be used to map biological and artificial systems and identify missing components.

7 Experimental proposals and benchmarks

We propose several experiments: embodied imitation tasks for LLM-augmented agents, social transmission simulations for multi-agent cultural emergence [16], modular-effectors robustness tests to mimic octopus arm autonomy, and an integrated ecological competence benchmark combining perception, manipulation and social coordination tasks.

8 Implications and ethical considerations

Design lessons include: embodiment matters; modularity and locality can improve robustness; social scaffolding helps communicative competence; and multi-timescale memory supports cumulative learning. Philosophically, cross-domain comparison supports a pluralistic, function-oriented conception of intelligence. Ethical cautions include respecting animal welfare, avoiding over-extended metaphors, and anticipating socio-technical impacts [11].

9 Conclusion

Cephalopods are unusual animals and offer a useful bridge. With three hearts and a highly distributed nervous system that includes several centralized ganglia, octopuses and their kin embody neural architectures radically different from ours; as Godfrey-Smith puts it, their minds are among the most genuinely “other" [17].

This prompts a central question: what kinds of non-linguistic intelligence, reasoning and consciousness could arise in novel computational substrates?

What kind of concepts might be engendered in novel computational substrates (such as LLMs)? Recent debates about anti-representationalism bear on this problem [18].

Anti-representationalism is the view that cognition does not fundamentally depend on internal, structured representations of the world: that thinking and intelligent behaviour can arise from direct, dynamic coupling between an agent and its environment. The position challenges traditional computationalist and representational accounts in cognitive science and AI by shifting explanatory focus away from symbol manipulation

Reservoir Computer models can learn and predict extremely complex dynamical patterns while apparently lacking rich, compositional internal representations from which parts of a target could be selectively extracted [18]. If so, they offer concrete models of intelligent behaviour that function without conventional concepts, raising the possibility that large language models and other systems might likewise operate with very different, or even without, conceptual representations.

Comparing cephalopods, marine mammals, humans, and large language models highlights multiple forms of intelligence. This pluralistic view can both improve our understanding of natural cognition.

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