Perception and cognitive control in rationally inattentive child behaviour

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Abstract

Astle (2024) and Mani (2024) raise important questions about the representativeness of the theory and neural network model presented in Jones et al. (2024). In response, we briefly lay out future research priorities and the implications of a fully developed theory of rational inattention for how we think about, measure, and respond to individual differences in child development.

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Astle (2024) and Mani (2024) raise important questions about the representativeness of the theory and neural network model presented in Jones et al. (2024). Astle (2024) notes that learning difficulties are rarely so discrete and rarely accompany areas of *absolute* rather than *relative* strength (Goh et al., 2021). Meanwhile, Mani (2024) questions the neurocognitive correlate of the network's cost function, and questions whether the model captures the developmental emergence of meta-cognitive awareness of knowledge gaps that drives information selection (De Eccher et al., 2024). We fully embrace these commentaries, and agree that the theory and model presented in Jones et al. (2024) require development in order to align more faithfully with child behaviour.

The deficits instantiated in Jones et al. (2024) are highly abstract, affording them a discreteness that is unlikely if lower-level deficits are modelled more accurately (see Jones et al., 2024, section 2.3 for rationale). Absolute domains of strength emerge in this network because noisy channels compete with channels entirely unaffected by perceptual imprecision. Crudely, then, generalised deficits and relative rather than absolute areas of strength may be simulated in this architecture by reducing the precision of multiple channels, making some more precise than others. However, to capture rich and experimentally verifiable cascading effects and cross-domain interactions it will be necessary to move beyond using an abstract rendering of channel precision as proxy.

As a starting point, we might imagine integrating the decision making model of Jones et al. (2024), which 'brackets out' the nature of perceptual experience, with low-level sensory modelling work of the form presented in Jones et al. (2023), which explains variance in language acquisition as a function of variance in the precision of neural responses from the cochlea. Such an approach may help to strengthen our claim that relatively subtle primary neurological deficits may drive the behavioural entrenchment of learning difficulties via rationally inattentive behaviour; a critical claim of the target article which speaks to Mani's (2024) closing remarks regarding the capacity of the framework to explain causal origins.

We believe that the neural network presented in Jones et al. (2024) does illustrate the emergence of metacognitive awareness described by Mani (2024), despite ourselves not using this term[1]. The network initially attends evenly across its environment, but later redistributes its attentional preferences as a function of learning progress, plotting a trajectory towards increasingly rich model-based exploration and learning underpinned by a single, plastic architecture (e.g., Jones et al., 2024, Figure 1). Training therefore instantiates bi-directional information flow between perceptual input and top-down cognitive control, with 'firewall' effects seen in the cost functions of trained networks with precision deficits. For instance, the cost function of the network with simulated developmental language disorder and dyslexia (e.g., Jones et al., 2024, Figure 5) evolves from

$$(1) \qquad speech\ MSE \times\ speech\ weight + text\ MSE\ \times\ text\ weight + numeric\ MSE \times\ numeric\ weight + social\ MSE\ \times\ social\ weight$$

to

$$(2) \qquad numeric\ MSE \times\ numeric\ weight + social\ MSE\ \times\ social\ weight$$

as the speech and text weights shift incrementally to zero, removing these terms. This makes explicit our claim that children work with subjective cost functions tailored by their perceptual experience. That said, we fully agree with Mani (2024) that considerable work is required to develop neurocognitively faithful cost functions. Ultimately, this should balance uncertainty reduction with reward procurement across varying timescales. It may be expedient, for instance, to attend to information sources that are endogenously imprecise when expected reward is high. Moreover, immediate uncertainty reduction is not always the best policy in the long-term – an often-cited game theoretic example is that it might be unwise to remove the mask of your captor. In updating weights exclusively as a function of the derivative of instantaneous error, the neural network model of Jones et al. (2024) is unable to capture such phenomena.

The commentaries highlight that the rational inattention framework requires elaboration and similarly that the associated model, which represents just one computational approach among many, constitutes a form of *ansatz*: a first assumption to be improved through ongoing empirical investigation. Capturing the authentic perceptual experience and cognitive

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[1] We avoid this term because top-down control is not necessarily a conscious process, as the word 'awareness' suggests.

control profile of the child is an important next step in reconciling the computational rationality framework with models of neurodivergent child behaviour. The result of this reconciliation would be, as Astle (2024) notes, a robust framework that may help to strengthen existing calls to modify, as far as possible, the child's learning environment to accommodate their relative strengths, rather than to pursue characteristically ineffective programmes of clinical intervention (see also Jones & Westermann, 2022).

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