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Role of Action Observation Therapy in Cortical Reorganization in Patients with Stroke: A Narrative Review

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ABSTRACT

Background: Stroke is a leading cause of long-term disability, often resulting in motor, cognitive, and emotional impairments due to cortical damage. Cortical reorganization, which is a key component of post-stroke recovery, involves neuroplastic changes that facilitate functional improvements. Action Observation Therapy (AOT) has emerged as a promising neurorehabilitation approach that enhances neuroplasticity by engaging the mirror neuron system, which links action observation with motor execution.

Purpose: This review aimed to explore the role of AOT in facilitating motor recovery after stroke and its effects on cortical activation and motor network reorganization, and the growing body of evidence supporting its use as a complementary intervention alongside conventional rehabilitation techniques.

Methods: A comprehensive literature search was conducted using PubMed, Cochrane Library, Web of Science, Scopus, and Google Scholar to identify relevant studies published between 2000 and 2024. The following search terms were used: ("Action observation therapy" OR "AOT") AND ("Stroke Rehabilitation" OR "Neurorehabilitation") AND ("Cortical Reorganization" OR "Neuroplasticity" OR "Brain Plasticity") AND ("Functional Recovery" OR "Motor Recovery"). Only randomized controlled trials (RCTs), systematic reviews, meta-analyses, and observational studies published in English were included. Studies that focused solely on psychological outcomes without assessing cortical reorganization or those conducted on animal models were excluded.

Results: AOT interventions have been associated with increased activation in the prefrontal cortex, enhanced functional connectivity in motor and cognitive networks, and improved participation in rehabilitation programs. Neuroimaging studies indicate that AOT-related cognitive restructuring and behavioral activation strategies modulate neural pathways involved in motor and cognitive recovery, particularly in the Inferior Frontal Gyrus, Inferior Parietal Lobule, Premotor Cortex (PMC), Primary Motor Cortex and Supplementary Motor Area (SMA). Furthermore, combining AOT with rehabilitation techniques, such as constraint-induced movement therapy (CIMT), and neurostimulation (tDCS, rTMS), has been shown to optimize recovery outcomes by reinforcing adaptive neuroplasticity.

Conclusion: AOT represents a promising intervention in stroke rehabilitation by targeting both neurological and psychological factors affecting recovery. The evidence supports its role in enhancing neuroplasticity, reducing emotional barriers, and improving functional rehabilitation adherence and integrating AOT into multidisciplinary rehabilitation programs may enhance patient engagement, cortical reorganization, and overall quality of life post-stroke.

KEYWORDS: Action observation therapy, Stroke Rehabilitation, Cortical Reorganization, Neuroplasticity, Functional Recovery.

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INTRODUCTION

Post-stroke motor impairment (PSMI)

Post-stroke motor impairment (PSMI) is one of the most common and debilitating consequences of stroke, resulting from damage to motor pathways within the brain. It encompasses deficits in muscle strength, coordination, balance, and motor control, which collectively hinder the ability to perform voluntary movements (1). These impairments often manifest as hemiparesis or hemiplegia, leading to difficulties in walking, grasping, and performing daily activities independently (2).

Moreover, motor impairment is closely associated with reduced social participation and increased dependency on caregivers. Consequently, substantial research efforts have been directed toward identifying effective rehabilitation strategies such as task-specific training, action observation therapy, and neuroplasticity-based interventions to promote motor recovery and improve functional outcomes in stroke survivors (3).

Stroke and Its Impact on Cortical Functions

Stroke is a leading cause of disability worldwide, affecting approximately 12.2 million individuals annually and significantly contributing to long-term functional impairments (4). It occurs due to an interruption of cerebral blood flow, either from an ischemic blockage or a hemorrhagic event, leading to neuronal death and subsequent neurological deficits (5). Depending on the location and severity of the stroke, affected individuals may experience impairments in motor control, speech, sensory perception, and cognitive functions, as different brain regions govern these abilities (6). The cerebral cortex, which is responsible for high-order functions often suffers extensive damage in stroke patients, leading to widespread functional loss (7).

Damage to cortical areas following a stroke disrupts neural pathways and weakens the connectivity between different brain regions, limiting the ability to perform everyday activities (8). Following a stroke, the brain engages in neural reorganization to compensate for lost functions, with the extent of recovery varying based on injury severity and rehabilitation intensity (9). The degree of impairment is closely linked to lesion size and location larger strokes typically result in more severe deficits and longer recovery periods. Therefore, understanding cortical disruptions is crucial for designing targeted therapies that promote neuroplasticity and optimize functional recovery after stroke (10).

Importance of Cortical Reorganization in Stroke Recovery

Cortical reorganization is a crucial neuroplastic process that enables the brain to adapt following a stroke, facilitating functional recovery by reallocating neural resources to undamaged areas (11). This process involves structural and functional modifications within the brain, such as synaptogenesis, dendritic sprouting, and alterations in excitability within perilesional and contralateral cortical areas (12). Studies using functional MRI (fMRI) and transcranial magnetic stimulation (TMS) have demonstrated that patients with better recovery outcomes exhibit increased activity in undamaged motor and sensory areas, suggesting that cortical plasticity plays a vital role in regaining lost abilities (13).

Intensive rehabilitation interventions enhance these adaptive changes, reinforcing new neural circuits that support functional improvements (14). However, the extent and efficiency of cortical reorganization depend on various factors, including the timing and intensity of rehabilitation, patient motivation, and the presence of compensatory strategies (15). Early intervention enhances neuroplasticity, while delayed rehabilitation can cause maladaptive plasticity and strengthen inefficient neural pathways. Psychological factors like depression, anxiety, and learned non-use may also reduce therapy engagement and hinder cortical reorganization. Therefore, combining motor, cognitive, and behavioral therapies may optimize recovery by targeting both neural and psychological aspects (16).

The Concept of Neural Plasticity and Cortical Reorganization

Neural plasticity is the brain's ability to adapt and reorganize following injury, allowing healthy areas to take over the functions of damaged regions by creating new neural connections (17). Neuroimaging studies (fMRI, PET) have shown increased activity in both perilesional and contralateral brain regions during recovery, reflecting the brain's compensatory mechanisms. This adaptive process is supported by mechanisms such as Hebbian plasticity, long-term potentiation (LTP), and long-term depression (LTD), which strengthen active neural pathways and help maintain neural circuit balance (18). Rehabilitation strategies like constraint-induced movement therapy (CIMT) capitalize on these mechanisms to promote motor and functional improvement. However, maladaptive plasticity, including learned non-use or inefficient compensatory behaviors, can limit recovery (19). Therefore, well-structured and targeted rehabilitation programs are essential to encourage beneficial neural reorganization and optimize post-stroke functional outcomes (20).

Factors Influencing the Extent of Cortical Reorganization

The extent of cortical reorganization after a stroke varies greatly among individuals and depends on factors such as lesion size, location, age, and rehabilitation intensity. Larger or strategically located lesions disrupt broader neural networks, reducing compensatory potential, while damage to association areas allows for better recovery through distributed pathways. Early rehabilitation, especially within the first three months post-stroke, is vital, as this period represents a critical window for enhanced neuroplasticity (21).

Psychological and environmental factors, including motivation, emotional health, and cognitive engagement, also influence recovery outcomes. Depression and learned non-use hinder adaptation, whereas positive reinforcement and goal-oriented therapy promote functional improvement (22). Additionally, non-invasive brain stimulation techniques like tDCS and rTMS show promise in enhancing neuroplasticity by modulating cortical excitability. Overall, understanding these biological, psychological, and therapeutic factors is key to designing individualized rehabilitation strategies that optimize post-stroke recovery (23).

Methods for assessment of Neural Plasticity and Recovery post stroke

Methods for assessment of Neural Plasticity and Recovery post stroke Quantitative electroencephalography (QEEG) is a simple, non-invasive, and cost-effective method for assessing cortical activity with high temporal resolution, offering real-time, objective insights into brain function. Alongside QEEG, neuroimaging techniques like fMRI and PET have shown that Action Observation Therapy (AOT) activates motor-related regions including the premotor cortex, inferior parietal lobule, and primary motor cortex similar to those used in actual movement (24). fMRI studies further reveal that AOT enhances perilesional activation, strengthens motor-visual connectivity, and increases ipsilesional hemisphere activity, all of which correlate with improved motor recovery and neuroplasticity in stroke rehabilitation (25)

Action Observation therapy (AOT) and Its Potential Role in Neural Plasticity

Action Observation Therapy (AOT) is a rehabilitation approach that leverages the mirror neuron system to enhance motor recovery by activating brain regions involved in both observing and executing movements. Through repeated observation and practice of goal-directed actions, AOT strengthens sensorimotor connections and promotes cortical reorganization, supporting neuroplasticity and functional recovery (26).

Neuroimaging evidence shows activation in premotor, parietal, and primary motor cortices during AOT. Its visual, cognitive, and motivational components make it effective and suitable for early rehabilitation, serving as a non-invasive complement to traditional stroke therapies that target both neural and psychological aspects of recovery (27).

Action observation therapy: Mechanisms and Applications

Action Observation Therapy (AOT) is a neurorehabilitation approach that leverages the brain's capacity for learning through observation to enhance motor function following neurological disorders. During AOT, patients observe goal-directed actions like reaching or grasping and then imitate these movements, activating the mirror neuron system (MNS) located primarily in the premotor and parietal cortices (28). This activation engages the same neural circuits involved in performing the observed actions, stimulating neuroplasticity and facilitating motor learning and functional recovery. Through repeated observation and practice, AOT strengthens motor pathways, improves coordination, and supports the reorganization of damaged neural networks. Additionally, by promoting motivation and self-efficacy, AOT contributes to better rehabilitation outcomes and enhances the overall quality of life for stroke survivors (29)

Action observation therapy (AOT) is based on activating the mirror neuron system (MNS) including the inferior parietal lobule, premotor cortex, and inferior frontal gyrus which respond during both action execution and observation (29). By repeatedly observing motor tasks, AOT enhances visual-motor coupling and internal motor simulation, promoting synaptic plasticity and cortical reorganization. fMRI studies show that AOT activates brain regions involved in movement, reinforcing motor memory and recovery (30). It also improves sensorimotor integration and interhemispheric connectivity, aiding functional restoration after stroke. Overall, AOT supports both neural and psychological recovery through adaptive brain reactivation (31).

Action observation therapy AOT in stroke rehabilitation use structured observation and imitation of meaningful motor tasks to activate the mirror neuron system and promote recovery. Typically, patients watch videos of goal-directed actions like grasping or folding and then practice the same movements, often from a first-person perspective to enhance motor engagement (26).

Some protocols include three phases: observation, mental rehearsal, and execution. Advanced versions integrate virtual reality (VR) to create immersive, motivating environments that boost cortical activation. AOT is also combined with physiotherapy, constraint-induced movement therapy, or mirror therapy, demonstrating its adaptability and effectiveness in enhancing motor relearning and neuroplasticity after stroke (32).

Review of Studies Linking AOT to Neural Plasticity and Recovery Multiple studies have shown that Action Observation Therapy (AOT) promotes neural plasticity in stroke rehabilitation by activating the mirror neuron system and motor-related cortical areas. Observing goal-directed actions engages regions such as the premotor cortex, inferior parietal lobule, and primary motor cortex similar to those involved in actual movement thereby enhancing motor learning and cortical reorganization (28). A meta-analysis by Peng et al. (2019) further reported that stroke patients receiving AOT alongside conventional therapy experienced significantly greater improvements in upper-limb motor function than those undergoing physical therapy alone (33)

Challenges and Limitations in Existing Research

Despite the proven benefits of (AOT), several challenges limit the widespread clinical use of (AOT) in stroke rehabilitation. Variability in intervention protocols such as differences in video content, observation time, and task execution hampers standardization and cross-study comparison (34). Patient-related factors like cognitive deficits, poor attention, and low motivation can also reduce therapy effectiveness. Moreover, the optimal intensity and duration of AOT for inducing neuroplasticity remain unclear, and individual differences in mirror neuron system activation affect outcomes (35). Most studies have small samples and short durations, limiting generalizability, while clinical implementation is further constrained by the need for specialized therapist training and adaptable, resource-dependent protocols (36)

Clinical Implications and Future Directions

Evidence supporting the neurophysiological basis of Action Observation Therapy (AOT) highlights its strong potential as an adjunct tool in neurorehabilitation, particularly for improving upper-limb function, apraxia, and post-stroke hemiparesis (37). AOT is easy to integrate into standard therapy since it requires minimal equipment and can use simple video-based protocols. Its cognitive engagement component enhances attention, imitation, and motivation, promoting better adherence and long-term outcomes compared to passive training (38). Emerging research shows that combining AOT with neuromodulatory techniques like tDCS or rTMS can boost cortical excitability and neuroplasticity. Additionally, integrating AOT with virtual or augmented reality offers immersive, personalized, and accessible rehabilitation options, extending therapy beyond clinical settings (39).

Action Observation Therapy (AOT) can be effectively integrated with other therapeutic approaches to enhance cortical excitability, neuroplasticity, and motor recovery. Combining AOT with motor imagery (MI) engages both visual and internal motor representations, producing stronger activation of motor cortices and corticospinal pathways (40). When paired with mirror therapy (MT), AOT further improves visuomotor integration and interhemispheric balance, accelerating recovery. The addition of non-invasive brain stimulation techniques such as tDCS or rTMS amplifies AOT's effects by priming the motor cortex and promoting long-term potentiation (41). Incorporating AOT into virtual or augmented reality environments increases sensory feedback, engagement, and cortical activation. Used alongside conventional physical therapy, AOT serves as a priming tool to enhance motor performance. Altogether, these multimodal combinations create synergistic effects that strengthen neural reorganization, making AOT a powerful component of comprehensive neurorehabilitation (42).

Although strong evidence supports Action Observation Therapy (AOT) as an effective method for enhancing cortical excitability and motor recovery, key research gaps remain. A major limitation is the absence of standardized protocols concerning observation time, task complexity, session frequency, and action type, hindering cross-study comparison and optimization of treatment parameters (43). Future large-scale randomized controlled trials with consistent neurophysiology and behavioral measures are needed to develop standardized, evidence-based guidelines for AOT application (44).

Conclusion

This review highlights the pivotal role of Action Observation Therapy (AOT) in enhancing cortical reorganization and facilitating functional recovery in stroke rehabilitation. Evidence indicates that AOT promotes neuroplasticity by engaging the mirror neuron system, improving motivation, and fostering adaptive behavioral and cognitive processes. Neuroimaging studies using fMRI and PET confirm increased activation and connectivity within motor-related brain regions, validating AOT's neurophysiological foundation. Furthermore, combining AOT with complementary interventions such as physical therapy, neurostimulation, and mindfulness-based techniques can amplify its therapeutic benefits, leading to more effective and sustained motor recovery in stroke patients.

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