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Movement-Based Priming: Clinical Applications and Neural Mechanisms

Mary Ellen Stoykov¹, Daniel Montie Corcos², and Sangeetha Madhavan³

¹Occupational Therapy, Rush University, Chicago, Illinois

²Department of Physical Therapy & Human Movement Sciences, Northwestern University, Chicago, Illinois

³Department of Physical Therapy, University of Illinois at Chicago, Chicago, Illinois

Abstract

Priming can be described as behavior change generated by preceding stimuli. Although various types of priming have been long studied in the field of psychology, priming that targets motor cortex is a relatively new topic of research in the fields of motor control and rehabilitation. In reference to a rehabilitation intervention, priming is categorized as a restorative approach. There are a myriad of possible priming approaches including non-invasive brain stimulation, motor imagery, and sensory-based priming, to name a few. The authors report on movement-based priming which, compared to other priming types, is less frequently examined and under reported. Movement-based priming includes, but is not limited to, bilateral motor priming, unilateral priming, and aerobic exercise. Clinical and neural mechanistic aspects of movement-based priming techniques are explored.

Keywords

bilateral; motor; occupational therapy; priming

Priming is a nonconscious process associated with learning where exposure to a stimulus alters the response of another stimulus. When used successfully in conjunction with a therapeutic intervention, priming results in a behavior change coinciding with changes in neural processes. Although various types of priming have long been studied in the field of psychology, priming that targets the motor cortex is a relatively new topic of research in the fields of motor control and rehabilitation. Moreover, there are very few studies in the occupational therapy (OT) literature that address motor priming (Grossi, Maitra, & Rice, 2007; Kakuda et al., 2011; Stoykov & Stinear, 2010). Priming is a mechanism that could be easily be part of a restorative occupational therapy approach, the latter of which is a therapeutic method with the intent to improve function by targeting underlying neural mechanisms (Pomeroy et al., 2011). The restorative approach is often used in neurologic rehabilitation poststroke as well as in neurodegenerative disorders.

It is important to note that priming is typically performed prior to training (Linder, Rosenfeldt, Rasanow, & Alberts, 2015; Nowak et al., 2008; C. M. Stinear, Petoe, Anwar, Barber, & Byblow, 2014; Takeuchi et al., 2005). However, some studies have used priming (often sensory-based priming) concurrently with training. For review, see Field-Fote (2015). Although some have considered that priming could occur and be more effective at posttraining (Roig, Skriver, Lundbye-Jensen, Kiens, & Nielsen, 2012), we consider such studies as consolidation and not priming. We will restrict our review to priming that occurs before or concurrent with training.

Motor priming may improve the effect of associated neurorehabilitation therapies, which might include, but are not limited to, task specific training, robotics, constraint-induced movement therapy, or gait training (for a review, see Stoykov & Madhavan, 2015). Utilization of priming plus intervention is not the same as the use of sequential interventions. For example McCombe Waller et al. (2014) reported on a sequential intervention which included six weeks of bilateral training with rhythmic auditory cueing followed by six weeks of SaeboFlex training (Saebo, Charlotte, NC) for the experimental group. Similarly, Corti, McGuirk, Wu, and Patten (2012) reported on the differential effects of strengthening versus functional task practice (FTP) in the context of sequential intervention techniques (ten weeks of strengthening followed by 10 weeks of FTP or vice versa). Although the use of sequential intervention techniques may be advantageous, in this review we focus on those studies that use a movement-based priming technique prior to intervention for each individual session.

There are various possible priming approaches for neurorehabilitation including noninvasive brain stimulation and sensory-based priming, to name a few. Motor imagery techniques (simulated or imagined movement) have also been used as priming techniques or as the therapy itself. Mirror therapy, a type of imagery based priming, is often reported on in the stroke rehabilitation literature. In this review we focus on movement-based priming, which, compared to other priming types, is less frequently examined and under reported.

Movement-based priming is the use of any type of continuous movement that may augment the effect of the subsequent primary therapy (Stoykov & Madhavan, 2015). The priming movements can be bilateral or unilateral, active or passive, and single or multijoint. Priming movement can also be a type of exercise such as aerobic, isometric, or balance exercise. The difference between movement-based priming and motor training is that the latter refers to goal-directed, skill-based training while the former typically refers to repetitive movement that is not skill based. For a movement to be considered as a primer, ideally the technique should have been established to either demonstrate changes in cortical excitability, or facilitate cognitive processing, thus inducing neuroplastic effects such as release of neurochemicals that may enhance the effect of subsequent training (Stoykov & Madhavan, 2015).

Stimulation-based priming (repetitive transcranial magnetic stimulation and transcranial direct current stimulation) are popular topics in neurorehabilitation research even though the long-term efficacy of stimulation-based priming is still inconclusive (Elsner, Kugler, Pohl, & Mehrholz, 2016; Kakuda et al., 2016) and safety is a concern (Byblow et al., 2012; Rossi et

al., 2009). There are, however, limited studies on movement-based priming. Compared to stimulation-based priming, movement-based priming is cost effective and quite safe for a greater number of individuals. It also does not require a skilled operator (Byblow et al., 2012). Movement priming techniques include but are not limited to bilateral motor priming, unilateral priming, and aerobic exercise. Here we examine the clinical and neural mechanistic aspects of movement-based priming techniques. We will also discuss these techniques in reference to current practices in OT.

Bilateral Motor Priming

Bilateral Priming versus Bilateral Training

Bilateral priming consists of symmetrical, continuous bilateral wrist flexion and extension with the use of a low-tech device that promotes symmetrical movement via an actuator. Bilateral priming is an offshoot of bilateral training. The latter is a more frequently researched movement training technique. Some studies have indicated that bilateral training has advantages over unilateral training (Cauraugh, Kim, & Duley, 2005; McCombe Waller, Harris-Love, Liu, & Whittall, 2006; Stoykov, Lewis, & Corcos, 2009), others have not found such advantages between bilateral and unilateral groups (Desrosiers, Bourbonnais, Corriveau, Gosselin, & Bravo, 2005). This may be due to the type of bilateral training, the impairment level of the participants, or the phase of poststroke rehabilitation. However, it is a therapeutic technique suitable for the 80% of stroke survivors with arm impairment who do not qualify for constraint induced movement therapy. Bilateral training may use devices (robotics or otherwise) with varying levels of assistance, or it may be unassisted as in bilateral isokinematic training where both the affected and less affected arm produce movements in temporal and spatial symmetry (Stoykov & Corcos, 2009).

The difference between bilateral training and bilateral priming lies in their respective purposes and proposed mechanisms. In bilateral training, the bilateral symmetrical movements are the actual training, and the proposed mechanism is the well-documented symmetry constraint, where both upper limbs have a propensity toward identical spatial and temporal movement trajectories (Kelso, Holt, Rubin, & Kugler, 1981). In bilateral priming, however, the bilateral symmetrical movements are used to ready the brain to better respond to the training that follows, whether it is unilateral or bilateral movements. The proposed neural mechanism of bilateral priming is normalization of cortical inhibition (C. M. Stinear, Barber, Coxon, Fleming, & Byblow, 2008).

Clinical Applications of Bilateral Priming

Relative to other movement-based priming techniques, bilateral motor priming has been examined most frequently in the poststroke motor control and rehabilitation science literature in conjunction with a variety of upper limb interventions. In the chronic phase of post stroke rehabilitation, bilateral priming (continuous wrist flexion and extension via a low-tech device) has been paired with home therapy programs using fine motor activities (C. M. Stinear et al., 2008), Wii-based therapy (Shiner, Byblow, & McNulty, 2014), and task-specific training (Stoykov & Corcos, 2013). The methodological designs of the previous studies are varied. However, all have implemented designs with controls, and the findings

have been consistent. Across studies, the greatest difference between test and control groups occurred at follow-up where the bilateral priming group continued to improve after treatment ended while the control did not. This speaks to the potential of bilateral priming to enhance a wide variety of interventions as well as promote neuroplasticity.

The mode of movement (active, active assist, or passive) used during bilateral priming depends on the device used and the abilities of the individual. Stinear et al. (2008) described a progression of attention during each session. Participants were first encouraged to attend to the active movement of the unaffected side followed by attention to the passive movement of the affected side. During the four-week progression, participants progressed from passive movement to imagining active movement coming from the affected hand during the priming exercise. Finally, active bilateral symmetrical movement from both hands was encouraged at week 4. Because of the actuator that couples the plates in the Bilateral Priming Device (Exsurgo Rehab, Ltd., Auckland, NZ), the movement is symmetrical even if the less affected hand is doing the majority of the work, and the inertial aspect of the device allows for hundreds of repetitions per session. Thus, it is not necessary for the patient to have active range of motion of the wrist in order to participate in bilateral priming. For individuals with wrist spasticity, stretching prior to priming is advised. Shiner et al. (2014) successfully used heat prior to the bilateral priming in individuals with increased wrist spasticity.

Hsieh et al. (2016) reported on a bilateral priming study using the Bi-Manu-Track (Rehab-Stim Co, Berlin, Germany), a robotic device allowing wrist flexion and extension as well as forearm supination and pronation. This device allows passive, active-assisted, active, and resisted movement. Speed, range of motion, and torque can be individually adjusted and, thus, the affected arm could start in a passive mode, and the therapist can progress it to a more active one.

Bilateral priming has also been examined in individuals in the subacute phase of poststroke recovery (C. M. Stinear et al., 2014; Stoykov & Stinear, 2010). A randomized clinical trial compared two groups receiving inpatient upper limb training by either an occupational therapist or a physical therapist. One group received 20 min of bilateral priming prior to training while the comparison group had 20 min of intermittent cutaneous stimulation designed to provide a mild sensation to the affected forearm prior to training (C. M. Stinear et al., 2014). At 12 weeks post-stroke, the bilateral priming group was three times more likely to reach their recovery plateau as compared to the comparison group. However, at 26 weeks poststroke, there was no significant difference between groups. The authors concluded that, in the subacute phase of poststroke rehabilitation, bilateral priming increases the rate of recovery rather than the magnitude of recovery. Also, C. M. Stinear and Byblow (2014) suggested that improving the rate of recovery rather than magnitude may be a more plausible goal for subacute poststroke rehabilitation.

Neural Mechanisms of Bilateral Priming

Studies examining the neural mechanisms mediating bilateral priming poststroke have included individuals with chronic (C. M. Stinear et al., 2008) and subacute (C. M. Stinear et al., 2014) poststroke hemiparesis. In chronic poststroke hemiparesis, results can be explained by the theory of asymmetry of hemispheric excitability due, in part, to the

decreased inhibition from the ipsilesional cortex on to the contralesional one. C. M. Stinear et al. (2008) compared two groups of subjects with chronic hemiparesis that performed a fine motor activity home program; in the test group, the fine motor activity was preceded by bilateral motor priming, and the comparison group performed the activity without priming. At baseline, both groups had reduced excitability in ipsilesional cortex, decreased short-interval cortical inhibition (SICI) in contralesional hemisphere, and decreased transcallosal inhibition from the ipsilesional to contralesional hemisphere. After treatment, an increase in cortical excitability of the ipsilesional hemisphere was found in both groups. However unlike the comparison group, the bilateral priming group had an increase in SICI in the contralesional hemisphere and a reinstatement of transcallosal inhibition (TCI) from the ipsilesional on to the contralesional hemisphere. Both groups improved in behavioral measures posttreatment. However only the bilateral group persisted in their behavioral improvements at follow-up and maintained the changes in SICI and TCI. This indicates that in chronic subjects the positive effect of bilateral priming is likely mediated by normalization of inhibition although more studies confirming this finding would be advantageous.

In a clinical trial with subacute stroke patients who were also tested at 26 weeks poststroke (C. M. Stinear et al., 2014), participants in the bilateral priming group, and not the comparison group, had a greater increase in ipsilesional excitability and a greater decrease in contralesional excitability from 2 to 26 weeks poststroke. At baseline, ipsilateral silent periods caused by transcallosal projections from the ipsilesional to the contralesional hemisphere were present in both groups. However, at 26 weeks poststroke (chronic phase), the priming subjects had an increase in depth and persistence of the silent periods, and the comparison group had a decrease in the same. The decrease in interhemispheric inhibition (IHI) from the ipsilesional to the contralesional hemisphere did not occur immediately after stroke but occurred over time. A firm causative relationship between the strengthening of TCI from the ipsilesional hemisphere and a decrease in motor impairment is not definitively established. More studies demonstrating the specificity of the relationship between TCI and motor recovery are needed before firm conclusions can be drawn.

The mechanisms of bilateral priming have also been examined in healthy participants (Byblow et al., 2012; J. W. Stinear & Byblow, 2002). J. W. Stinear and Byblow found that intracortical inhibition is decreased when bilateral movement is synchronous (mirror symmetric) as compared to asynchronous (alternating). In another study using healthy participants, Byblow et al. (2012) compared the effects of mirror symmetric wrist flexion and extension (MIR) to asynchronous (alternating) wrist movement using a variety of measures such as transcranial magnetic stimulation (TMS), median nerve stimulation for H reflexes, and behavioral motor assessments. Subjects were examined in separate sessions comparing two movement conditions MIR and ALT. After 20 min of either MIR or ALT, Byblow et al. (2012) found a significant increase in corticomotor excitability in the target hemisphere in the MIR condition but not in the ALT condition and a decrease in IHI from active to passive hemisphere in the MIR but not in the ALT. The decrease in IHI from the active hemisphere is comparable to a decrease in inhibition from the contralesional hemisphere in chronic stroke survivors. The more excitable hemisphere (contralesional in stroke survivors) sends inhibition to the less excitable one, and this can interfere with

poststroke motor movement recovery. Another experiment examined H reflexes via stimulation of the median nerve before and after MIR and ALT conditions. After 20 min of either movement condition, there were no changes in H reflexes for either of the conditions indicating that the effects of priming are likely supraspinally mediated. The final experiments provided evidence that mirror symmetric movement promotes an increase in movement-specific cortical excitability as well as an increase in the rate of motor learning.

Unilateral Motor Priming

Types of Unilateral Priming

Unilateral priming is a type of movement-based priming induced by unilateral movement. For stroke survivors, unilateral priming can originate from either the affected or less affected limb. Stoykov and Corcos (2013) compared stroke survivors who received unilateral priming of the affected hand consisting of continuous, active-assisted wrist flexion and extension of the affected wrist to those who had bilateral motor priming. In both groups, priming was followed by the same task specific training protocol. Positive changes were noted in the participants who received unilateral priming; however, the magnitude of improvement was greater for those who received bilateral motor priming.

A second possible type of unilateral priming is also known as cross-training, a strength training paradigm where one limb is trained to strengthen the opposite one. We have not found any literature that specifically defines cross training as a priming technique. However, strengthening and facilitation techniques to the less affected side during therapy with individuals with neurological impairment have been historically used in physical therapy and OT. For example, proprioceptive neuromuscular facilitation may start with manual facilitation and strengthening techniques (also termed irradiation) of the less affected side in order to prime the nervous system prior to training the affected side (Reznik, Biros, & Bartur, 2015).

Clinical Applications of Unilateral Priming

Dragert and Zehr (2013) investigated a unilateral ankle strengthening program for the less affected ankle in individuals with poststroke upper extremity hemiparesis. Results included improved muscle activation in the untrained, affected side as well as increased bilateral strength. Urbin, Harris-Love, Carter, and Lang (2015), examined stroke survivors as well as healthy subjects, all of whom served as their own controls using multiple baseline measures. The study demonstrated that, in stroke survivors with severe upper limb hemiparesis, high-intensity resistive training on the less affected arm improved range of motion of the affected, untrained arm. As predicted, the healthy subjects had significantly greater strength in the untrained arm at postintervention as compared to preintervention.

We previously mentioned a study by Corti et al. (2012), who examined intense, dynamic strengthening of the affected arm. This was a sequential intervention study and not a priming one per say. However, the study clearly showed the positive effects of unilateral dynamic, high intensive resistance (POWER) training of the affected arm delivered prior to FTP. Compared to FTP followed by POWER training, the POWER/FTP group demonstrated

reduced compensatory movements that enabled re-emergence of normal shoulder and elbow movement patterns. Corti et al. concluded that “functional outcomes are enhanced when therapeutic interventions train the capacity of the motor system prior to engaging in repetitive task practice” (p. 851).

Neural Mechanisms of Unilateral Priming

High-intensity resistance training using cross-training or cross-education techniques has been reported to strengthen homologous muscles (Munn, Herbert, Hancock, & Gandevia, 2005) and increase cortical drive (Lee, Gandevia, & Carroll, 2009). Carroll, Herbert, Munn, Lee, and Gandevia (2006) contended that cross training techniques may be mediated by both supraspinal and spinal mechanisms. Evidence of supraspinal mechanisms mediating cross training has been noted in studies using functional magnetic resonance imaging (fMRI); (Farthing, Borowsky, Chilibeck, Binsted, & Sarty, 2007) as well as TMS (Hortobagyi et al., 2011). Hortobagyi et al. used TMS to measure inhibition and found a decrease in IHI from the trained to the untrained hemisphere that was also correlated with gains in strength of the untrained hand. Changes in supraspinal mechanisms documented by TMS have also been found in cross-training studies with stroke survivors (Urbin et al., 2015). Urbin et al. found that, after heavy resistance training of the less affected arm, motor-evoked potentials from the affected untrained limb, not present at pretraining, were elicited at posttraining. This indicates an increase in the corticospinal drive.

Farthing et al. (2007) used fMRI and compared two groups of healthy subjects; one group received imagery training while the test group received unilateral resistive training to evaluate the cross-training effect. At posttraining, fMRI data of the cross training group showed enlarged regions of activation in the untrained arm area of contralateral sensorimotor cortex as well as areas of ipsilateral temporal lobe. Significant pre to post increases in bilateral wrist strength were also found in the cross-training group. The imagery group also had enlarged regions of activation from pre- to posttraining only in the contralateral sensorimotor cortex; however, no significant strength increases in either arm were found. Farthing et al. contended that the increase in ipsilateral temporal lobe activation observed only in the cross-training group could possibly indicate a role of memory retrieval for movements learned by the trained arm.

In a dorsiflexion strengthening study with healthy subjects, Dragert and Zehr (2011) predicted a bilateral strength increase with modulation of H reflex excitability in the trained soleus only as indicated in previous studies. As predicted, bilateral strength gains in tibialis anterior (TA) were found. However, the hypothesis that H-reflex modulation would be found in the trained leg only was not supported. Instead, there was a bilateral decrease in excitability of high threshold motor units in the soleus indicating changes in spinal excitability in the untrained leg. As the soleus is the antagonist to the trained muscle group, reduction in excitability is advantageous to prevent coactivation in neurological populations. Dragert and Zehr (2013) completed a similar study in stroke survivors. Findings included bilateral strength improvements in TA at posttraining as well as an increase in reciprocal inhibition in the untrained TA. Reciprocal inhibition was defined as a depression of the agonist (TA) as a response to stimulation of the nerve (tibial) for the antagonist (soleus). The

authors concluded that an increase in reciprocal inhibition indicates improved response to descending motor commands as well as increased sensitivity to Ia inhibitory interneurons.

Aerobic Exercise as Priming

Aerobic Exercise in Rehabilitation

Aerobic exercise is an important component of rehabilitation, and it is well established that aerobic exercise is beneficial for cardiovascular health, reduces the risk for occurrence of secondary diseases, and improves quality of life. It is only over the past two decades that the benefits of exercise on brain health are becoming more apparent. Engaging in regular aerobic exercise induces several positive effects on cognitive function (Brett, Traynor, & Stapley, 2016; Colcombe, Kramer, McAuley, Erickson, & Scalf, 2004; Cox et al., 2016; Groot et al., 2016). Older individuals participating in high levels of physical activity show a reduced risk of cognitive decline and dementia (Blondell, Hammersley-Mather, & Veerman, 2014; Colcombe & Kramer, 2003). Higher levels of physical activity have also been associated with improved health and physical function in those with neurological conditions such as Parkinson's disease (Abrantes et al., 2012; Cruise et al., 2011; Uc et al., 2014) and stroke (El-Tamawy, Abd-Allah, Ahmed, Darwish, & Khalifa, 2014; Tiozzo et al., 2015).

Aerobic Exercise as Priming

Given the effects of acute and long-term exercise on neural plasticity, learning, and memory, there is a recent surge of interest in investigating aerobic exercise as a priming mechanism to enhance motor function. Roig et al. (2012) demonstrated that 20 min of intense cycling performed immediately before or after practicing a visuomotor skill task improves retention of the motor skill more than practicing the task alone. This finding was further supported by Statton, Encarnacion, Celnik, and Bastian (2015) and Mang, Snow, Campbell, Ross, and Boyd (2014) who observed that 20–30 min of moderate aerobic exercise led to an immediate improvement in motor performance of a skilled task. It has been suggested that when exercise precedes practice, improvements in skill learning could be due to better encoding of procedural information whereas when exercise is performed after practice is perhaps due to consolidation of long-term memory. More experimental studies are needed to confirm this hypothesis.

Studies have also examined the positive effects of acute bouts of aerobic exercise on plasticity inducing protocols using noninvasive brain stimulation. McDonnell, Buckley, Opie, Ridding, and Semmler (2013) reported that a single bout of low-intensity cycling (and not moderate intensity) promoted continuous theta-burst stimulation induced plasticity within the upper limb motor cortex. These results have been partly confirmed by Mang et al. (2014), who reported that 20 min of moderate-intensity cycling is conducive to the neuroplastic effects generated by paired associative stimulation within the upper limb primary motor cortex (M1). These findings regarding the effectiveness of aerobic exercise on plasticity inducing mechanisms are very promising as long-term potentiation and long-term depression are key neural processes related to motor learning and functional recovery.

Clinical Applications of Aerobic Priming

Given the cohort of studies examining the effects of aerobic exercise on motor skill acquisition in healthy individuals, studies establishing aerobic exercise effectiveness in patient populations are limited. Chronic stroke survivors have difficulty reaching their aerobic target due to motor deficits and declines in cardiorespiratory systems secondary to lack of activity (Billinger, 2010). One case study has examined the feasibility of combining aerobic exercise and repetitive upper limb task practice in an individual with stroke (Linder et al., 2015). The aerobic exercise was completed using a forced-rate exercise paradigm. A motorized stationary cycling unit forced a faster pedaling rate and did not allow the subject's preferred rate. The subsequent upper limb treatment was a series of object-oriented grasp and reaching tasks that were continuously upgraded to improve skill. The results provided early promising results of implementing such a paradigm. However, the applications of this study are limited by the absence of a control design.

Aerobic exercise is a cost-effective way to enhance the capacity of the neuromotor system to be more receptive to task specific training and optimize motor learning and recovery. As the effects of aerobic exercise are global, the aerobic task (e.g., biking, walking, rowing) could be individualized to the functional ability of the participant. Evidence indicates that aerobic exercise may need to be administered immediately prior to the therapy in order to be effective as a priming mechanism. There still exist questions regarding the optimal parameters of aerobic exercise such as the intensity and duration of exercise that is most suitable as an adjunctive technique. It is not clear whether low-intensity or moderate-intensity exercise maybe most beneficial.

Neural Mechanisms of Aerobic Priming

Aerobic exercise has been shown to influence brain plasticity. Studies examining the mechanisms of exercise on brain plasticity using animal models have revealed that exercise influences synaptic transmission (Vaynman, Ying, Yin, & Gomez-Pinilla, 2006), enhances neurogenesis (van Praag, Christie, Sejnowski, & Gage, 1999) and neuronal activation (Holschneider, Yang, Guo, & Maarek, 2007), increases cerebral blood flow (Pereira et al., 2007), and moderates activity of neurotransmitters (Real, Ferreira, Hernandez, Britto, & Pires, 2010) and synaptic proteins (Ferreira, Real, Rodrigues, Alves, & Britto, 2010) responsible for neural plasticity. A few studies have investigated the effects of acute aerobic exercise on M1 excitability. The M1 plays an important role in motor learning and movement execution, and is critical for functional recovery after neurological impairment. Also, M1 has shown to exhibit higher levels of activation during exercise (Christensen et al., 2000), and it is possible that this activation may help prime subsequent movements. An acute bout of lower extremity cycling exercise (20–30 min) at moderate and high intensity has been reported to reduce SICI in the M1 that lasts for up to 30 min after exercise (Singh, Duncan, Neva, & Staines, 2014; Smith, Goldsworthy, Garside, Wood, & Ridding, 2014). It is important to note that, in both these studies, the global effect of exercise was studied by examining M1 excitability of an unexercised upper limb muscle. Thus, aerobic exercise has priming effects that are not effector or muscle specific.

Although not well understood, one of the key mechanisms through which an acute bout of exercise triggers neural plasticity is via the expression of neurotrophins. Brain-derived neurotrophic factor (BDNF) seems to be the most responsive neurotrophin to physical activity especially after acute aerobic exercise. BDNF is expressed by the BDNF gene and promotes the survival of neurons by playing a role in the growth, differentiation, and neuroprotection of these cells. Over two dozen studies have examined the effects of exercise on BDNF in healthy and patient populations. In general, most (70%) of studies have reported that there is a transient increase in serum or plasma concentration of BDNF following an acute bout of aerobic exercise (Knaepen, Goekint, Heyman, & Meeusen, 2010). This finding is not very robust in long-term exercise training studies, with some studies reporting increases in basal BDNF values following several weeks of exercise (Baker et al., 2010; Rasmussen et al., 2009; Zoladz et al., 2008) and with others not supporting this result (Schiffer, Schulte, Hollmann, Bloch, & Struder, 2009; Schulz et al., 2004). Available evidence also suggests that aerobic exercise and not strength training induces changes in BDNF levels (Goekint et al., 2010; Levinger et al., 2008; Schiffer et al., 2009; Schulz et al., 2004).

The evidence reviewed above indicates that aerobic exercise has the potential to prime the motor cortex, and this has important implications for neurorehabilitation. Because the effectiveness of acute and long-term exercise to induce plasticity in the damaged brain is not well established, further studies in neurological populations are needed for the successful implementation of aerobic exercise as motor priming protocol.

Discussion

We have discussed three methods of movement-based priming that are cost effective, safe for most individuals, and do not require a skilled operator. These priming methods can and should be easily implemented into clinical OT practice. Movement-based priming is a broad category of priming that uses repetitive movements to prime motor cortex prior to motor training. The field of OT has a tradition of intervening at the body structure and body function level (including improving motor, perceptual or cognitive systems) as well as intervening using compensatory techniques to improve safety and independence in ADL. The former is appropriate when the clinician ascertains that there is a reasonable chance that impaired body structures and functions might improve. Prabhakaran et al. (2008) state that motor recovery reflects improvement in actual biological processes. Thus, our definition of motor recovery is reduction in motor impairment reflecting true biological recovery. For stroke survivors, priming is appropriate when the overall purpose of therapy is to remediate impairment and, to the extent possible, encourage neuroplasticity, and hence elicit recovery.

Compensation, however, refers to using compensatory movement strategies. In addition to compensatory movement strategies, a compensatory approach may focus away from personal abilities to modify a task or change the human and/or nonhuman environment (i.e., use of assistive devices). Although the two approaches do not have to be mutually exclusive, a clinician may favor one intervention approach over the other depending on the time post neural injury, the level impairment of a particular patient, or the knowledge and skills of the therapist. According to Prabhakaran et al. (2008), remediation of impairment is part of

recovery rather than compensation and occurs mainly during the first three months poststroke. However, evidence shows that chronic subjects can also improve, whether it is through recovery or compensation. In a recent published opinion, C. M. Stinear and Byblow (2014) contend that it is currently unclear whether chronic stroke survivors who reflect improved motor recovery do so because (a) they did not reach their proportional recovery maximum in the subacute phase due to inadequate dose, (b) their recovery represents a reversal of deterioration, or (c) there was a genuine raising of the recovery plateau.

Given the background of the field OT and the focus on purposeful activity and occupation-based treatment, one might ask why an occupational therapist would use a technique that appears to be similar to rote exercise. Priming is a means of maximizing neuroplasticity that, in theory, could lead to improved occupational performance. Doucet (2012) argued that occupational therapists have a moral obligation to try to improve the lives of their patients by any means possible. More information is certainly needed about the efficacy of certain priming techniques; however, occupational therapists working in neurorehabilitation should become knowledgeable in the various types of motor priming and have an idea of how to combine them with various types of neurorehabilitation interventions.

There are limitations that therapists should acknowledge before clinical guidelines for priming can be established. For example, the duration or intensity of priming is yet to be established. Typically laboratory studies have used convenience duration of 15–20 min of movement-based priming prior to motor training. Another limitation is the few studies documenting a combination of priming and training techniques. Thus, we cannot recommend one type of priming, movement based or otherwise, over another. Finally, motor consolidation is not the same as priming, and the neural mechanisms are likely dissimilar. Moreover, there are few studies documenting motor consolidation techniques. More studies are needed to develop definitive criteria for movement-based priming techniques and for establishing clinical guidelines related to priming in the patient population.

Obstacles for implementing priming into OT practice might include the division between academic OT and the realities of occupation therapy practice. For example, leaders of OT have called for occupational therapists to work in the community and nontraditional settings. While we agree with this, we also acknowledge that the majority of occupational therapists work in nonmental health hospital based settings (American Occupational Therapy Association, 2010). In an appeal to strengthen occupational therapy research in neurorehabilitation, Doucet (2012) argued,

“as occupational therapists, we can increase our value to consumers, insurers, policymakers, and society simply by being more effective at what we do: Neurorehabilitation practice will be more effective if we step outside our comfort zone and are proactive in developing the clinical–academic alliances needed to improve patient care through rigorous scientific inquiry.” (p. e117)

Current OT education emphasizes occupation-based treatment, which is the use of everyday ordinary tasks to improve function. However, Doucet (2012) appropriately called for neurorehabilitation occupational therapists to “accept that some of the methods we use to enable occupation in our clients will not be occupation-based” (p. 492). She urged

occupational therapists to go beyond current treatment standards and discontinue use of ineffective strategies.

While there have been limited studies which describe current neurorehabilitation occupational therapy practice, a multisite observational study was conducted which documented types of OT interventions used in stroke rehabilitation in six hospitals across the country (Latham et al., 2006; Richards et al., 2005). This group of authors found that the two most frequent treatment activities were upper extremity dressing and upper extremity motor control tasks. One of the most common interventions for upper extremity dressing was teaching one-handed skills that utilize only the less affected arm and not the affected one. In the multivariate analysis, the time spent on upper extremity motor control tasks did not translate into success in upper extremity dressing tasks. Richards et al. speculated that because most training in activities of daily living is compensatory the dressing training may have undermined the upper extremity motor control training. This finding should be further explored. With ample evidence on the effects of disuse, one might reflect on why teaching one handed techniques with the less affected arm still abounds in clinical practice and why it is emphasized in occupational therapy curriculums.

A paradigm change for both clinicians and students may be beneficial to the field of occupational therapy. Indeed, as research and technology evolve, occupational therapists in neurorehabilitation will need to be versed in techniques that maximize the potential of the nervous system. Occupational therapy practitioners, students, and faculty need an in depth understanding how behavior influences neural activity.

To facilitate this change, the neuroscience education component of occupational therapy training programs should be further developed. Besides conventional neuroanatomy training that consists of learning about brain structures and their functions, various types of plasticity (both adaptive and maladaptive) as well as neural mechanisms of recovery need to be emphasized. Textbooks in neurorehabilitation will need more frequent updating. Indeed, for the sake of future recipients of OT service, OT education must demand greater proficiency in this rapidly changing body of knowledge.

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