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Mental Recognition of Objects via Ramsey Sentences

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Abstract

Dogs display vast phenotypic diversity, including differences in height, skull shape, tail, etc. Yet, humans are almost always able to quickly recognize a dog, despite no single feature or group of features are critical to distinguish dogs from other objects/animals. In search of the mental activities leading human individuals to state *"I see a dog*", we hypothesize that the brain might extract meaningful information from the environment using Ramsey sentences-like procedures. To turn the proposition *"I see a dog"* in a Ramsey sentence, the term dog must be replaced by a long and complex assertion consisting only of observational terms, existential quantifiers and operational rules. The Ramsey sentence for *"I see a dog"* sounds: "*There is at least an entity called dog which satisfies the following conditions: it is an animal, it has four legs, …, etc, …, and is something that I have in my sight*". We discuss the biological plausibility and the viable neural correlates of a Ramsey-like mechanism in the central nervous system. We accomplish a brain-inspired, theoretical neural architecture consisting of a parallel network that requires virtually no memory, is devoid of probabilistic choices and can analyze huge but finite amounts of unique visual details, combining them in a single concept. In sum, Ramsey sentence stands for a versatile tool that can be used not just as a methodological device to cope with biophysical affairs, but also for a model to describe the real functioning of cognitive operations such as sensation and perception.

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Introduction

As John was passing by, he saw a dog under a tree. He said to himself: *I' see a dog*". John says the same words when he sees a dog collar, when he hears barking, when he catches the typical smell of dog in an empty room. In all these cases, John is almost always capable of recognizing a dog. What happens in John's brain when he watches a dog? How does John recognize that he is watching a dog? We will leave apart auditory, olfactive, tactile cues and will confine ourselves to the assessment of a specific case related with visual cues, i.e., a human individual who watches an object, a painting, a sketch, a photo illustrating something that he terms "a dog". Scientists tackled the issue and formulated manifold responses. Some scholars provide a holistic account of perceptive contents, suggesting that the observed object displays as a whole emergent properties that cannot be found zooming in any part of its constituents (Pastukhov 2017). In turn, others contend that an image is first perceived in terms of its basic individual elements/features, then is recognized (Grainger et al., 2008). Others suggest that the visual system might split the processing of an object's form and color ("what") from its spatial location ("where") (Rao et al., 1997). Others believe that quick recognition of things like dogs involve both category-specific computational hubs in the ventral visual stream and distributed cortical memory networks (Woolnough et al., 2020). Further, template matching models of pattern recognition suggests that mental comparison takes place between external inputs and internal schemes (Hirai 1980).

We will take a different turn. At first, we will break the concept of dog into its component parts, looking for the minimal features or traits that allow human observers to recognize that this is a dog. The problem is twofold:

1. By one side, the visual and non-visual features allowing John to say "*I see a dog*" must be defined.
2. By another side, despite dogs are among the most variable mammals, John is almost always able to quickly recognize that this is a dog. Therefore, the second problem sounds as follows: looking at different images depicting manifold canine breeds, how does it happen that John is almost always able to state "*I see a dog*"?

We will conclude that no single feature or group of features allow John to distinguish the dog from other objects or animals, nevertheless John is always able to recognize that this is a dog. To solve this seeming contradiction, a theory of sensation and perception can be built using an approach borrowed from the last writings of Frank Plumpton Ramsey, just before his premature death in 1930. We will suggest that the brain might use Ramsey language-like procedures to extract meaningful information from the environment. Further, we will examine the biological plausibility and the possible neural correlates of a Ramsey-like mechanism in the brain.

Defining Dogs with Ramsey Sentences

How does John recognize a dog? We will analyze both the visual and non-visual features that allow John to state *I see a dog*". The Oxford Learners' Dictionary defines the dog as an animal with four legs and a tail, often kept as a pet or trained for work such as hunting or guarding buildings. The dog can also be defined as a highly variable domestic mammal (Canis familiaris) closely related to the gray wolf. Yet, these definitions are rather general. How many features of a dog are required to say "this is a dog"? How many features of different dogs are required to identify the dog's breed?

We could say that John recognizes a dog because it is an animal, but it is a too vague concept. We could say that John recognizes a dog because it has four legs, but John is able to recognize a dog even if, unfortunately, has three legs. We could say that John recognizes a dog because is a domesticated descendant of the wolf, but he is able to easily recognize a dog even if he is unaware of phylogenesis and evolution. We could say that John recognizes a dog through its genome sequencing (Hayward et al., 2016; Plassais et al., 2019; Letko et al., 2023), but he can recognize a dog even if he never heard about DNA. We could say that John recognizes a dog because it has an upturning tail, but he can recognize a dog even if, unfortunately, has a cut tail. Despite there are many different shapes for dog tails, from straight up to curled or corkscrew, John says that he recognizes that it is a dog. The same holds for the weight, the height, the eye gaze, the facial expression, the body posture, the manifold coats of different breeds, the different-shaped snout, the Carnivorans-like teeth arrangement for cutting meat, the non-retractable claws, etc. We could say that John recognizes a dog because it is uniquely adapted to human behavior, having acquired the ability to understand and communicate with humans. But John effortlessly recognizes also a wild dog.

In sum, our examples suggest that no single observable and non-observable feature or group of features are critical to define the dog and distinguish it from other objects or animals. Nevertheless, the lack of explicit identifying features and the huge morphological and behavioral diversity between breeds do not prevent John to be almost always able to recognize that he is seeing a dog. To resolve this apparent contradiction, we are going to introduce the Ramsey sentence and show how it could be used to describe the mental activities that lead John to state "*I see a dog*".

The proposition "*I see a dog*" can be turned in a Ramsey sentence. Ramsey introduced a technique of examining a scientific theory by means of long and complex formal propositions (Ramsey 1931), later termed "Ramsey Sentences" by Hempel (1958). Ramsey's account is built on the observation that scientific theories often describe abstract, theoretical terms such as "*spin*" and "*electron*" that cannot be observed and are difficult to distinguish from the metaphysical terms so often encountered in philosophy (Carnap 1966). A finitely axiomatized scientific theory T can be formulated in a formal language of first order predicate logic (Hintikka 1998), where the predicates are usually divided into two groups, namely the observational terms (O1, O2,…, On) and the non-observational terms (N1, N2,…, N2). Therefore, the theory can be expressed as:

$$T = O1, O2, \ldots On; N1, N2, \ldots Nn.$$

Aiming to build scientific theories by means of both existential propositions and explicit definitions representing experiences, Ramsey removed the theoretical entities Nn from T. Non-observable entities can be tackled through second order variables X, i.e., primitive observation terms not referring to individuals, but to properties of individuals or relations between individuals. A Ramsey's sentence is achieved, i.e., a second-order, extended observational statement where the theoretical terms and/or postulates are replaced by a high but finite number of variables and observables bound to initial existential quantifiers ∃. In formal terms:

$$TR = \exists X1\ \exists X2 \ldots \exists Xn, O1, O2, \ldots On.$$

Where the proposition TR stands for the Ramsey sentence of T.

Theoretical terms are replaced by the assertion that "*there is at least one entity that displays the same formal connection with the observational properties that the theory T and that satisfies certain conditions*". For example, instead of explicitly using theoretical terms such as "*electron*", a long and complex proposition can be drawn that goes through all the cases satisfying the laws and consequences, so that the term "*electron*" turns out to designate the conjunction of all the properties needed to specify the meaning of the term, such as, e.g., the properties 1, 2, 3, plus 4,5,6, plus the additional properties 7,8, etc.

The same Ramsey humbly asked to himself: is it necessary to use such intricate definition for the legitimate use of theory? The answer is positive. According to functionalistic scholars, Ramsey sentences provide empirically adequate descriptions of the things that can be described just by observational terms (Berardi and Steila, 2015; Lowther 2022). The Ramsey–Carnap approach, or Ramseyfication, has been widely used to assess scientific issues such as, e.g., infrared spectroscopy in analytical chemistry (Toppel 2021). Further, David Lewis (1972) suggested to use Ramsey sentences to tackle mental issues. He introduced a general method for constructing Ramsey sentences to define mental operations such as pain. All the mental state terms related with pain are removed from the statement and replaced by variables X plus existential quantifiers:

$$\exists X1\ \exists X2\ \exists X3\ \exists X4, \ldots \exists Xn.$$

In this case, the variable X includes:

a. Quantifiers that range over mental states.
b. Terms that denote stimulations/behavior.
c. Terms that specify various causal relations among them.

In the sequel, we suggest to look at the Ramsey sentence in realist terms, advising that it is not just a useful methodological tool, but might also be a reliable model to explain cognitive mental processes such as sensation and perception.

Could Ramsey Sentences be performed by Human Brains?

We argue that the term "*dog*" can be treated as a theoretical term in a Ramsey's sentence. For children who never saw a dog, the dog stands for a theoretical entity. Only with time, habituation and social consensus children learn to climb the steps from theoretical to observable entities, becoming able to say: "*I see a dog*". Therefore, the mental schemes that allow human individuals to say: "*I see a dog*" require time and training to give a meaning to the observed object. In touch with this observation, it has been reported that face looking in monkeys is not innate, rather experience is required for the formation/maintenance of face domains (Arcaro et al., 2017).

Our aim is to provide a Ramsey sentence for the (apparently) trivial assertion:

> *"I see a dog".*

To achieve Ramseyfication, the assertion can be modified in:

> *"I have a dog in my sight".*

Then, it can be described in Ramsey's terms through second order variables do not referring to individual dogs, but to properties/relations among dogs:

> *"There is at least an entity called dog which satisfies the following conditions: it is an animal, it has four legs, it is a domesticated descendant of the wolf,…, etc, …, and is something that I have in my sight".*

All the observable features encompassed in the concept of "*dog*" must be explicitly expressed using a long but finite list of dog-related features that can be empirically confirmed.

In sum, a Ramsey sentence can be used to assess how the human brain perceives and recognizes a dog. The next step will be to evaluate the biological feasibility and the viable neural correlates for Ramsey sentences.

Subcortical and cortical areas related to visual sensation and perception have been widely investigated (Hayama et al., 2016). When a dog is in front of John's eyes, the sequence of neuronal activation can be followed throughout John's visual system (**Figure 1**). We hypothesize that in the short 280–400 ms time window that occurs from the view of the dog to the assertion "*I see a dog*", the brain performs manifold parallel computations. Every parallel neural channel examines one of the numerous observational terms X of a Ramsey sentence (namely, every single feature of the dog), combining to produce a single final output that turns out to be the assertion "*I see a dog*" (**Figure 1**). We accomplish a logical-mathematical framework in the form of a Ramsey sentence, which is useful in reasoning about the unification of analytic observables and concept.

The next step is to look for feasible neural correlates of this Ramsey-like mechanism. Clues point towards the biological plausibility of Ramsey-like processes that occur in the brain during cognitive processes such as sensation and perception. To start with, the Ramsey's account requires manifold parallel channels able to simultaneously perform computations related with different dog features. To watch and recognize a dog requires simultaneous parallel information processing in sensorimotor, associative and limbic circuits modulated by both sensory cues and previous learning (Macpherson et al., 2021). It is noteworthy that the nervous system is a distributed large-scale network characterized by parallel processing loops. In touch with a Ramsey framework, widespread inter-area fluctuation modes transmit sensory data and task responses through parallel non-interfering channels, so that the neocortical sensory processing overcomes the substantial variability of neuronal sensory responses and generates reliable sensory discrimination (Ebrahimi et al., 2022). Parallel computing and parallelization strategies are widely used in theoretical neuroscience and artificial neural networks' optimization to perform human-like tasks, to capture neuron and synapse dynamics and to deal with data processing, pattern recognition and classification (Liu et al., 2016; Pastur-Romay et al., 2017; Ben-Nun and Hoefler, 2018; Peres and Rhodes, 2022; Kanwisher et al., 2023). Compared with sequential architectures, parallel neural network architectures display optimized performance, higher efficiency, better flexible behavioral control (Hikosaka et al., 1999; Åström and Koker, 2011, Peres and Rhodes, 2022). Furthermore, parallel training is robust and capable of yielding accurate long-term predictions in realistic scenarios (Ribeiro and Aguirre, 2018), facilitating performance of complex and simultaneous behaviors (Macpherson et al., 2021). In the central nervous system, the sparce, parallel pathways underlying Ramsey sentences require in the final stages inputs convergence towards the assertion "*I see a dog*". In touch with this claim, it has been demonstrated that, despite the extreme sparseness of the magnocellular LGN inputs to the macaque primary visual cortex, the V1 produces robust orientation selectivity/continuity in the orientation map, together with simple/complex classification (Chariker et al., 2016). While the neocortex at rest displays single pattern of functional connections, different areas share co-fluctuations and task-related information within 300 s after the onset of the sensory stimulus (Ebrahimi et al., 2022).

The Ramsey's account of sensation and perception suggest that the brain analyses huge amounts of single visual details in a sparce code manner. In agreement with this hypothesis, the representation of semantic processing, that is crucially engaged when judgements are formulated based on association or conceptual similarity (Jackson et al., 2015), is scattered throughout vast areas of the cortical surface (Huth et al, 2016). Another crucial item of the Ramsey sentences, namely, the existential quantifiers, display well-known neural correlates. BOLD fMRI studies point towards the existence of a large-scale fronto-parietal network contributing to specific aspects of logical quantifiers' comprehension (Olm et al., 2014; Zhan et al., 2017; Heim et al., 2020). All the quantifiers (e.g., "at least three") recruit both the right inferior parietal cortex, suggesting that a numerosity component contributes to quantifier comprehension, and the thalamus/anterior cingulate, suggesting an involvement of selective attention (McMillan et al., 2005). A Ramsey-like account of perception and sensation requires the involvement of numerous mental processes including attention, motivation, memory formation and extinction. In touch with this account, separate neuronal mice subpopulations in the central amygdala selectively encode a wide range of different salient stimuli from various sensory modalities with distinct valences and physical properties (Yang et al., 2023). Furthermore, evidence has been found for a specific role of subregions in the medial parietal cortex for the rapid recognition of distinctive entities such as faces and scenes (Woolnough et al., 2020). The Ramsey's framework commands a reductionistic interpretation of widely used complexity measures, providing a feasible account for the spatial and temporal autocorrelation phenomena that explain various measures of network topology and capture individual and regional variations (Shinn et al., 2023). Describing different visual properties as related and intertwined, Ramsey-like models suggest that a comprehensive picture based on cortical population dynamics is required to explain function, hinting to a system that is less feedforward and more dominated by intracortical signals than previously thought.

In sum, clues from the literature point toward the possibility to build a realistic Ramsey-like model for the cognitive operation of the brain.

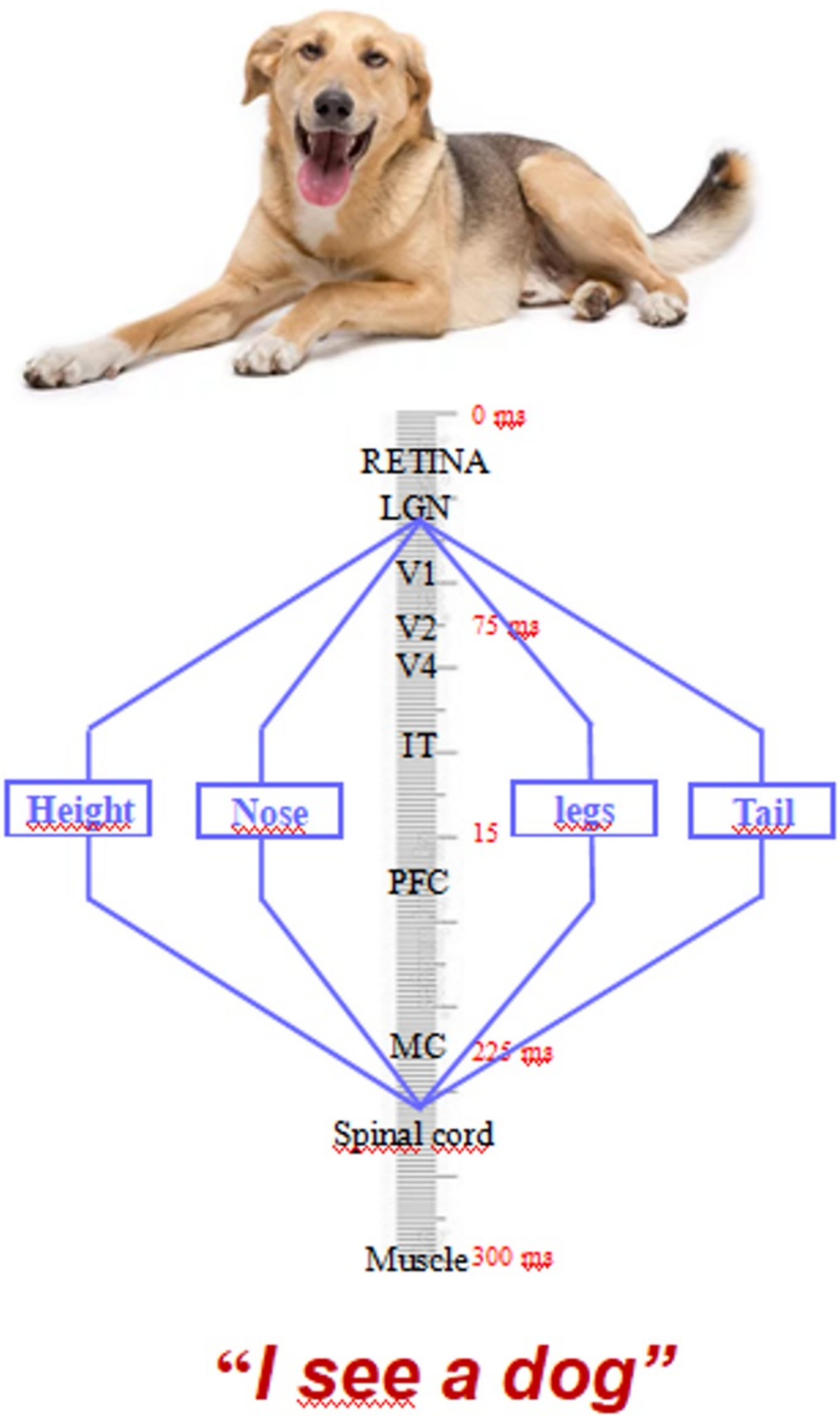

Figure 1. A Ramey-like account of human sensation and perception. The graduated scale at the centre illustrates the latency time (in milliseconds) along the human visual pathway. When an human individual sees a dog, the retina is first activated after 20–40 ms, then they follow the lateral geniculate nucleus (LGN), the primary, secondary and tertiary visual cortices (V1, V2, V3, V4), the infero-temporal area (IT), the prefrontal cortex (PFC), the motor cortex (MC) and the peripheral effectors that generate, after >280 ms, the motor output leading to the assertion *"I see a dog"* (modified from Grimaldi et al., 2023). The Figure depicts four parallel paths, every one processing a single observable variable related with the concept of dog. Just four of the numerous available parallel pathways are illustrated. The

Ramsey-like nervous circuitry is characterized by proximal divergence, central parallel processing and distal convergence.

Conclusions

The human mind is almost always able to recognize a dog, despite dog breeds vary widely in shape, size, color, etc. We suggest that this cognitive phenomenon can be tackled via a methodological and functional approach based on Ramsey sentences. A Ramsey-like approach to the cognitive activities such as sensation and perception suggests that mental states can be intended in terms of parallel and simultaneous activation of specific cortical subareas. A Ramsey-like approach suggests that the brain does not split the environment perceived as a whole in manifold components, rather manifold components act as inputs to analytically build the mental representation of the surrounding environment. In terms of computer science, fitting, optimization and objective function of the target output are not anymore achieved via learning algorithms (Kanwisher et al., 2023), rather via a huge but finite number of parallel computations, each one regarding a single feature of the input's training data. This means that Ramsey sentences might contribute to the human ability to represent relations between concepts, to code relationships between items sharing basic conceptual properties (e.g., dog and wolf) and to simultaneously represent associative links between dissimilar items co-occurring in peculiar contexts (e.g., dog and bone) within a single, unified concept (Jackson et al., 2015).

The possibility to use Ramsey sentences in neuroscientific contexts leads to intriguing outcomes. First of all, criticism can be levelled at the concepts of pair correlation and predictive code in the brain. The paradigm of pair correlations suggests that different brain regions work together in a coordinated and strongly correlated manner, where sensory responses result from comparisons between bottom-up inputs and contextual predictions (Uran et al., 2022), achieving a collection of morphisms, i.e., maps between objects and their mental representation. In other words, the brain would recognize a dog by performing pair correlation between the immaterial dogs stored in the brain and the one that is currently watched. On the contrary, the Ramsey's account points towards the counterintuitive hypothesis that the brain does not perform matching between external visual inputs and an internal database, or between a model output and a target output matching the error. All the content of a dog that can be observed is explicitly expressed in a long and complex formal sentence generated in the parallel circuitry of the brain. No mental interpretation of vague, non-observable entities is required, rather observational terms capable of empirical confirmation are achieved. This means that the concept of the dog arises naturally from the parallel flow occurring in different subcortical and cortical areas, without the need of pre-stored mental concepts of the dog and of comparison among observable variables expressed in terms of atomic propositions. Paraphrasing Ramsey, the concept of a dog must be built out of simple observational facts, leaving apart the use of a set of axioms and a dictionary of correspondence rules that translates the primary language into the secondary language. Theoretical terms contribute to the observational component of a theory not through bridge laws connecting theoretical and observational concepts, rather the only bridge principle is the given theory itself (Hintikka 1997). Further, a Ramsey-like circuitry permits the addition of parallel lines to perform always new atomic propositions o improve and enlarge the very definition of terms such as "*dog*".

A Ramsey-like approach to cognitive activities cast doubts on the utility of the energetically expensive long-term memory storage in the brain. Engrams of specific memories are thought to be distributed and stored in ensembles of neurons across multiple brain regions that are functionally connected, via cross-regional recruitment of presynaptic neurons initiated by downstream memory neurons (Lavi et al., 2022; Roy et al., 2022). The Ramsey account suggests that the brain is a collection of numerous but finite functional units, everyone performing a single operation. The concept of dog arises from the simultaneous, sparce activation of many single parallel processes. What is termed memory ends up depending on the countless sparce sources that have been activated together, keeping in mind that the same anatomical unity can be recruited during different cognitive tasks. In long times, the single, variable features of a dog (such as breed, cheek features, neck length, and so on) have been gathered in scattered and parallel brain circuits. In touch with this theoretical account, it has been demonstrated in monkeys that environmental inputs drive neuronal activity by sculpting cortical domain formation (Arcaro et al., 2017). Selective viewing behavior at birth bias category-specific visual responses toward retinotopic representation, with no need of category-specific templates.

Another outcome of using Ramsey sentences for the assessment of human cognitive activities is the demise of probabilistic and Bayesian accounts of choices and beliefs (Cazettes et al., 2023). Probabilistic and classical inference patterns have been suggested to subtend both artificial and natural neural networks. Looking for the statistics of features in images, artificial and natural systems might use gradient descent learning that builds representations that are more sensitive to common features (Benjamin et al., 2022). Bayesian accounts point towards the brain as an inferential machine equipped with a priori beliefs (Ramstead et al., 2020). For instance, a Bayesian inference semantics for probabilistic reasoning in natural language successfully deals with various probabilistic semantic phenomena, including generalised quantifiers (Bernardy et al., 2019). On the contrary, Ramsey sentences guarantee neural multiplexing that does not require outputs based on pondering of probabilities. The Ramsey sentence displays a crucial component that runs counter probabilistic interpretations of human choices and beliefs, namely the existential quantifier. Thanks to the existential quantifier, the assertion "*I see a dog*" must be treated as an evolving existential statement such as "*there is at least one thing termed dog that…*". The assertion becomes a shorthand expression of all the judgements and beliefs about dogs whose consequences will meet the future successfully or not. The possibility that "*I see a dog*" might be determined in a way that John is unable to statistically anticipate must not be foreclosed, since "*I see a dog*" is open to John's future revision due to further additions made within the scope of the quantifier (Misak 2020). Leaving apart probabilistic accounts, we suggest that a Selfridge's Pandemonium-like "the-winner-takes-all" mechanism (Tozzi and Peters, 2018) might provide a plausible account subtending the coalescence of the single observational features in the final output.

The use of a Ramsey-like approach to human cognitive activities has limitations. It has been objected that Ramsey sentences do not carry out a genuine elimination of theoretical concepts (Majer 1989; Koslow 2008). It has been pointed out that Ramsey sentences cannot provide a satisfactory formalism to functionalism, being just a type of behaviourism plus a cardinality constraint on the number of relations between mental-relevant events (Lowther 2022). Another objection can be raised: Ramsey sentences could be unfeasible in the human brain, since they would require a huge amount of time and computational power. The objection concerning time is easily removed if we consider that parallel networks are able to simultaneously perform a finite but huge number of operations. Yet, the requisite of high amount of computational power for the functioning of Ramsey-like's brain mechanisms is not necessarily bad. It is well-known that huge, overparametrized neural networks do help for robustness, i.e., for the ability of computer systems to cope with both erroneous inputs and errors during execution. Bubeck et al. (2021) investigated the balance between the size of a neural network (i.e., the number of neurons k) and its robustness as measured by the Lipschitz constant of the data fitting model $f \in Fk(\psi)$). To accomplish a robust two-layers neural network and perfectly fit the data, a huge amount of information is required, corresponding to one neuron per datapoint (Bubeck and Sellke, 2022). In sum, the large size of a network required by Ramsey sentences permits the achievement of optimal smoothness robustness.

Apart from neuroscience, Ramsey approaches could be used for the evaluation of other biological systems too. For example, Ramsey sentences could provide a systematic perspective on the intercellular wiring of the human immune system. The human immune system's distributed network of cells circulating throughout the body is dynamically connected via interactions between cell-surface proteomes (Shilts et al., 2022). Ramsey sentences might be used to systematically map direct protein interactions and receptor wiring across the surface proteins detectable on human leukocytes.

To sum up, the Ramsey sentence might stand for a versatile device that can be used not just as a methodological tool to cope with biophysical affairs, but also as a reliable model to describe the real functioning of biological systems.

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