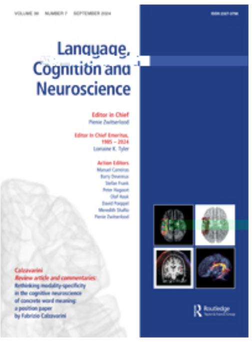

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Not clear what properties are found or should be: a commentary on Calzavarini (2024)

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COMMENTARY

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Not clear what properties are found or should be: a commentary on Calzavarini (2024)

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characteristic that the peripheral V1 carries low-spatial-resolution visual information. Cheung et al. (2009) reported a case with severe acuity reduction and exhibited that the foveal V1 of the subject responded to tactile input requiring high spatial resolution (i.e. Braille reading), while the peripheral V1 responded to visual stimuli perceived by the subject's remaining vision. That is, the responses to tactile stimuli respected the similar visual foveal-peripheral arrangement that processes fine-grained versus coarse spatial properties. Such a principle has also been observed in the resting-state functional connectivity patterns in the V1 of congenitally blind individuals (Striem-Amit et al., 2015). We are not aware of other types of spatial representation that have been tested positively in nonvisual modalities in V1.

Importantly, beyond the visual cortex, evidence is lacking for the "supramodal" representation of content properties in other primary regions of sensory (e.g. auditory, somatosensory, olfactory) or motor modalities. Of course, we are not arguing against the possibility that even the so-called primary cortices represent modality-invariant "properties". We simply emphasise that the current evidence is too thin to conclude that "primary regions also show multi-modality plasticity". Further studies are warranted to more directly test representation principles in not only primary visual, but also in other sensory/motor cortices to uncover the extent and nature of the potential modality-invariance representations across various processing hierarchies and systems.

Theoretical proposal for a feature-based view of brain organisation: not so clear either

The Review proposes that instead of looking at the conceptual organisation as modality-specific, a better hypothesis is to look at it as property-specific. The critical question of the research endeavour then becomes – what are properties? What kind of properties should be postulated and tested? Is there a set of primitive, atomic properties having a theoretical advantage over others? These are not easy questions and have long haunted the research of conceptual representations. The Review is mute on how to proceed to study the "property" representations, making it short of a tangible framework. We here pose two immediate questions most relevant to the current discussion.

First, how to evaluate the validity of a property as the effective information content of a neural representation? Take the most extensively studied region – the ventral occipitotemporal cortex (VOTC) as an example. It has been shown to process multiple types of information, such as shape (e.g. Amedi et al. (2007); Peelen et al. (2014)), size and/or manipulability (e.g. He et al. (201); Konkle and Oliva (2012)), and animacy (e.g. Mahon et al. (2009)), across multiple modalities. Do shape, size, or animacy counts as "properties"? If so, are they equally represented, or one is more dominant or fundamental than the others? How do we deal with the ambiguity of natural language when describing a type of representation as a property using word labels? For instance, when we talk about "shape" as a property, are we talking about holistic object shape or potentially more primitive geometric properties (different components of shape, e.g. curvature versus rectilinear)? What about properties that could not be labelled with linguistic concepts? For instance, Fan et al. (2021), combining computational vision models and fMRI experiments, employed a parametric modulation method and identified the voxel-wise representation weights in VOTC of a comprehensive set of visual features, much broader than the conventionally studied object "properties". Should they all become candidates for conceptual/semantic properties to be tested?

Another significant question is the relationship between modalities and properties. One can push the multimodal characteristics of a property to primary sensory cortices, but ultimately the starting point of the signal into the brain is sensory-modality-specific. How do modality-specific signals transform into multimodal properties? Is multimodality a necessary criterion for a property? Again consider the VOTC. Evidence shows that it represents information that can only be derived from one modality such as colour (e.g. Wang et al. (2020)); it also shows a complex interaction between modality and object domains, such that the modality-sensitivity is modulated by how transparently shape maps with action in the object (e.g. Bola et al. (2022); see Bi et al. (201) for discussion). Abandoning the information modality perspective misses both important questions and clues to the understanding of information representation, even in the "supramodal brain regions".

Taken together, while we appreciate the comprehensive review of empirical evidence challenging the modality-based view of neurosemantics, we reason that the "property-based, modality-invariant" framework, in the current stage, is not an articulated scientific theory yet. Progress can only be made by making concrete hypotheses and empirical tests about the informational contents, as well as the relationship between such information and modalities, at the target neural system.

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