LETTER TO THE EDITOR

Morality: incomplete without the cerebellum?

Asli Demirtas-Tatlidede¹ and Jeremy D. Schmahmann²

¹ Behavioural Neurology and Movement Disorders Unit, Department of Neurology, Istanbul University, Istanbul Faculty of Medicine, Istanbul, Turkey
² Ataxia Unit, Cognitive Behavioural Neurology Unit, Laboratory for Neuroanatomy and Cerebellar Neurobiology, Department of Neurology, Massachusetts General Hospital and Harvard Medical School, Boston, MA, USA

Correspondence to: Jeremy D. Schmahmann, MD, Department of Neurology, Massachusetts General Hospital, CPZS-340, 175 Cambridge Street, Boston, MA 02114, USA
E-mail: jschmahmann@partners.org

Sir,

Fumagalli and Priori (2012) present an overview of the functional neuroanatomy of morality, in which they discuss cortical and subcortical structures involved in normal and aberrant moral behaviour. Recognizing the complexities of moral judgement and action, the authors invoke in their dissertation a consideration of cognitive processes critical to morality. These include theory of mind, social cognition, moral decision processing, conflict resolution and emotional regulation. The authors also analyse aggression, violence and psychopathy as specific indicators of subverted morality. These high level human attributes are embodied in distributed neural systems comprising association and paralimbic cortical areas and subcortical nuclei, all included in the review. Fumagalli and Priori (2012) do not, however, mention the cerebellum, which renders incomplete the full consideration of the neural basis of moral cognition.

Anatomical investigations in non-human primates show that the cerebellum is reciprocally interlinked with precisely those areas discussed in the review implicated in the neural basis of reason, emotion, moral behaviour and aggression. These include the dorsolateral prefrontal, medial prefrontal, anterior and posterior cingulate, superior and middle temporal, posterior parietal and posterior parahippocampal cortices and the hypothalamus (Schmahmann and Pandya, 1997; Strick et al., 2009; Schmahmann, 2010). Further, the basis pontis and thalamus are obligatory way stations in the feedforward and feedback limbs of the cerebellar connections with the cerebral hemispheres, and physiological studies point to cerebellar connections with the amygdala, septum and hippocampus (Heath and Harper, 1974; Schmahmann, 1991).

The cerebellum is essential not only for motor control, but also for intellectual function, decision making, and emotional processing (Heath et al., 1974; Berman et al., 1978; Leiner et al., 1986; Schmahmann, 1991; Schmahmann and Sherman, 1998; Baumann and Mattingley, 2012; Rosenbloom et al., 2012) including the behaviours underlying anger, aggression and violence that are pertinent to moral judgement and action (Scarpa and Raine, 1997; Moll et al., 2005; Nelson and Trainor, 2007; Ugazio et al., 2012). Neuroimaging studies underscore the cerebellar contribution to several aspects of moral processing discussed by Fumagalli and Priori (2012): theory of mind (Brunet et al., 2000; Gallagher et al., 2003; Grèzes et al., 2004), moral judgement (Harada et al., 2009), deception (Gamer et al., 2007), and empathy (Singer et al., 2004; Jackson et al., 2005; Shamay-Tsoory et al., 2005; Lamm et al., 2007; Schulte-Rüther et al., 2007; Lang et al., 2011). Impairments of theory of mind and/or social cognition are reported in patients with cerebellar damage (Roldan Gerschcovich et al., 2011) and spinocerebellar ataxias (Garraud et al., 2008; Sokolovsky et al., 2010; D’Agata et al., 2011). Lability of mood is described with irritability, anger, aggression and pathological laughing and crying in patients with both acquired and developmental cerebellar lesions (Schmahmann and Sherman, 1998; Levisohn et al., 2000; Parvizi et al., 2007; Schmahmann et al., 2007) and spinocerebellar ataxias (Genis et al., 1995; Stone et al., 2001; Rolfs et al., 2003). These clinical reports are consistent with behavioural studies in

© The Author (2013). Published by Oxford University Press on behalf of the Guarantors of Brain. All rights reserved.
For Permissions, please email: journals.permissions@oup.com
animals of the role of the cerebellum (vermis and fastigial nucleus in particular) in sham rage, predatory attack, and aggression (Reis et al., 1973; Berman et al., 1978; Kling et al., 1979).

Accepting that human morality is embodied in a complex system consisting of a wide array of neural circuits that operate as functional modules in a decentralized, highly parallel fashion selectively engaged by environmental demands to produce adaptive behaviour (Funk and Gazzaniga, 2009), a central question emerges – what is regulating these distributed systems? We have suggested, in the dysmetria of thought theory (Schmahmann, 1991, 2010), that the cerebellum modulates behaviour automatically, without conscious awareness, optimizing behaviour around a homeostatic baseline appropriate to context. Loss of this universal cerebellar transform leads to dysmetria of behaviour around a homeostatic baseline appropriate to context. The demonstration functional topography in cerebrocerebellar circuits for sensorimotor, cognitive and emotional behaviours (Schmahmann and Pandya, 1997; Strick et al., 2009; Buckner et al., 2011; Stoodley et al., 2012) provides the basis for segregated functional modules in the cerebellum that subserve high level human attributes.

Fumagalli and Priori (2012) argue that brain stimulation may hold promise as a therapeutic intervention for the ‘moral brain’ and abnormal moral behaviour. This issue certainly raises ethical, political, and other concerns, but there are intriguing reports of the beneficial effects of electrical stimulation applied to the brain, cerebellum in particular, showing improvement in intractable aggressive and violent behaviours in patients with epilepsy (Cooper et al., 1976). Further, stimulating electrodes implanted over vermal and paravermal regions of the cerebellum produced substantial improvements in patients with uncontrollable aggression, severe neurosis and schizophrenia (Heath, 1977). These studies suggested that aggression may be ameliorated by enhancing cerebellar modulation of the same functional networks postulated by Fumagalli and Priori (2012) to be essential for moral behaviour. In a preliminary safety study in patients with schizophrenia we used transcranial magnetic stimulation, a contemporary analogue of electrical stimulation, applied to the cerebellar vermis and showed it to be safe while producing clinically relevant improvements particularly in negative symptoms (Demirtas-Tatlidede et al., 2010). It is conceivable that non-invasive cerebellar stimulation using transcranial magnetic stimulation can ameliorate aggression and violence, as was suggested by the electrical stimulation studies of Cooper et al. (1976) and Heath (1977), but this remains to be shown. It is also a fair cry from the claim of attempting brain/cerebellar stimulation to improve morality judged to be deficient.

In summary, the cerebellum is an essential node in the brain circuits critical to the cognitive and emotional processes that underlie morality. This recognition has theoretical implications for brain organization and function, and potential practical application for therapeutic intervention within the tightly controlled constraints of unequivocal clinical necessity. The possible neurobiological underpinnings of morality are worthy of study, but on the topic of proposed interventions, healthy doses of introspection, scepticism, caution and Human Study Committee oversight are warranted.

**Funding**

Supported in part by NIH RO1 MH06044, the National Ataxia Foundation, National Organization for Rare Disorders, and the Sidney R. Baer Jr, Birmingham and MINDlink Foundations.

**References**

Heath RG, Harper JW. Ascending projections of the cerebellum fastigial nucleus to the hippocampus amygdala and other temporal lobe sites.
Reis DJ, Doba N, Nathan MA. Predatory attack, grooming, and consummatory behaviors evoked by electrical stimulation of cat cerebellar nuclei. Science 1973; 182: 845–47.
Schmahmann JD, Sherman JC. The cerebellar cognitive affective syndrome. Brain 1998; 121: 561–79.