

CROSS TALK

Crosstalk rebuttal: Marr's three levels of analysis are not useful as a framework for neuroscienceMáté Lengyel^{1,2} ¹Computational and Biological Learning Lab, Department of Engineering, University of Cambridge, Cambridge, UK²Center for Cognitive Computation, Department of Cognitive Science, Central European University, Budapest, Hungary

Email: m.lengyel@eng.cam.ac.uk

Handling Editors: Francisco Sepúlveda & Vaughan Macefield

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Pillow (2024) provides further evidence that distinguishing Marr's three levels of analysis (Marr, 1982) is an altogether different affair from advocating the primacy of any one of those levels. In my previous article (Lengyel, 2024), I presented arguments for the usefulness of the former but the potential risks of the latter. Much of the arguments of Pillow (2024) are also about the inadequacy of the latter, so we are in agreement on that. What we do not agree on is Marr's stance on the primacy of the computational level in general. In my reading, Marr did not advocate for such a generic primacy. Instead, it was in the *specific* historical context of vision research at the time, that he – and in fact, already Barlow (1961) – felt computational-level analyses needed a boost.

We also agree that it should not be expected that all research projects will fit neatly into exactly one of Marr's levels. However, I argue that it is precisely the three levels that help us appreciate even better the value of such misfits by recognising how they bridge different levels. In other words, I see Marr's levels as signposts for navigating the space of approaches in (theoretical) neuroscience, rather than Procrustean categories – and as such, I find them useful.

As to the specific case of recurrent neural network models, their place in the taxonomy depends on the kind of questions they are used to answer. After

all, such questions form the very definition of the three levels. Classical approaches with heuristically picked parameters (to which Marr could have referred) answer questions somewhere between the algorithmic and implementational levels. However, when their parameters are chosen to be optimal for performing some task – either through analytical derivation (Deneve et al., 2001; Lengyel et al., 2005) or numerical optimisation (an approach that has recently 'surged in popularity,'; see e.g. Mante et al., 2013) – they are examples of computational-level analysis (though sometimes additional analytical work is necessary to glean deeper computational insights into their workings; Echeveste et al., 2020; Stroud et al., 2023).

As it happens, we also agree on the non-uniqueness and imperfect nature of Marr's taxonomy, and even on our favourite alternative taxonomy (Dayan & Abbott, 2005). However, beside normative and descriptive approaches, it is also important to distinguish the third approach from that taxonomy: mechanistic modelling. Nevertheless, to me, the glass is half full: Marr's taxonomy is good enough, and certainly more useful than no taxonomy at all, or engaging in lengthy debates on what a new consensus taxonomy should be.

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