The Symbol as Such: Morphological Computation and Perceptual Consciousness

Ben Gaskin

In the beginning of heaven and earth there were no symbols. Symbols came out of the womb of matter.

—Lao Tzu

The argument in brief

1. **What is perceptual consciousness?**
   We will begin by defining perceptual consciousness in terms of the stages of sensory integration in the evolution of adaptive behaviour.
2. **Learning in large language models (LLMs)**
   We will turn to LLMs as an instance of language learning in the absence of perceptual consciousness and sensory integration. This will be formalised in terms of morphological computation and Kolmogorov complexity.
3. **Consciousness and the symbol**
   Finally we consider consciousness with regard to symbols, viewing language as a system of replicable constraints through Howard Pattee and then integrating this with a view of consciousness as functioning to generate information.

What is perceptual consciousness?

Part 1.

The absence of perceptual consciousness

- **Blindsight:** “when ‘forced-choice’ behavioural methods were applied to explore possible residual visual functions that a different picture emerged for, **despite their blindness**, the patients might be able to **look towards stimuli** presented in their field defects, to **localize them** by pointing, and to **detect and discriminate movements**.”
  - Cowey & Stoerig, 1991
- **Action without perception:** “when presented with a large slot that could be placed in one of a number of different orientations, she showed **great difficulty in indicating the orientation either verbally or manually** (i.e. by rotating her hand or a hand-held card). … she was **as good as normal subjects at reaching out and placing her hand or the card into the slot, turning her hand appropriately** from the very onset of the movement.”
  - Milner & Goodale, 1992
- **Blindsmell:** “We have illustrated two types of phenomena. First, that odours can be **detected by the brain, without accompanying evidence of conscious awareness**. Second, that odours can **affect psychological processes—mood, learning, perception—without conscious awareness** that these processes have been affected.”
  - Zucco et al., 2014

The phylogeny of conscious perception

- **Zucco et al., 2014**
  - “From a phylogenetic viewpoint, **the most recent pathway is the retino-geniculo-striate** one. This pathway originates from the eye and its projections reach V1, through the lateral geniculate nucleus of the thalamus. This pathway is **responsible for conscious vision**. If this is the case, then a different pathway must be activated when blindsight-related phenomena arise. Indeed, the most probable candidate for explaining blindsight is the **retino-tecto-pulvinar-extrastriate pathway**, a **phylogenetically older visual stream**. In this pathway, visual information reaches the extrastriate cortices indirectly by means of projections that originate from the retina. These projections are directed to the superior colliculi, and then to the pulvinar. Finally, from the pulvinar projections reach the extrastriate visual cortices. **When visual input to this pathway is prevented, blindsight disappears.**”
- Conceptually, at least, from an evolutionary perspective, this is reasonable

Stages of sensory integration

- **Primary sensory integration:** inputs are **extinguished in outputs**
  - Present in cases such as blindsight, action without perception, etc.
  - Does not preclude learning, but may be insufficient for trace conditioning
  - Presumably in simpler forms of animal life, especially **protein computation**
- **Secondary sensory integration:** inputs are **consciously represented**
  - Absent in cases such as blindsight, action without perception, etc.
  - Entails a **behavioural distancing** from the contents of perception
- This is **not to be taken as a teleological progression**: “Human anatomy contains a key to the anatomy of the ape. The intimations of higher development among the subordinate animal species … can be understood only after the higher development is already known.”

Learning in large language models

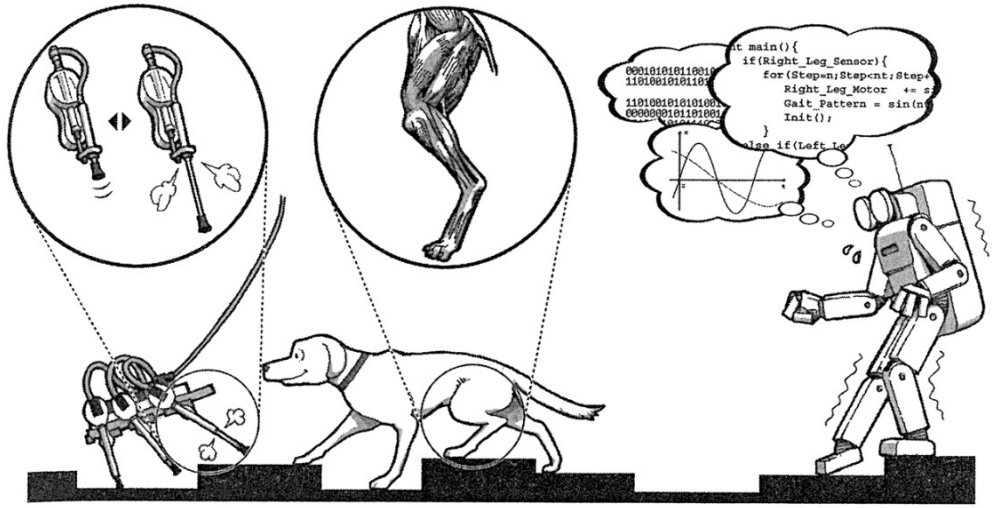
Part 2.

Language learning in children and machines

- LLMs are trained on **text data**, primarily taken from the internet
  - Decomposed into ‘tokens,’ which can be **words, sub-words, or even phrases**
- The exact quantity is unknown, but estimates are LLMs likely require **three orders of magnitude more than even a highly literate human**
  - Frank (2023)
- How do LLMs learn?
  - Simply put, they model the **probability distribution of sequences of tokens**
    - They are trained by having them predict the next token, given a prior sequence
    - When they make a mistake, the network elements responsible for the error are tuned
- What do LLMs learn?
  - They learn **to predict the next token**, by repeating this they infer larger units

Morphological computation

- "By '**morphological computation**' we mean that **certain processes are performed by the body that otherwise would have to be performed by the brain**."
  - Pfeiffer & Bongard, 2007
- Müller & Hoffman (2017) define these cases as "**morphology facilitating control**"
  - Similarly, that the structure of perceptual experience acts as "morphology facilitating control"



Kolmogorov complexity

- **Andrey Kolmogorov (1903–1987)**
- “In everyday language we identify the information in an individual object with the essentials of a description for it. We can formalize this by **defining the amount of information in a finite object** (like a string) as **the size (i.e., number of bits) of the smallest program that, starting with a blank memory, outputs the string** and then terminates.”
  - Li and Vitányi, 1990

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Conditional Kolmogorov complexity

- "The conditional Kolmogorov complexity of hypothesis h given h', K(h|h'), is defined as the length of the shortest program that outputs the program h given h' as input. K(h|h') measures the amount of constructive information h' contains about h—**how much information h' contains for the purpose of constructing h**."
  - Mahmud & Ray, 2007
- For our purposes, therefore, we can roughly formalise this as follows:

$$K(L|C) < K(L)$$

  - K = the number of tokens required for linguistic aptitude
  - L = a given level of linguistic aptitude, roughly that of an adult
  - C = integrative access to perceptual consciousness

Multi-modal language learning in LLMs

- **Wang et al., 2024**
  - "The visual representation produced by the vision encoder is used to **initialize the hidden state** of the uni-directional LSTM. …the captioning network shares the same LSTM architecture [as the text-only LSTM] for language processing and is trained to optimize the same objective, next token prediction."
  - "The improvements for most syntactic categories are statistically significant, but in particular, **nouns and verbs benefit the most** from additional visual information."
- **Zhuang et al., 2024**
  - "… **when only a small amount of data is available**, **Visual + Word models are more efficient than Language-Only models** in learning to relate words and predict semantic features."

Multi-modal language learning in LLMs, cont.

- **Reasonable evidence** for cross-modal grounding of language
  - Currently limited to visual input, **cross-modal rather than truly multi-modal**
  - Children also have access to aural, proprioceptive, etc.
    - **No reason in principle to doubt this extension**, perhaps requiring architectural advances
- But what does this really mean for our argument?
  - **Simply providing multi-modal data** can be more efficient
  - And yet we are **not claiming that these models are conscious**
- If so, then what is the purpose of perceptual consciousness?
  - Machine learning and language models **require an extant structure**
  - In contrast, will address the **initial origin of symbolic meaning**

Consciousness and the symbol

Part 3.

Language as a system of replicable constraints

- **Howard Pattee, 1987:** “It is useless to search for meaning in symbols without complementary knowledge of **the dynamics being constrained** by the symbols.”
  - Pattee defines language as the interaction between a syntactic system and the dynamics of a physical system which it constrains, where a symbol’s **meaning is understood in terms of the constraint thereby effected** upon the system
- The meaning of a term can be understood forwards and backwards:
  - Forwards, how do we expect it to constrain a given dynamic?
  - Backwards, how does it in fact constrain a given dynamic?
- Symbols are selected based on the interplay between these aspects

The arbitrariness of symbolic constraints

- **Rączaszek-Leonardi, 2012:** "what makes physical stimuli the carriers of constraints is **their history in the system**. In natural language, this history involves processes on several timescales: a structure is selected **for bringing about a particular effect** (here and now; for interaction or an individual) and **for being transmittable** (both here and now: heard, perceived; and in ontogeny: learned)."
  - They maintain that these symbols are arbitrary, with their shape determined solely by the history of their selection and role within a system: "supported by the often quoted fact that **names of the same things are different in deferent languages."**
- **Chandler, 1995:** "As Lévi-Strauss noted, **the sign is arbitrary *a priori* but ceases to be arbitrary *a posteriori***—after the sign has come into historical existence it cannot be arbitrarily changed."
  - **But how, then, does the sign come into historical existence?**

Consciousness as information generation

- “A weak version of the hypothesis simply claims that a function associated with conscious experience is to **generate and maintain representations of events detached from the current sensory input**.”
  - Kanai et al., 2019
- They derive this functional role from two lines of evidence—
  - “… in disorders of consciousness, the presence of consciousness depends on **intentional, deliberate behavior** as opposed to automated, reflexive behavior triggered solely by the properties of the current sensory input.”
  - “ … empirical evidence suggests that successful **trace conditioning** requires awareness of the relationship between CS and US, whereas delay conditioning occurs automatically regardless of whether the subject became aware of the relationship.”
- Kanai and colleagues use this to **explain counterfactual predictions**
  - This same capacity underpins the use of symbols as morphological computation

The symbol as such

- The line from Kanai et al. (2019) aligns with our notion of secondary sensory integration: that the sensory object is somehow **lifted out of the stream of sensory input** and **represented as distanced presence**
  - Compare the tree as affordance, for instance, to the tree as symbol
- We argue that **the symbol must be experienced as such**— through the medium of consciousness—to structure a symbolic constraint
  - Symbol grounding for multi-modal language models **depends upon a set of extant data**, that this **provides it with an adequate structure and objective**
    - This is a scenario which **does not hold at the very earliest origins of language**
  - Perceptual consciousness thus provides access to symbols as such, which in turn provide a structured core around which language can crystallise
    - Particularly in the case of a minimal ontology, which is shared across languages

An experiential account of logic

- **Lakoff & Johnson, 1980:** “we tend to structure the less concrete and inherently vaguer concepts … in terms of more concrete concepts, which are more clearly delineated in our experience.”
- Take **formal logic in the line of Aristotle**: that this is structured in terms of containment, an image schema drawn from experience
  - **Prior Analytics 24b:** “That one term should be **included in another**, as in a whole, is the same as for the other **to be predicated** of all of the first.”
  - **The law of excluded middle (Lakoff and Johnson, 1999):**
    - “Given a container and an entity, the entity is **either inside or outside and not both** at once.”
    - “An object **cannot both have a property and its negative** (in the same respect at the same time).”

Conclusion

Overview of the argument

- The structure of a symbol, encountered in perceptual consciousness, determines the fundamental shape of its effect as a constraint
  - As with a joint, say, which simultaneously allows and restricts movement
  - Conscious access to the symbol as such provides a means of grasping this
  - LLMs must instead brute force their way to a probabilistic reflection of this
- There is no reason in principle, however, that LLMs would not be able to leverage multi-modal data to increase their training efficiency
  - This depends, however, on the tracks already laid down by language use
- What is in doubt, and the argument here, is whether language could ever have originated without initial access to the symbol as such
  - That this requires consciousness in terms of secondary sensory integration

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