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Alien Hand Syndrome as a Disorder of Motor Agency and Volitional Control

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***Abstract*—** *Alien Hand Syndrome (AHS) is a rare and intriguing neurological phenomenon characterized by complex, goal-directed movements of one limb that occur without conscious intention and are experienced as involuntary or "alien" by the individual. Unlike simple motor disorders, AHS represents a profound disturbance in motor agency and volitional control, wherein patients recognize the limb as anatomically their own but deny authorship over its actions. The syndrome provides a unique window into the neural mechanisms underlying voluntary action, self-agency, and the integration of intention, motor planning, and execution. Clinically, AHS is marked by purposeful movements such as grasping, manipulation of objects, and intermanual conflict, often accompanied by compulsive grasping and release of primitive reflexes. These motor phenomena are frequently associated with disturbances in body schema, sensory integration, and higher cognitive functions, depending on the underlying neuroanatomical lesion. Based on lesion location and phenomenology, AHS is classically divided into frontal (medial premotor), callosal (interhemispheric disconnection), and posterior (parietal) variants, each highlighting distinct contributions of cortical networks to motor control and self-attribution. Pathophysiologically, AHS arises from disruption of distributed neural circuits linking premotor regions, primary motor cortex, parietal areas, and interhemispheric connections, leading to dissociation between motor execution and conscious agency. Although no definitive cure exists, multidisciplinary rehabilitation strategies and selected pharmacological interventions may alleviate symptoms. Understanding AHS not only advances clinical management but also offers fundamental insights into the neuroscience of action, volition, and the sense of self.*

***Keywords*—** *Alien hand syndrome; Motor agency; Volitional control; Corpus callosum; Supplementary motor area; Cognitive neuroscience.*

I. Introduction

Alien Hand Syndrome (AHS) is a rare and striking neurological disorder in which a patient's hand performs complex, purposeful movements that are not consciously initiated or controlled by the individual. Affected individuals experience one of their limbs as "alien," acting autonomously and often in opposition to their will, such as unbuttoning clothes while the other hand buttons them, or grasping objects without intention. AHS is not merely a motor disorder; it represents a profound disruption in the sense of motor agency the subjective feeling that "I am the one who is causing this movement" and in volitional control over one's own body[1, 2]. This syndrome offers a unique window into the neural mechanisms underlying voluntary action, self-agency, and the integration of motor planning, execution, and conscious awareness, making it a paradigmatic example of a disorder of motor agency and volitional control in cognitive neuroscience and neuropsychiatry.

Clinical Features and Phenomenology

Core Motor Symptoms

The hallmark of AHS is the presence of seemingly purposeful, goal-directed movements of one hand that occur without conscious intention and are experienced as involuntary or "alien." These movements are not simple tremors or spasms but complex, coordinated actions such as grasping, manipulating objects, or performing coordinated bimanual tasks, yet they are dissociated from the patient's conscious will[3]. The affected hand may interfere with the actions of the other hand, leading to intermanual conflict for example, one hand may reach for a glass while the other hand pushes it away, or one hand may unbutton a shirt while the other hand buttons it.

In some cases, the alien hand may exhibit "compulsive grasping" or "grasp reflex," where the hand clutches objects tightly and is difficult to release, resembling a pathological release of primitive reflexes. The movements are typically more prominent in the nondominant hand, especially in right-handed individuals, and are often exacerbated by attention to the limb or by the presence of nearby objects.

Disturbances of Motor Agency and Volition

AHS is fundamentally a disorder of motor agency, the sense that one is the author of one's own actions. Patients with AHS report that the movements of the affected hand are not "theirs" but belong to an external agent or a separate "self," even though they recognize the hand as anatomically their own. This dissociation between motor execution and the sense of agency is a key feature: the hand moves purposefully, but the patient does not feel that they are initiating or controlling those movements. Volitional control is also impaired; patients may be unable to stop the alien movements voluntarily, or may only partially suppress them, often requiring the use of the unaffected hand to restrain the alien limb[4 – 7]. In some cases, patients report that the alien hand "has a mind of its own" or "acts on its own," reflecting a breakdown in the normal integration of intention, action, and self-attribution.

Sensory and Cognitive Features

In addition to motor and agency disturbances, AHS may be associated with sensory and cognitive symptoms depending on

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the underlying lesion. Some patients report a sense that the hand is "foreign" or "not part of me," or even the sensation of an additional limb, reflecting disturbances in body schema and self-representation. In posterior (parietal) variants, there may be associated sensory deficits, such as impaired proprioception or tactile agnosia, contributing to the feeling of alienation.

Cognitive features such as apraxia, aphasia, or executive dysfunction may co-occur, particularly in frontal and callosal variants, reflecting the involvement of higher-order cortical networks in motor planning and control. In some cases, patients may be unaware of the abnormal movements (anosognosia for the alien hand), further emphasizing the disruption of self-monitoring and metacognitive awareness.

Neuroanatomical Subtypes and Pathophysiology

Frontal (Medial Premotor) Variant

The frontal variant of AHS is typically associated with lesions in the medial frontal cortex, particularly the supplementary motor area (SMA), anterior cingulate cortex, and adjacent prefrontal regions. These areas are critical for internally guided, voluntary movements and for the generation of the sense of agency. The SMA is involved in the preparation and initiation of self-initiated actions, and damage to this region may lead to disinhibition of lateral premotor and primary motor areas, allowing movements to occur without the normal premotor "pre-activation" that normally accompanies voluntary action.

In this model, normal voluntary movement is associated with an orderly sequence of activation: premotor areas (including SMA) activate before primary motor cortex, and this premotor "pre-activation" is thought to be linked to the emergence of the sense of agency. In frontal AHS, this normal sequence is disrupted, leading to autonomous activity in primary motor cortex that generates movements without the associated sense of self-control, resulting in the experience of an alien hand.

Callosal (Interhemispheric Disconnection) Variant

The callosal variant of AHS arises from lesions of the corpus callosum, particularly the anterior portion, which disrupts communication between the two cerebral hemispheres. In right-handed individuals, the left hemisphere is typically dominant for language and conscious control of action, while the right hemisphere controls the left hand[8, 9]. When the corpus callosum is damaged, the right hemisphere can still generate movements of the left hand, but these movements cannot be integrated into the left hemisphere's conscious narrative, so the patient experiences the left hand as acting independently and "alien."

This disconnection model explains why patients with callosal AHS often show intermanual conflict: the dominant (language-linked) hemisphere perceives the actions of the nondominant hand as being controlled by a separate, inaccessible agent, leading to the attribution of "alien" agency to that limb.

Posterior (Parietal) Variant

The posterior variant of AHS is associated with lesions in the posterior parietal cortex, particularly in the dominant hemisphere, and is often seen in conditions such as corticobasal degeneration and stroke. The posterior parietal cortex is involved in spatial attention, body schema, and the integration of sensory and motor information for goal-directed action. Damage to this region may impair the ability to monitor and control limb movements, leading to purposeful but unintended actions that are experienced as alien[10, 11].

Functional imaging studies in AHS have shown that alien hand movements involve a network of brain areas including primary motor cortex, premotor cortex, parietal cortex (precuneus), and right inferior frontal gyrus, suggesting that these movements are generated by a partially preserved motor network that is decoupled from the normal volitional and self-attribution systems.

AHS as a Disorder of Motor Agency and Volitional Control

Neural Basis of Motor Agency

AHS provides compelling evidence that the sense of motor agency is not simply a byproduct of movement but depends on specific neural mechanisms that link intention, motor planning, and execution. In normal voluntary movement, the sense of agency is thought to arise from the match between the predicted sensory consequences of an action (the "forward model") and the actual sensory feedback. When this match is preserved, the movement is experienced as self-generated; when it is disrupted, as in AHS, the movement is experienced as externally caused or alien.

In AHS, the normal premotor–motor sequence is disturbed, so that movements occur without the premotor "pre-activation" that normally signals self-initiation, leading to a mismatch between motor output and the expected sense of agency[12, 13]. This explains why patients with AHS can recognize that the hand is theirs anatomically but still feel that the movements are not under their control.

Volitional Control and Inhibitory Mechanisms

AHS also highlights the role of inhibitory mechanisms in volitional control. The frontal and callosal variants are often conceptualized as disorders of disinhibition, in which damage to premotor or interhemispheric control systems releases lower motor centers from normal inhibitory control, allowing autonomous movements to emerge. This loss of inhibition may explain why patients with AHS are unable to voluntarily suppress the alien movements, or can only do so with great effort or by using the unaffected hand to restrain the alien limb.

The persistence of purposeful, goal-directed movements in AHS, despite the lack of conscious volition, suggests that motor programs can be executed independently of conscious will, but that volitional control normally acts as a "gate" or "brake" on these programs. In AHS, this gate is impaired, allowing motor programs to run off without conscious authorization.

Associated Conditions and Etiology

AHS is not a disease in itself but a symptom complex that can arise in a variety of neurological conditions. The most common causes include:

- Stroke, particularly involving the corpus callosum, medial frontal cortex, or posterior parietal cortex.

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- Neurodegenerative disorders, especially corticobasal degeneration and Alzheimer's disease, where AHS is often part of a broader syndrome of apraxia, alien limb phenomena, and cognitive decline.
- Brain tumors, trauma, and infections affecting the relevant cortical and subcortical networks.
- Postoperative states, especially after corpus callosotomy for intractable epilepsy, where the callosal variant of AHS is well documented.

The fact that AHS occurs across such a wide range of circumstances points to the conclusion that it originates from a disruption in a distributed network responsible for motor planning, execution, and self-attribution, as opposed to a single isolated lesion [14 - 17].

Management and Treatment Approaches

Non-Pharmacological Interventions

There is no cure for AHS, but several non-pharmacological strategies can help reduce symptoms and improve function. A common practical approach is to keep the alien hand occupied with a task, such as holding an object (e.g., a cane, a ball, or a cloth), which can reduce unwanted movements and give the patient a sense of control. Specific learned tasks and bimanual exercises can also help restore voluntary control over the affected hand to a significant degree.

Rehabilitation strategies often include visuospatial coaching, goal-oriented training, mirror box therapy, and cognitive-behavioral techniques to help patients cope with the distressing experience of an alien limb. In some cases, multidisciplinary rehabilitation focusing on bimanual tasks and attentional strategies has led to significant improvement or even resolution of symptoms[18, 19].

Pharmacological Options

Pharmacological treatment of AHS is limited and largely based on case reports. Clonazepam, a benzodiazepine, has been reported to reduce alien hand movements in some patients, possibly by enhancing inhibitory GABAergic transmission and restoring some degree of motor control. Botulinum toxin injections into specific muscles of the affected limb have also shown benefit in reducing excessive grasping and dystonic postures in selected cases[20]. Other agents such as baclofen have been tried with variable results, and there are no standardized pharmacological guidelines for AHS, reflecting the rarity of the condition and the lack of large controlled trials.

II. Conclusion

Alien Hand Syndrome is a rare but profoundly illuminating disorder that reveals the neural underpinnings of motor agency and volitional control. It demonstrates that the sense of "I am the one who is moving" is not automatic but depends on specific neural circuits that integrate intention, motor planning, and execution, and that damage to these circuits can lead to purposeful movements that are experienced as alien and involuntary[21-25].

The frontal, callosal, and posterior variants of AHS highlight different aspects of this network: frontal AHS emphasizes the role of medial premotor areas in generating the sense of agency, callosal AHS illustrates the importance of interhemispheric communication for unified self-control, and posterior AHS underscores the contribution of parietal regions to body schema and motor monitoring. Together, these variants show that motor agency and volitional control are emergent properties of a distributed cortical–subcortical network, not localized to a single brain region.

Understanding AHS not only advances our knowledge of the neuroscience of action and self but also has practical implications for the management of patients with this distressing condition[26, 27]. Future research using advanced neuroimaging and computational models of motor control will further clarify the mechanisms of alien agency and may lead to more targeted interventions for disorders of motor volition and self-awareness.

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