The Role of Task-Specific Training in Rehabilitation Therapies

Nestor A. Bayona, Jamie Bitensky, Katherine Salter, and Robert Teasell

Task-oriented therapy is important. It makes intuitive sense that the best way to relearn a given task is to train specifically for that task. In animals, functional reorganization is greater for tasks that are meaningful to the animal. Repetition alone, without usefulness or meaning in terms of function, is not enough to produce increased motor cortical representations. In humans, less intense but task-specific training regimens with the more affected limb can produce cortical reorganization and associated, meaningful functional improvements. **Key words:** animal models, cerebral vascular accident, constraint-induced therapy, humans, motion therapy, physical mobility, recovery of function

The popularity of neurodevelopmental therapeutic techniques in physiotherapy and occupational therapy has to some extent overshadowed a basic principle of motor learning, that is, the best way to relearn a task is to repeatedly practice that particular task.

**Task-Oriented Rehabilitation**

**Animal studies**

**Meaningful tasks improve functional reorganization**

Kilgard and Merzenich have proposed that experience is necessary but not sufficient to induce brain plasticity. The authors argued that for functional reorganization to occur, it is necessary to “mark” the importance of a stimulus with input from limbic and paralimbic structures.

Chronic impairment of forelimb and digit movement is a common problem after stroke, which is often resistant to therapy. In animal research, environmental enrichment seems to improve behavioral outcome after ischemia, although post stroke environmental enrichment alone is not sufficient to improve fine digit and forelimb function. Environmental enrichment combined with daily skilled-reaching training following middle cerebral artery occlusion (MCAO) in rats has been reported to result in significant improvements in the Montoya staircase reaching task compared with control (nonenriched, standard housing without skilled-reaching training) animals. Furthermore, it was demonstrated that functional improvements of the affected limb persisted even at 9 weeks after treatment and that enriched animals were indistinguishable from sham (non-MCAO) animals in a beam-traversing task. In contrast, control animals (nonenriched housing without skilled-reaching training) remained impaired in both skilled reaching and beam traversing. The authors attributed the enhanced functional improvements in enriched animals to enhanced dendritic arborization.

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of layer V pyramidal cells within the undamaged motor cortex when compared with control animals. These results suggested that environmental enrichment combined with task-specific rehabilitative therapy is capable of augmenting intrinsic neuronal plasticity within noninjured, functionally connected brain regions, as well as promoting enhanced functional outcome.

Repetitive activity is not enough

Nudo has noted that repetitive motor activity alone is not enough to produce representational plasticity in cortical motor maps. When monkeys were trained to retrieve food pellets from a very small well, a difficult task requiring skilled use of the digits, progressive increments in motor performance were seen over a period of about 10 days. Monkeys who were trained to retrieve pellets from a larger food well, a much easier task, displayed accurate performance from the beginning of training so that no additional skill was required. In both groups, the total number of finger flexions was matched. Comparisons were made between pretraining and posttraining maps of cortical movement representations. The researchers found no task-related changes in the cortical area devoted to the hand in the large well (easy task) group. Movement-specific changes in the small well (difficult task) group were large and consistent and corresponded to the actual movement kinematics of the task. Thereafter, the authors concluded that repetitive motor activity alone does not appear to produce functional reorganization of cortical maps. Motor learning appears to be a prerequisite factor in the development of representational plasticity in the motor cortex. Similarly, Remple et al. found that reorganization of forelimb representations within the rat cortex was associated with the development of skilled forelimb movements but not with increased forelimb strength.

Kleim et al. found that rats trained on a skilled reaching task exhibited an expansion of wrist and digit movement representations within the motor cortex when compared to rats in a motor activity control group. This functional reorganization was restricted to the distal forelimb area, with no differences in movement representations observed within the proximal forelimb area. Trained animals also had significantly more synapses per neuron than controls within layer V of the distal forelimb area. No differences in the number of synapses per neuron were found in the forelimb areas. According to Nudo, “this study provides support for the co-occurrence of functional and structural plasticity within the same cortical regions and provides strong evidence that synaptic formation may play a role in supporting learning-dependent changes in cortical function.”

Conclusions

Functional reorganization is greater for tasks that are meaningful to the animal. In animals, repetitive activity alone is not sufficient to produce increased motor cortical representations. Instead, an element of skilled motor learning is required in addition to repetition for cortical reorganization/plasticity to occur.

Clinical studies

Meaningful tasks improve cortical reorganization

As noted by Richards et al., “many clinical reports and motor learning-related findings indicate that the best way to learn an activity is to practice that activity, which means task-specific training.”

Research has demonstrated that rehabilitation may be more successful if the tasks and stimuli are important to the person. This provides an example of how experience changes the brain (i.e., so that some tasks have more functional importance than others), which in turn changes the effects of experience.

Role of repetition and consistent practice

According to Kilgard and Merzenich, repetition plays a major role in inducing and maintaining brain changes. This principle is illustrated by the work of Pascual-Leone et al. who found that the cortical maps of Braille readers changed in size, depending on whether they had worked for 6 hours or had taken the day off from work. From a
clinical perspective, this phenomenon supports the need for consistent practice to maintain gains acquired in therapy.²

**Improvements from specific motor training**

It is well established that task-specific practice is required for motor learning to occur.³ According to Classen et al.,³ focal transcranial magnetic stimulation (TMS) and functional magnetic resonance imaging (fMRI) have shown that task-specific training, in comparison to traditional stroke rehabilitation, yields long-lasting cortical reorganization specific to the corresponding areas being used. More specifically, Karni et al.,⁴ using fMRI, and Classen et al.,³ using TMS, both reported a slowly evolving, long-term, experience-dependent reorganization of the adult primary motor cortex after daily practice of task-specific motor activities.

According to Page,¹⁵ intensity alone does not account for the differences between traditional stroke and task-specific rehabilitation. Task-specific sessions, consisting of thumb and hand movements, for as short as 15 minutes have resulted in lasting cortical representational changes.¹³,¹⁶ Galea et al.¹⁷ reported that stroke patients who underwent a 3-week-long program that consisted of 45-minute task-specific, upper limb training showed improvements in measures of motor function, dexterity, and increased use of the more affected upper limbs. According to Page,¹⁵ other task-specific, low-intensity regimens designed to improve use and function of the affected limb have also reported significant improvements.¹⁸–²⁰

In a randomized clinical trial (RCT) by Dean and Shepherd,²¹ 20 participants at least 1 year post stroke were randomized into an experimental or control group. The experimental group participated in a standardized training program involving practice of reaching beyond arm’s length. The control group received sham training involving completion of cognitive-manipulative tasks within arm’s length. Performance of reaching while in a sitting position was measured before and after training using electromyography, videotaping, and two force plates. After training, participants in the experimental group were able to reach faster and further, increase load through the affected foot, and increase activation of affected leg muscles compared with the control group (p < .01). In comparison, improvements in reaching were not found with the control group. Hesse et al.²² have noted that “task-specific therapy can enable hemiplegic patients to practice walking repetitively, in contrast to conventional treatment in which tone-inhibiting manoeuvres and gait-preparatory tasks during sitting and standing dominate.”²²

Langhammer and Stanghelle²³,²⁴ in a study of 61 stroke patients compared therapeutic approaches to rehabilitation. Stroke patients were treated with a motor relearning program consisting of physiotherapy with task-oriented strategies or Bobath techniques, which involve physiotherapy with facilitation/inhibition strategies. Stroke patients who were treated with the task-oriented strategies were more likely to improve on tests of motor function but not on more general functional outcome testing.

**Visual and tactile neglect**

Perceptual problems such as visual and tactile neglect lend themselves well to task-specific rehabilitation therapies. It has been suggested that consistent and specific strategies such as task-specific practice improve cognitive and perceptual abilities following stroke.²⁵ Indeed, an ongoing evidence-based review of stroke rehabilitation has concluded that, in general, specific perceptual training interventions improve perceptual functioning.²⁶ Although a wide range of treatment interventions or strategies have been studied regarding improving perceptual function in stroke patients with neglect, less attention has been paid to the durability of the effects of intervention or the impact of intervention strategies on functional ability such as the performance of activities of daily living.²⁶,²⁷

**Conclusions**

Repetition plays a major role in inducing and maintaining brain changes. However, repetition of a task in the absence of new meaningful skill learning is unlikely to induce cortical changes of significance. Less intense (e.g., 30–45 min), task-specific
training regimens with the more affected limb can produce cortical reorganization and associated meaningful functional improvements. This has been demonstrated with regard to specific motor retraining, but perceptual retraining interventions designed specifically to treat neglect may also result in improved perceptual functioning.

Table 1 summarizes the animal and clinical research on the role of task-oriented rehabilitation on stroke recovery.

<table>
<thead>
<tr>
<th>Animal research</th>
<th>Clinical research</th>
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<tr>
<td>Association exists between tasks that are meaningful to the animal and greater functional reorganization.</td>
<td>Rehabilitation outcomes are more successful when the tasks are meaningful to the patient.</td>
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<tr>
<td>Repetitive motor activity alone is not sufficient to produce functional reorganization of cortical maps.</td>
<td>Repetition and consistent practice play important roles in inducing and maintaining cortical changes acquired in therapy.</td>
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<td>Task-specific motor learning seems to be a prerequisite for cortical reorganization.</td>
<td>Task-specific training results in long-lasting cortical reorganization of the corresponding areas being used.</td>
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<tr>
<td>Not studied.</td>
<td>Low-intensity task-specific programs also produce cortical reorganization and functional improvements.</td>
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<td>Specific treatment of visual neglect and perceptual disorders result in significant improvement in functional outcomes.</td>
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Constraint-Induced Movement Therapy

Constraint-induced movement therapy (CIMT) consists of a new set of rehabilitation techniques designed to reduce functional deficits, primarily in the affected upper extremity of stroke patients. CIMT is based on the principle that stroke survivors may experience “learned non-use” of the upper extremity. Constraint-induced movement therapy (CIMT) is, in fact, an example of task-specific and intensive therapy being combined. CIMT is designed to overcome the “learned non-use” by restraining the unaffected arm while training the affected extremity for a minimum of 2 weeks.

Animal studies

Taub and colleagues tested the hypothesis that nonhuman primates learn to avoid using an injured limb, based on negative experiences in the early phase after an injury, and that this early “learned non-use” prohibits later functional recovery of the affected limb. In these early studies, Taub and colleagues deafferented the limbs of nonhuman primates, an injury that leads to transient weakness of a limb. Although the potential for motor behavior improved over time, they found that the animals permanently ceased to attempt to use the injured limb. However, if the animals’ intact limb was restrained during the chronic period post injury and a shaping technique was used to teach functional movements, the animals learned to reuse the injured limb during normal activities.

Similar results have been demonstrated in monkeys. Monkeys who were placed in restraint jackets to restrict the use of the unimpaired limb and who had received postinjury behavioral training showed retention of the undamaged hand representations. Nudo et al. noted that, on average, there was a net gain of approximately 10% in the total cortical hand area adjacent to the lesion. More recently, Friel et al. demonstrated that the retention of the hand area adjacent to a microlesion in the primary motor area required repetitive behavioral training in addition to restraining, because the use of the restraint jacket alone resulted in no change in hand representations beyond that which was seen with spontaneous recovery.

One can conclude that CIMT in animals has been shown to accelerate recovery of paretic ex-
tremities and to increase cortical representation. During the chronic period after a stroke, animals with paretic extremities show increased use of the affected limb when the unaffected limb is restrained.

Clinical studies

Hallett\textsuperscript{33} stated that one of the principles of plasticity is that use of a limb is critical to achieving and maintaining cortical representation. This principle means that not exercising the weakened limb will further limit the limb representational area through disuse. Two studies\textsuperscript{34,35} using TMS reported an increase in the size of cortical maps after constraint-induced therapy. These results suggest that intensive CIMT produces cortical changes in humans as well as animals. Liepert et al.\textsuperscript{35} using TMS found that before treatment cortical representation of the affected hand muscles was significantly smaller than the intact contralateral side, while after treatment the cortical representation in the affected hemisphere was significantly enlarged and appeared to be a consequence of the recruitment of adjacent brain areas. Liepert et al.\textsuperscript{35} noted that this improvement persisted, although the cortical sizes in both hemispheres tended to equalize over time.

Whitall et al.\textsuperscript{19} have noted that “forced-use or ‘constraint-induced’ training, in general, has major implications for stroke rehabilitation.”\textsuperscript{pd301} Intensive practice with the impaired limb can result in additional recovery in stroke patients, who had previously reached a plateau.\textsuperscript{36} Both TMS and fMRI studies\textsuperscript{37} have shown that functional plasticity in the motor cortex accompanies recovery associated with CIMT therapy. Changes include expansion of the hand representation after training and increased activation on the ipsilateral cortex, including the perilesional cortex.\textsuperscript{38,39} Based on criteria established by Taub et al.\textsuperscript{40} and Wolf et al.,\textsuperscript{41} approximately 20% to 25% of patients with chronic stroke motor deficits may benefit from CIMT.\textsuperscript{42}

CIMT is not a complete solution to improving motor deficits in all stroke patients; however, motor function in a large percentage of patients with chronic stroke can be substantially modified by CIMT.\textsuperscript{42} The results of CIMT vary and are dependent upon the degree to which active range of motion is impaired at the outset of therapy.\textsuperscript{42} Although higher functioning individuals may experience greater improvements,\textsuperscript{43} CIMT may result in improved movement in the upper extremities, particularly at the elbows and shoulders, even in individuals with very little motor function.\textsuperscript{42,43} Because many functional activities require use of the hand, improvements in movement of the elbow and shoulder may not translate to greater ability to perform activities of daily living.\textsuperscript{42}

According to Dromerick et al.,\textsuperscript{44} constraint of the unaffected arm by use of a mitten (6 hours per day for 14 days), and forced use of the affected arm soon after stroke (mean = 6 days) is feasible. However, trials reporting small but significant reductions in arm impairment, especially for patients with sensory disorders and hemi-neglect,\textsuperscript{45} have also reported a high number of deviations from the randomized treatment schedule. This has led to trials investigating the effectiveness of modified or shorter periods of CIMT.\textsuperscript{46}

Wolf et al.\textsuperscript{41} confirmed the benefit of this treatment in humans; they reported that forced use of hemiplegic upper extremities in chronic stroke and head-injured patients improved functional recovery. Liepert et al.\textsuperscript{35} also reported improved rehabilitation function with constraint of the intact upper extremity in 13 patients with hemiplegic strokes.

In a review of CIMT by Teasell et al.,\textsuperscript{26} the results from several “good” quality RCTs reported a positive impact for the patients receiving CIMT.\textsuperscript{40–46} However, functional benefits appeared to be largely confined to those individuals with some active wrist and hand movement, particularly among individuals with sensory deficits and neglect. However, there were concerns with small numbers in several of the trials and some methodological difficulties in the larger trial. The selective benefit demonstrated within certain subsets of stroke patients raises concerns with regard to the efficacy of the treatment in other settings or with varying patient populations. The authors concluded that although there was evidence of a significant benefit of CIMT in comparison to traditional therapies, functional benefits appeared to be confined to a subset of stroke patients with some active wrist and hand movements, particularly those with sensory loss and neglect. Within this specialized population, CIMT at any intensity improved outcomes.\textsuperscript{26}
Conclusions

In summary, more intensive training of that part of the motor cortex injured by stroke through constraint-induced therapy increases cortical representation. CIMT provides an example of information derived from animal studies being translated into a form of treatment that allows motor improvement in a specific subset of stroke patients, namely those patients who had already obtained some wrist and finger extension. Although associated with learned non-use, CIMT does result in cortical reorganization.

Table 2 summarizes the animal and clinical evidence for the usefulness of CIMT in stroke recovery.

Summary

Task-specific activities and activities that are meaningful to the person have been shown to produce cortical reorganization and associated functional improvements.

CIMT is an example of combining task-specific training and intensive therapy post stroke. CIMT is an excellent example of a treatment that was first tested on animals and was eventually translated into a treatment that could be applied to humans. CIMT has been shown to lead to some cortical reorganization and promotes motor improvement in a specific subset of stroke patients, namely those patients who had already obtained some wrist and finger extension.

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Role of Task-Specific Training


