A Predictive Perspective on the Cerebellum

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The cerebellum's role in motor and cognitive functions remains highly controversial. The cerebellum is involved in motor timing, motor coordination, motor learning and sensorimotor integration. For example, cerebellar contributions have been inferred in situations as diverse as timing of the conditioned eyelid response (Perrett and Ruiz, 1993), shifting of attention (Akshoomoff and Courchesne, 1992), adaptation of the vestibulo-ocular reflex (Lisberger et al., 1994) and coordination of eye and hand motor systems (van Donkelaar and Lee, 1994). Some of these studies also suggest that the cerebellum may be involved in some cognitive aspects of information processing. Several theories of cerebellar function have been proposed. The motor learning theories of Marr (1969), and Albus (1971) are often cited; many others have been proposed (Bloedel, 1992; Chapeau,1991; Darlot, 1993; Fujita, 1982; Ito, 1984; Keeler, 1990; Kawato, 1992; Leiner, 1989; Llinas, 1993; Miall et al., 1993; Paulin, 1989; Thach, 1992), yet few of these theories have attempted to give a consistent view of the role of the cerebellum in the diverse tasks in which the cerebellum is involved.

We have developed a new approach based on a predictive function for the cerebellum that provides a consistent explanation for the observed phenomena. We propose that the prediction of sensorimotor neural signals can be used to establish appropriate timing information and can play an important role to construct motor control strategies. In the presentation our approach, we 1) suggest a representation and a role for the climbing fibers of the inferior olive in the process of adaptation in the cerebellum and the deep cerebellar nuclei, 2) determine the representations encoded in the parallel fibers of the cerebellum, 3) propose synaptic learning mechanisms based on the interaction between Purkinje cells, cerebellar parallel fibers and climbing fibers of the inferior olive, as well as between Purkinje cells, climbing fibers and deep cerebellar nuclei neurons, and 4) specify the function of the parasagittal microstructure of Purkinje cells which receives correlated and simultaneous climbing fiber inputs.

The theory provides detailed explanations for a wide range of behaviors. In particular, we present two applications of this theory to the eyelid blink conditioning and the modulation of the vestibulo-ocular reflex.

O.J.M.D.C. was supported by a McDonnell-Pew Graduate Fellowship and T.J.S. by the Howard Hughes Medical Institute.

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