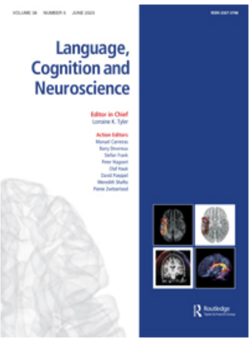

Language, Cognition and Neuroscience

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/plcp21

Not clear what properties are found or should be: a commentary on Calzavarini (2023)

Ziyi Xiong, Haoyang Chen & Yanchao Bi

To cite this article: Ziyi Xiong, Haoyang Chen & Yanchao Bi (2023): Not clear what properties are found or should be: a commentary on Calzavarini (2023), Language, Cognition and Neuroscience, DOI: 10.1080/23273798.2023.2210235

To link to this article: https://doi.org/10.1080/23273798.2023.2210235

Published online: 18 May 2023.

LANGUAGE, COGNITION AND NEUROSCIENCE
https://doi.org/10.1080/23273798.2023.2210235

COMMENTARY

Not clear what properties are found or should be: a commentary on Calzavarini (2023)

Ziyi Xiong[a,b]†, Haoyang Chen[a,b]† and Yanchao Bi [a,b,c]

[a]State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, People's Republic of China; [b]Beijing Key Laboratory of Brain Imaging and Connectomics, Beijing Normal University, Beijing, People's Republic of China; [c]Chinese Institute for Brain Research, Beijing, People's Republic of China

ABSTRACT
This is a commentary on Calzavarini (2023), Rethinking Modality-Specificity in the Cognitive Neuroscience of Concrete Word Meaning: A Position Paper. DOI: 10.1080/23273798.2023.2173789 .

ARTICLE HISTORY
Received 10 April 2023
Accepted 25 April 2023

Main text

The modality-specificity has been identified as a major architectural principle of how the human brain processes information. Whether it is also the principle dimension in which conceptual knowledge is organised has been one of the major debates of the neural underpinning of semantics. Calzavarini's review (2023) (referred to as the Review hereafter) synthesises up-to-date empirical evidence, including those showing that even the primary sensory cortices exhibit a higher degree of multimodality than previously assumed, and argues for a strong position of abandoning the modality-specific premise and opting for a "property-specific and modality-invariant" approach to study semantic representation. We agree that the evidence and arguments are too rich to defend the modality-specific framework for (semantic) knowledge representation. However, simply changing the word from "modality" to "property" is not productive without being clear about the empirical and theoretical stands. We wish to point out a few major confusions that need to be clarified to make progress.

Empirical findings of the primary sensory and motor cortices: not so clear yet

One line of strong evidence against the modality-specific view discussed in the Review was that the primary sensory and motor cortices, which were conventionally considered "unimodal" brain regions, have a supramodal nature, and represent modality-invariant spatial information:

> … some studies suggest that V1 might retain its task-specificity even in the absence of visual input, as shown by the selectivity of this region for spatial information in the blind (Ptito et al., 2008; Thaler et al., 2011)

Do we have robust evidence that the primary visual cortex's (V1) activity encodes multimodal (spatial) properties? The two cited studies actually do not show that. Ptito et al. (2008) applied transcranial magnetic stimulation to stimulate the occipital cortex in blind individuals, resulting in reported tactile sensations on their fingers, which is not necessarily related to spatial perception; the activation of V1 for contralateral-preferred (as observed in light-related activity in the V1 in the sighted brain) echolocation tasks was not observed in the late blind subject (Thaler et al., 2011). A recent study failed to observe a significant correlation between the retinotopic response of V1 in echolocation tasks and subjects' echolocation abilities (Norman & Thaler, 2019). Furthermore, most of the "supramodal" or "multimodal" findings showed that V1 is involved in modalities beyond vision, but they either did not directly compare the cross-modality activation patterns to visually-induced ones, or failed to observe positive evidence for **modality-invariant** activation patterns.

There is indeed evidence illustrating modality-invariant activation patterns in V1 that were not cited in the Review, although still scarce. In one recent study, Vetter et al. (2020) found that V1 showed a gradient, such that its peripheral subregions carried more predictive information of environmental sounds than the foveal parts did, in both sighted blindfolded and blind human subjects. The preference for low-spatial-resolution auditory information is consistent with the

CONTACT Yanchao Bi ybi@bnu.edu.cn
†Ziyi Xiong and Haoyang Chen contributed equally

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. (2013); 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. (2016) 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.

Acknowledgements

We thank Xiaosha Wang and Haojie Wen for their helpful discussions.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This work was supported by the STI2030-Major Project under grant [2021ZD0204100 (2021ZD0204104)]; the National Natural Science Foundation of China under grant [31925020]; the Changjiang Scholar Professorship Award under grant [T2016031].

ORCID

Yanchao Bi http://orcid.org/0000-0002-0522-3372

References

Amedi, A., Stern, W. M., Camprodon, J. A., Bermpohl, F., Merabet, L., Rotman, S., Hemond, C., Meijer, P., & Pascual-Leone, A. (2007). Shape conveyed by visual-to-auditory sensory substitution activates the lateral occipital complex. *Nature Neuroscience*, *10*(6), 687–689. https://doi.org/10.1038/nn1912

Bi, Y., Wang, X., & Caramazza, A. (2016). Object domain and modality in the ventral visual pathway. *Trends in Cognitive Sciences*, *20*(4), 282–290. https://doi.org/10.1016/j.tics.2016.02.002

Bola, Ł, Yang, H., Caramazza, A., & Bi, Y. (2022). Preference for animate domain sounds in the fusiform gyrus of blind individuals is modulated by shape–action mapping. *Cerebral Cortex*, *32*(21), 4913–4933. https://doi.org/10.1093/cercor/bhab524

Calzavarini, F. (2023). Rethinking modality-specificity in the cognitive neuroscience of concrete word meaning: A position paper. *Language, Cognition and Neuroscience*, 1–23. https://doi.org/10.1080/23273798.2023.2173789

Cheung, S.-H., Fang, F., He, S., & Legge, G. E. (2009). Retinotopically specific reorganization of visual cortex for tactile pattern recognition. *Current Biology*, *19*(7), 596–601. https://doi.org/10.1016/j.cub.2009.02.063

Fan, S., Wang, X., Wang, X., Wei, T., & Bi, Y. (2021). Topography of visual features in the human ventral visual pathway. *Neuroscience Bulletin*, *37*(10), 1454–1468. https://doi.org/10.1007/s12264-021-00734-4

He, C., Peelen, M. V., Han, Z., Lin, N., Caramazza, A., & Bi, Y. (2013). Selectivity for large nonmanipulable objects in scene-selective visual cortex does not require visual experience. *Neuroimage*, *79*, 1–9. https://doi.org/10.1016/j.neuroimage.2013.04.051

Konkle, T., & Oliva, A. (2012). A real-world size organization of object responses in occipitotemporal cortex. *Neuron*, *74*(6), 1114–1124. https://doi.org/10.1016/j.neuron.2012.04.036

Mahon, B. Z., Anzellotti, S., Schwarzbach, J., Zampini, M., & Caramazza, A. (2009). Category-specific organization in the human brain does not require visual experience. *Neuron*, *63*(3), 397–405. https://doi.org/10.1016/j.neuron.2009.07.012

Norman, L. J., & Thaler, L. (2019). Retinotopic-like maps of spatial sound in primary 'visual' cortex of blind human echolocators. *Proceedings of the Royal Society B: Biological Sciences*, *286*(1912), 20191910. https://doi.org/10.1098/rspb.2019.1910

Peelen, M. V., He, C., Han, Z., Caramazza, A., & Bi, Y. (2014). Nonvisual and visual object shape representations in occipitotemporal cortex: Evidence from congenitally blind and sighted adults. *The Journal of Neuroscience*, *34*(1), 163–170. https://doi.org/10.1523/JNEUROSCI.1114-13.2014

Ptito, M., Fumal, A., De Noordhout, A. M., Schoenen, J., Gjedde, A., & Kupers, R. (2008). TMS of the occipital cortex induces tactile sensations in the fingers of blind Braille readers. *Experimental Brain Research*, *184*(2), 193–200. https://doi.org/10.1007/s00221-007-1091-0

Striem-Amit, E., Ovadia-Caro, S., Caramazza, A., Margulies, D. S., Villringer, A., & Amedi, A. (2015). Functional connectivity of visual cortex in the blind follows retinotopic organization principles. *Brain*, *138*(6), 1679–1695. https://doi.org/10.1093/brain/awv083

Thaler, L., Arnott, S. R., & Goodale, M. A. (2011). Neural correlates of natural human echolocation in early and late blind echolocation experts. *PloS one*, *6*(5), e20162. https://doi.org/10.1371/journal.pone.0020162

Vetter, P., Bola, Ł, Reich, L., Bennett, M., Muckli, L., & Amedi, A. (2020). Decoding natural sounds in early "visual" cortex of congenitally blind individuals. *Current Biology*, *30*(15), 3039–3044. e3032. https://doi.org/10.1016/j.cub.2020.05.071

Wang, X., Men, W., Gao, J., Caramazza, A., & Bi, Y. (2020). Two forms of knowledge representations in the human brain. *Neuron*, *107*(2), 383–393. e385. https://doi.org/10.1016/j.neuron.2020.04.010