CEREBELLAR FORWARD MODELS AND THEIR ROLE IN AUDITORY PROCESSING

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Evidence is accumulating of the cerebellum as a rapidly evolved brain structure supporting a previously underappreciated variety of cognitive processes. This goes far beyond its more established role in motor control is a promising subject of study for cognitive science. The present work aims to shed light on cerebellar contributions to sensory feedback prediction mechanisms in auditory processing. The cerebellum is well-known for its role in the anticipation of somatosensory feedback following movements, but how far this function can be generalised across modalities, and how much it is tied to self-generated movements as opposed to more general sensory consequences, is less well understood. Understanding the role of the cerebellum during predictive auditory processing can serve as a guide for how to approach the more general questions of cerebellar contributions to cognition, the evolution of these capacities and the consequences of their potential disruption. It can also help us to form new predictions about the relationship between sensorimotor processing and cognition. To be able to anticipate the auditory consequences of motor acts is especially interesting in the context of vocal learning, in which case the function of sensory feedback prediction goes beyond being predicting a mere side-effect of a movement, but instead becomes crucial for the evaluation of the accuracy of the vocalisation (Torgeir Moberget & Ivry, 2016). Whether or not self-generated speech in this case employs different mechanisms from externally generated speech is an open question which we aim to explore further.

Research on the cerebellum has recently gained a lot of momentum, as its role as an important player during a wide variety of cognitive processes has become more established. A recent comprehensive investigation on cerebellar activation during a wide variety of motoric, cognitive and affective test conditions has highlighted the involvement of the cerebellum in a diverse set of processes such as language comprehension, autobiographical recall, and mental arithmetic (King, Hernandez-Castillo, Poldrack, Ivry, & Diedrichsen, 2019).

The cerebellum has furthermore been in the spotlight of evolutionary research concerning recent developments in the evolution of modern human cognition, which makes it an interesting candidate of study for understanding the evolutionary history of modern human specific capacities such as language (Barton & Venditti, 2014; Gunz et al., 2019).

The well-established consensus about cerebellar function during motor coordination suggests that the cerebellum generates internal forward models. These are thought to serve as predictors of anticipated sensory feedback of movements in order to compensate for the inherent timing delay that comes with sensory feedback (Albus, 1971; Marr, 1969).

The general idea that this concept could be applied not only to cerebellar motor function but also to the role the cerebellum plays in cognition have been articulated on many occasions (famously by Ito, 2008), but the specific dynamics of such a mechanism are yet to be understood clearly. To study the application of internal forward models supported by the cerebellum and their role in non-motor functions, we can turn to auditory language processing as an example of cerebellar involvement in sensory processing in the absence of movement.

We will present a systematic review of the state of the art of our knowledge on the role of the cerebellum during auditory processing. We will pay special attention to insights that can be gained from clinical research on auditory hallucinations. It is a widely held belief that the sense of agency of one's own actions depends on accurate prediction of the anticipated sensory feedback to those actions, and that this function relies in part on the (Moberget et al., 2018). The malfunctioning of these predictive processes may further be linked to a specific type of auditory hallucination involving disrupted sensory feedback prediction (Andreasen & Pierson, 2008). We evaluate the current evidence on a biological, mechanistic/computational and behavioural level in order to gain a clearer understanding of how the medical literature can inform our theories of cerebellar involvement in auditory processing and sensory processing generally, and we highlight the different levels on which this affects language behaviour and cognition more generally.

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