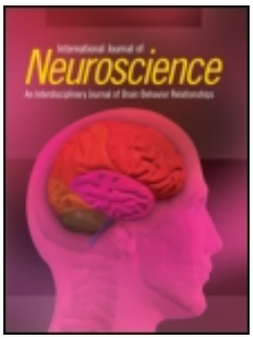

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Letter to the Editor

MAGNETIC FIELDS AND THE HABENULAR COMPLEX

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To the Editor:

Experimental findings over the past 20 years suggest that living organisms are sensitive to ambient magnetic fields (Gould, 1984). Several studies have found correlations between alterations in magnetic fields and behavior (Rudolph et al., 1985), neuroendocrine changes (Stoupel et al., 1983), seizure activity (Rajaram & Mitra, 1981; Anninos et al., in press), analgesia (Kavaliers & Ossenkopp, 1986), and immune responses (Jankovic et al., in press).

The mechanisms by which magnetic fields exert their biological effects are only partly understood. The pineal gland has been identified as a magnetosensitive organ (Semm et al., 1980; Cremer-Bartels et al., 1984), indicating that the biological effects of magnetic fields may be partly mediated through an interaction with the pineal gland (Welker et al., 1983). In addition, electrophysiological and biochemical studies in rodents and pigeons reveal that magnetic fields influence the activity of habenular neurons (Semm, 1983). In the guinea pig, earth strength magnetic stimulation has been reported to produce activation of habenular neurons (Semm, 1983). These findings were validated with the use of the deoxyglucose method which demonstrated an *extensive increase in glucose uptake in the habenular nuclei following magnetic stimulation* (Semm, 1983). Collectively, these findings demonstrate that the habenular nuclei are sensitive to magnetic fields and that their activity may be influenced by the geomagnetic environment.

The habenular nuclei are an integral component of the dorsal diencephalic pathway (Sutherland, 1982; Sandyk, in press), which originates in the anterior portion of the medial forebrain bundle, and which is composed of the stria medullaris thalami, the habenular complex, and the fasciculus retroflexus (Sutherland, 1982). Efferent fibers from the habenular complex reach the midbrain via the fasciculus retroflexus which then projects to the midbrain tegmentum. Thus, the habenular complex represents a potential site of confluence between limbic and motor-related pathways (Nauta, 1968; Sutherland, 1982).

Several studies have indicated that the habenular nuclei exert major modulatory effects on the activity of central dopaminergic functions. The lateral habenular nucleus receives massive afferents from dopamine rich cortical, limbic, and extrapyramidal areas via the stria medullaris (Herkenham & Nauto, 1979). Specifically, the internal segment of the globus pallidus is a major source of afferents to the lateral habenbular nucleus (Herkenham & Nauto, 1979). The habenular nuclei also receive mesohabenular dopaminergic afferents from the ventral tegmental area (VTA) (Skagerberg et al., 1984). Efferents from the lateral habenular nucleus, in turn, project via the fasciculus retroflexus to various midbrain areas, including the substatia nigra pars compacta and VTA in which the perikarya of dopamine neurons are located (Herkenham & Nauta, 1979). Thus, there are intimate functional reciprocal interactions between the lateral habenular nucleus and striatal and mesolimbic dopaminergic systems which are supported by the following lines of evidence:

Metabolic Studies

Studies of the metabolic alterations induced by dopamine receptor agonists and antagonist based on the 2-deoxyglucose method have demonstrated that the lateral habenular nucleus is functionally related to the expression of dopamine-mediated behaviors. Dopamine receptor agonists such as apomorphine and D- and L-amphetamine have been shown to reduce radiolabeled 2-deoxyglucose incorporation in rats within the lateral habenular nucleus (Brown & Wolfson, 1978; Wechsler et al., 1979; McCulloch et al., 1980). *In contrast, dopamine receptor antagonists such as haloperidol increase its incorporation to the lateral habenular nucleus* (Carvey et al., 1985). These findings indicate that alterations in CNS dopaminergic tone and/or their associated influence on motor activity produce consistent alterations in neuronal activity within the lateral habenular nucleus (Sokoloff et al., 1977). Furthermore, since small concentrations of dopamine receptor agonists and antagonists were sufficient to alter glucose metabolism in the lateral habenular nucleus (McCulloch et al., 1980), it appears that the functional activity of this nucleus is extremely sensitive to pharmacologic manipulations of striatal and mesolimbic dopaminergic neurons. Moreover, the finding that haloperidiol increases the metabolic activity in the lateral habenular nucleus (McCulloch et al., 1980), suggests that dopaminergic neurons in the striatum normally inhibit the metabolic activity of the lateral habenular nucleus.

Stimulation Studies

Electrical stimulation of the lateral habenular nuclei has been reported to cause inhibition of about 90% of identified dopamine neurons in the VTA and in about 85% of neurons in the substantia nigra (Christoph et al., 1983; 1986). The lateral habenular nucleus has direct bilateral efferent projections to the substantia nigra and VTA (Herkenham & Nauta, 1978) and stimulation of either the ipsilateral or contralateral lateral habenular nucleus was equally effective in inhibiting dopaminergic neurons.

Based on the interrelationships between the habenular complex and the dopaminergic system, Phillipson and Pycock (1982) have proposed that the habenular complex functions as a relay station for dopaminergic-mediated motor behavior. Thus, the observation that magnetic field stimulation increases the activity of habenular neurons (Semm, 1983) suggests that magnetic fields may influence dopaminergic activity and, additionally, that alterations in the geomagnetic field may influence dopamine-mediated behavior. Specifically, since magnetic field stimulation and dopamine blocking drugs such as haloperidol produce a similar effect on the habenular nuclei (i.e., increase glucose uptake into the habenular nuclei) (McCulloch et al., 1980; Semm, 1983), it appears *that magnetic fields may mimic the effects of neuroleptic drugs on the nigrostriatal dopamine system.* In summary, exposure to magnetic fields may inhibit the activity of nigrostriatal and mesolimbic dopaminergic neurons, whereas shielding of magnetic fields may enhance dopaminergic functions.

The hypothesis that magnetic fields inhibit dopaminergic activity is supported further by endocrine studies in humans demonstrating increased prolactin secretion during periods of enhanced geomagnetic activity (Stoupel et al., 1983). These findings suggest that magnetic fields are capable of inhibiting the activity of the hypothalamic dopaminergic system as well.

The finding that magnetic fields inhibit striatal and limbic dopaminergic activity is of both theoretical and clinical significance. For instance, magnetic field stimulation could be used therapeutically in the management of neuropsychiatric disorders related to increased dopaminergic activity such as schizophrenia, Tourette's syndrome, Tardive

dyskinesia, chorea, and mania. In addition, since neuroleptics mimic the effects of magnetic fields on the habenular nuclei, it is possible that some of their therapeutic effects could be mediated in part via the alterations of the brain's magnetic activity, which in itself has been shown to influence various biological and endocrine systems (Stoupel et al., 1983; Kavaliers & Ossenkopp, 1986; Jankovic et al., in press). Similarly, some of the long-term side effects of neuroleptic drugs such as tardive dyskinesia could be related partly to alterations in the brain's magnetic activity.

Moreover, it is possible that seasonal and circadian alterations of the geomagnetic field, by altering nigrostriatal and mesolimbic dopamine systems, may in part underlie seasonal variations in cerebral dopaminergic activity (Losonczy et al., 1984) and hence the seasonal variations of those disorders which are associated with disturbances of dopaminergic functions. For instance, it has been reported that symptoms of Tourette's syndrome tend to wane during the summer months (Goetz, 1986), a period associated with increased geomagnetic activity (Persinger et al., 1973). Likewise, alterations in the activity of the geomagnetic field may underlie the seasonal variations in the prevalence of psychiatric admissions to mental hospitals (Friedman et al., 1963; Carney et al., 1988).

In conclusion, the habenular complex is a crucial "gate" through which the limbic system interacts with the midbrain/extrapyramidal motor system (Nauta, 1986). Since magnetic fields alter the activity of the habenular nuclei, the natural geomagnetic field may exert important modulatory effects on limbic-basal ganglia functions. In fact, it is conceivable that the impact of the geomagnetic field on the habenular complex and its long-term implications on human behavior may be far greater than has been previously recognized. Furthermore, the potential influence of magnetic fields on the dopaminergic system opens new avenues in applying magnetic stimulation to the treatment of neuropsychiatric disorders.

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