Open Peer Commentary

When do rich and noisy experiences yield one memory representation or two?

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Abstract

Excess-capacity learning captures details that improve the stability and generalizability of what is learned, but are those details always integrated into a single representation? Or are they sometimes segregated into distinct, context-specific representations such as intuitive versus scientific theories? Coexisting representations produce errors and inconsistencies in reasoning, making it imperative to identify conditions that distinguish these two learning outcomes.

Cognitive scientists typically assume that experiences are stored as abstractions, with context-specific details stripped away from core regularities, but Dubova and Sloman challenge this assumption on two grounds: there is no neurological evidence that memory is so limited as to require stripped-down representations, and there is no computational evidence that stripped-down representations generalize to new situations better than fully detailed representations. In fact, the opposite is often true.

These two factors motivate the possibility of excess-capacity representations, or representations that integrate the full range of details experienced within a domain, but they also motivate the possibility of coexisting representations, or the construction of multiple representations that segregate details by context (Bélanger et al., 2023). Consider our experience of the sun. We see the sun rise in the east and set in the west each day, implying that the sun orbits the earth. But we learn in school that the earth orbits the sun and that it spins as well, constantly changing our view of the sun. Are both sets of information stored as part of the same representation?

Probably not. We probably have two ways of representing information about the sun: a geocentric representation that captures our everyday, earth-bound observations of the sun's motion and a heliocentric representation that captures our scientific knowledge of the sun's relation to other celestial objects. The possibility of storing two distinct representations of solar information is not precluded by an excess-capacity approach to learning, but it does raise questions about when this happens – when learning "rich and noisy experiences" yields one complex representation or multiple, context-specific representations.

This question is important for at least two reasons. First, our experience of the sun is not unique; many experiences lend themselves to distinct interpretations and, hence, distinct representations. Our experiences with most natural phenomena – heat, motion, gravity, growth, illness, or inheritance – are encoded using intuitive representations that are supplemented by, rather than supplanted with, later-acquired scientific representations (Shtulman & Valcarcel, 2012; Shtulman, 2017).

Coexisting representations emerge in other areas of reasoning as well, including social reasoning, where statistical beliefs coexist with stereotypes (Hammond & Cimpian, 2017); probabilistic reasoning, where algorithmic strategies coexist with heuristics (Swaryandini et al., 2025); evidential reasoning, where firsthand observations coexist with secondhand reports (McCloskey & Zaragoza, 1985); mathematical reasoning, where naïve conceptions coexist with expert ones (Stricker et al., 2021); and metaphysical reasoning, where natural explanations coexist with supernatural ones (Järnefelt, Canfield, & Kelemen, 2015). Coexisting representations are usually established at different times, in different contexts, for different purposes, and they tend to compete rather than converge when used to make inferences or inform decisions.

Indeed, another reason why the question of plurality matters is that multiple representations can cause cognitive conflict – conflict that yields inconsistent responses, inaccurate responses, and response delays. Such problems are, in fact, the main evidence for coexisting representations. They have been documented with tasks designed to elicit incompatible interpretations of the same stimuli across a variety of measures, including statement verifications (Ellefson et al., 2026), categorization judgments (Vosniadou et al., 2018), explanation endorsements (Legare & Gelman, 2008), forced-choice comparisons (Potvin & Cyr, 2017), contextual priming (Harris & Giménez, 2005), lexical priming (Preston & Epley, 2009), mouse tracking (Murray et al., 2021), and neuroimaging (Allaire-Duquette et al., 2021).

For example, in a statement-verification study, participants are asked to make true-or-false judgments as quickly as possible for statements like "the moon orbits the earth" and "the earth orbits the sun." The first statement is true on any representation of the solar system, whereas the second is true on a heliocentric representation but false on a geocentric representation. If participants hold both representations, then responding to the second statement should elicit cognitive conflict, and indeed it does: participants are slower and less accurate when responding to statements of the second type relative to the first.

These studies were originally conducted to demonstrate that earlier-acquired representations are not replaced by later-acquired ones, but they also demonstrate that these representations are functionally distinct. And if they are distinct, then the details associated with the earlier-acquired representation would not contribute to the robustness or generalizability of the later-acquired representation. Instead, they would constitute a different pattern of generalization altogether – a pattern triggered by different contextual cues and prone to systematic error. Put differently, if the "noisy details" of an experience correspond to an alternative interpretation of the experience, then encoding those details in a separate representation would not only compromise the robustness of the original representation but would also interfere with a reasoner's ability to make use of both representations, as they would actively conflict with one another.

That said, Dubova and Sloman do not propose that all learning results in excess-capacity representations, only some learning, and they outline several considerations for assessing the likelihood of forming such representations. Representational coexistence is another consideration to add to the list. Many domains of experience that could be represented holistically appear instead to be represented dichotomously, with details of those experiences segregated by when they are learned, where they are learned, or how they are interpreted at encoding. A sunset, for example, could be represented as an occurrence of the earth rotating away from the sun and stored with other heliocentric details about the sun, but it is instead represented as an occurrence of the sun moving behind the earth and stored with other geocentric details, at least for most people.

Determining when and why learners establish two (or more) representations of a domain is an empirical challenge on par with determining the expressivity of particular learning mechanisms and the capacity those mechanisms need to capture the details of particular experiences. Dubova and Sloman's analysis of the computational demands of distinct learning regimes provides an apt framework for studying not only high-capacity representations but also coexisting representations – a recurrent feature of higher-order cognition that went unappreciated and unexplored for decades given the ingrained assumption that learners extract a single, optimally abstract representation of each domain they encounter.

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References

Allaire-Duquette, G., Brault Foisy, L. M., Potvin, P., Riopel, M., Larose, M., & Masson, S. (2021). An fMRI study of scientists with a Ph. D. in physics confronted with naive ideas in science. *NPJ Science of Learning*, *6*, 11. https://doi.org/10.1038/s41539-021-00091-x

Bélanger, M., Potvin, P., Horst, S., Shtulman, A., & Mortimer, E. F. (2023). *Multidisciplinary perspectives on representational pluralism in human cognition*. Routledge.

Ellefson, M. R., Wang, R., Britton, A., Godfrey, H., & Feeney, A. (2026). The roles of switching and inhibition in adult counterintuitive scientific thinking. *Cognition*, *268*, 106377. https://doi.org/10.1016/j.cognition.2025.106377

Hammond, M. D., & Cimpian, A. (2017). Investigating the cognitive structure of stereotypes: Generic beliefs about groups predict social judgments better than statistical beliefs. *Journal of Experimental Psychology: General*, *146*, 607–614. https://doi.org/10.1037/xge0000297

Harris, P.L., & Giménez, M. (2005). Children's acceptance of conflicting testimony: The case of death. *Journal of Cognition and Culture*, *5*, 143–164. https://doi.org/10.1163/1568537054068606

Järnefelt, E., Canfield, C. F., & Kelemen, D. (2015). The divided mind of a disbeliever: Intuitive beliefs about nature as purposefully created among different groups of non-religious adults. *Cognition*, *140*, 72–88. https://doi.org/10.1016/j.cognition.2015.02.005

Legare, C. H., & Gelman, S. A. (2008). Bewitchment, biology, or both: The coexistence of natural and supernatural explanatory frameworks across development. *Cognitive Science*, *32*, 607–642. https://doi.org/10.1080/03640210802066766

McCloskey, M., & Zaragoza, M. (1985). Misleading post-event information and memory for events: Arguments and evidence against memory impairment hypotheses. *Journal of Experimental Psychology: General*, *114*, 1–16. https://psycnet.apa.org/doi/10.1037/0096-3445.114.1.1

Murray, G., Willer, C. J., Arner, T., Roche, J. M., & Morris, B. J. (2021). Contextualized knowledge reduces misconceived COVID-19 health decisions. *Journal of Applied Research in Memory and Cognition*, *10*, 381–391. https://doi.org/10.1016/j.jarmac.2021.07.007

Potvin, P., & Cyr, G. (2017). Toward a durable prevalence of scientific conceptions: Tracking the effects of two interfering misconceptions about buoyancy from preschoolers to science teachers. *Journal of Research in Science Teaching*, *54*, 1121–1142. https://doi.org/10.1002/tea.21396

Preston, J., & Epley, N. (2009). Science and god: An automatic opposition between ultimate explanations. *Journal of Experimental Social Psychology*, *45*, 238–241. https://doi.org/10.1016/j.jesp.2008.07.013

Shtulman, A. (2017). *Scienceblind: Why our intuitive theories about the world are so often wrong*. Basic Books.

Shtulman, A., & Valcarcel, J. (2012). Scientific knowledge suppresses but does not supplant earlier intuitions. *Cognition*, *124*, 209–215. https://doi.org/10.1016/j.cognition.2012.04.005

Stricker, J., Vogel, S. E., Schöneburg-Lehnert, S., Krohn, T., Dögnitz, S., Jud, N., Spirk, M., Windhaber, M. C., Schneider, M., & Grabner, R. H. (2021). Interference between naïve and scientific theories occurs in mathematics and is related to mathematical achievement. *Cognition*, *214*, 104789. https://doi.org/10.1016/j.cognition.2021.104789

Swaryandini, G., Graham, J., Griffith, S., Grilo, V., Ruzzante, F., Zhang, X., Yeung, S. K., Mangiarulo, M., Basarkod, G., Ng, C., Parker, P., Tangen, J., Saeri, A., Grundy, E., Slattery, P., & Noetel, M. (2025). Systematic review and meta-analysis of educational approaches to reduce cognitive biases among students. *Nature Human Behaviour*, *9*, 2510–2538. https://doi.org/10.1038/s41562-025-02253-y

Vosniadou, S., Pnevmatikos, D., Makris, N., Lepenioti, D., Eikospentaki, K., Chountala, A., & Kyrianakis, G. (2018). The recruitment of shifting and inhibition in on-line science and mathematics tasks. *Cognitive Science*, *42*, 1860–1886. https://doi.org/10.1111/cogs.12624