Chapter 55
Speech and Language

Peter Mariën and Kim van Dun

Abstract The traditional view of the cerebellum as the sole coordinator of sensorimotor function has been substantially redefined during the past decades. Neuroanatomical, neuroimaging and clinical studies have extended the role of the cerebellum to the modulation of cognitive, affective and social processing. Neuroanatomical studies have demonstrated cerebellar connectivity with the supratentorial association areas involved in higher cognitive, affective and social functioning, while functional neuroimaging and clinical studies have provided evidence of cerebellar involvement in a variety of cognitive, affective and social tasks. This chapter provides an overview of the recently acknowledged role of the cerebellum in speech and language processing.

Keywords Cerebellum • Language • Speech • Cognition • Affect

55.1 Introduction

Clinical and experimental research on the cerebellum has been overshadowed for more than two centuries by an overwhelming interest in the role of the cerebellum in sensorimotor control (Manto et al. 2012; Mariën et al. 2014). A wealth of experimental and clinical evidence supports the view that the cerebellum coordinates movement, resulting in various cerebellar ataxic syndromes in cases where the motor zones of the cerebellum sustain neurological damage. However, during the past decades, the long-standing view of the cerebellum as a pure coordinator of

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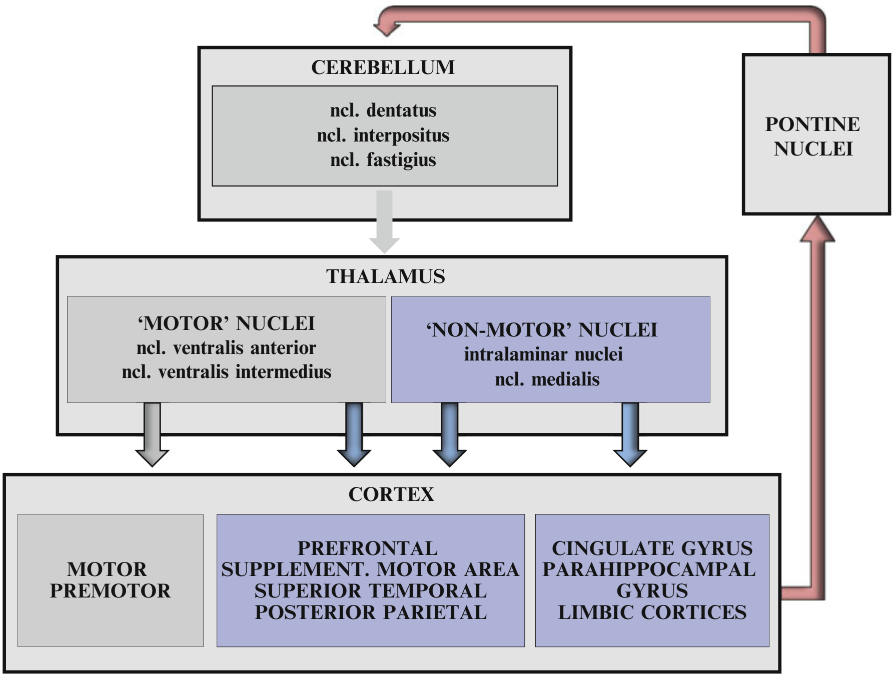

Fig. 55.1 Diagram depicting the cerebello-cerebral connectivity network underlying cognitive and affective processes. The feedback or efferent loop originates from the deep nuclei of the cerebellum that project to the motor (*grey arrows*) and nonmotor (*blue arrows*) nuclei of the thalamus. In turn, the motor nuclei of the thalamus (ncl. ventralis anterior and intermedius) project to motor and premotor cortices (*grey arrows*) but also to nonmotor areas among which the prefrontal cortex, the supplementary motor area, the superior temporal, and posterior parietal regions (*blue arrows*). The nonmotor nuclei of the thalamus project to the cingulate gyrus, the parahypocampal region, and the limbic cortices (*blue arrows*). The feedforward or afferent system of the cerebello-cerebral circuit is composed of corticopontine and pontocerebellar mossy fiber pathways (*red arrows*) (After Schmahmann and Pandya (1997) and from Mariën et al. (2013)

sensorimotor function has been modified. From the late 1970s onwards, major advances have been made in elucidating the many functional neuroanatomical connections of the cerebellum with the supratentorial association cortices that subserve nonmotor language, cognition, and affect (Fig. 55.1). In addition, neuroimaging studies in healthy subjects and neurophysiological and neuropsychological research in patients showed that the cerebellum is critically implicated in a large spectrum of cognitive and affective impairments. As a result, converging evidence derived from these different strands of research substantially extended the sensorimotor role of the cerebellum to include that of a crucial modulator of cognitive and affective processes.

55.2 Motor Speech Production: Planning and Coordination of Articulatory Movements

At the beginning of the twentieth century Gordon Holmes put forward the view that the cerebellum plays a crucial role in motor speech production. *Ataxic dysarthria* is a typical cerebellar motor speech disorder characterized by distorted articulation and prosody (Spencer and Slocomb 2007). Ataxic dysarthria shares a number of characteristics with *apraxia of speech*, a motor speech planning and coordination disorder that typically follows from injury to the language dominant motor speech regions. These similarities led some researchers to believe that both conditions are related phenomena resulting from disruption of the motor speech planning and coordinating network subserved by the motor speech areas of the language dominant hemisphere and the cerebellum (Mariën et al. 2006).

55.3 Verbal Fluency and Lexical/Semantic Retrieval

The right lateral cerebellum has been consistently implicated in *word generation* tasks. Papathanassiou et al. (2000) used positron emission tomography (PET) to show activation in the right cerebellum during a covert verb generation task. Silveri et al. (1998) found *verbal short-term memory* deficits after surgical removal of the right cerebellar hemisphere in an 18-year-old patient. They identified the functional locus of the deficit at the level of the phonological output buffer. Leggio et al. (1995, 2000) studied patients with focal or degenerative left and right cerebellar lesions and showed that cerebellar damage specifically affects phonological fluency. These findings were confirmed by Schweizer et al. (2010) who also showed that patients with right cerebellar lesions were significantly more impaired than patients with left cerebellar lesions.

55.4 Syntax Impairment

Agrammatism has been repeatedly observed in patients with focal cerebellar lesions. Silveri et al. (1994) described a patient who, following ischemic damage of the right cerebellum, presented with expressive agrammatism. Single photon emission computed tomography (SPECT) showed a relative hypoperfusion (cerebellocerebral diaschisis) in the entire left cerebral hemisphere (Silveri et al. 1994). Several other studies subsequently showed that the right cerebellar hemisphere is embedded within a distinct neural network devoted to the processing of grammar, together with the basal ganglia and the language dominant left prefrontal, temporal and parietal cortex (Mariën et al. 2001).

55.5 Aphasia

The co-occurrence of deficits affecting different linguistic levels may give rise to cerebellar-induced aphasia (Mariën et al. 1996). Mariën et al. (1996) described a 73-year-old, right-handed patient with a dynamic aphasia-like language disorder after an ischemic lesion in the vascular territory of the right superior cerebellar artery. SPECT revealed a significant hypoperfusion in the anatomoclinically suspected prefrontal language region of the left hemisphere. Impairment of linguistic functions after cerebellar lesions may therefore result from a decrease of excitatory impulses through the cerebello-ponto-thalamo-cortical pathways causing functional depression of the supratentorial regions subserving linguistic functions (cerebello-cerebral diaschisis). Other cases have been published of adult patients who suffered from various aphasic symptoms (Mariën et al. 2009; Baillieux et al. 2010). A more skeptical opinion on the role of the cerebellum in linguistic processing has been advanced by Timmann and co-workers who address the limitations of lesion studies and negative findings in patients with cerebellar lesions in a number of studies (e.g. Frank et al. 2007).

55.6 Acquired and Developmental Dyslexia

Acquired dyslexia (alexia) following cerebellar lesions is typically related to non-linguistic disturbances such as imperfect oculomotor control (nystagmus) (Moretti et al. 2002) or functional disruption of the cerebellar-encephalic projections involved in attentional and alerting mechanisms (Mariën et al. 2009; Moretti et al. 2002).

However, Nicolson et al. (1995, 2001) included the cerebellum in the pathogenesis of *dyslexia*. They introduced the “cerebellar deficit hypothesis” to explain dyslexia as a disruption of the automatization of learned skills such as articulation, reading, spelling, and phonological abilities, caused by cerebellar dysfunction. Several neuroimaging studies of dyslexic subjects have demonstrated abnormal cerebellar function in a range of cognitive and linguistic tasks (Brown et al. 2001; Rae et al. 2002; Nicolson et al. 1999; Baillieux et al. 2009).

55.7 Peripheral and Central Agraphia

Cerebellar damage might induce motor writing disorders such as *afferent dysgraphia* and *macrographia* (Silveri et al. 1997). However, central agraphias may be observed following cerebellar damage as well. The patient of Mariën et al. (2009) presented with *surface dysgraphia* after a right superior cerebellar artery infarction. Supported by SPECT findings they hypothesized that the writing deficits resulted from functional disruption of the cerebellar-encephalic pathways connecting the cerebellum to the frontal supratentorial areas, which subserve attentional and planning processes. Clinical evidence suggests involvement of the cerebellum in the neural network of *graphomotor planning*. Distortion of the spatiotemporal features of handwriting (*apraxic agraphia*) has been observed after disruption of the cerebello-cerebral network subserving the planning and execution of skilled motor actions (Mariën et al. 2007; De Smet et al. 2011).

55.8 Conclusion

Clinical and experimental evidence shows that different neuroanatomic parts of the cerebellum are critically implicated in a variety of speech and language functions. The neuroanatomical substrate subserving the role of the cerebellum in nonmotor language processing is a dense and reciprocal network of crossed cerebro-cerebellar pathways that establish a close connection between the cerebellum and the supratentorial autonomic, limbic, and association cortices. In addition, the majority of anatomoclinical studies of patients with linguistic impairments following focal cerebellar lesions and experimental neuroimaging studies consistently show a lateralized involvement of the right lateral cerebellar regions in nonmotor linguistic processes. The exact underlying pathophysiological mechanisms, however, remain to be elucidated.

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