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Thinking About Better Speech: Mental Practice for Stroke-Induced Motor Speech Impairments

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Abstract

Background—Mental practice (MP) is a mind-body technique in which physical movements are cognitively rehearsed. It has shown efficacy in reducing the severity of a number of neurological impairments.

Aims—In the present review, we highlight recent developments in MP research, and the basis for MP use after stroke-induced motor speech disorders.

Main Contribution—In this review, we: (a) propose a novel conceptual model regarding the development of learned nonuse in people with motor speech impairments; (b) review the rationale and efficacy of MP for reducing the severity of stroke-induced impairments; (c) review evidence demonstrating muscular and neural activations during and following MP use; (d) review evidence showing that MP increases skill acquisition, use, and function in stroke; (e) review literature regarding neuroplasticity after stroke, including MP-induced neuroplasticity and the neural substrates underlying motor and language reacquisition; and (f) based on the above, review the rationale and clinical application of MP for stroke-induced motor speech impairments.

Conclusions—Support for MP use includes decades of MP neurobiological and behavioral efficacy data in a number of populations. Most recently, these data have expanded to the application of MP in neurological populations. Given increasingly demanding managed care environments, efficacious strategies that can be easily administered are needed. We also encounter clinicians who aspire to use MP, but their protocols do not contain several of the elements shown to be fundamental to effective MP implementation. Given shortfalls of some conventional aphasia and motor speech rehabilitative techniques, and uncertainty regarding optimal MP implementation, this paper introduces the neurophysiologic bases for MP, the evidence for MP use in stroke rehabilitation, and discusses its applications and considerations in patients with stroke-induced motor speech impairments.

Stroke remains the leading cause of disability in the United States (U.S.) (American Heart Association, 2011), a leading source of disability internationally (e.g., Ferri, Schoenborn, Kalra, et al., 2011), and frequently causes behavioral, cognitive, and physical deficits that undermine independence and quality of life. Data also show that stroke incidence is not changing (e.g., Kleindorfer et al, 2006); thus, the human and financial burden of stroke will only increase over time, especially as the world population ages and becomes more obese (for a review, see Rundek & Sacco, 2008).

Among the myriad of deficits exhibited after stroke, aphasia constitutes one of the most common impairments, with up to 35% of all stroke survivors exhibiting some form (e.g., Code & Petheram, 2011; Dickey et al, 2010). Aphasia also constitutes one of the most disabling stroke-induced impairments; patients with stroke-induced aphasia tend to experience longer lengths of rehabilitative stay, smaller functional gains, and are less likely to return home after rehabilitation than patients without aphasia (e.g., Dickey et al, 2010; Paolucci et al., 2005). Additionally, stroke-induced aphasia often deleteriously affects mood, social outcomes, quality of life (e.g., Code & Herrmann, 2003; Davidson et al., 2008; Ferro, Mariano, & Madureira, 1999), and is associated with more frequent mortality (e.g., Bersano, Burgio, Gattinoni, & Candelise., 2009).

Motor speech impairments are frequently observed concurrent to stroke-induced aphasia, and may include apraxia of speech, spastic dysarthria, hyperkinetic dysarthria, and other specific deficits (e.g., Delaney & Potter, 1993). Yet, despite the widely appreciated impact of these impairments, conventional speech and language therapy techniques often yield immediate acquisition of trained items, but render limited generalization to items not practiced in the clinic, and limited generalization to real-world contexts (e.g., Kendall, Rosenbek, Heilman, Conway, Klenberg, et al, 2008). For example, patients may become quite adept with the lists or cues learned during their clinical sessions, but may experience difficulty in everyday conversations encountered outside of the clinical environment. Hence, functional language and communication deficits often persist, despite gains observed by the clinician during treatments. This phenomenon is further complicated by diminishing lengths of stay (which limit the amount of therapist-patient contact time), and the inherent challenges associated with targeting a community-based behavior within a clinical environment.

Many patients with motor speech impairments are also thought to exhibit “learned nonuse,” which refers to the suppression of spontaneous language use due to communicative impairments. For example, a patient exhibiting motor speech impairments and learned nonuse may excessively use gestures during conversations to identify particular objects, instead of making attempts to name the objects. Or, he/she may use the same utterance repeatedly with different inflections to convey meaning. This may be because new naming or phrases requires great effort, whereas using other communicative strategies (e.g., gesturing, having a spouse or care partner communicate the patient's intent) may require less effort and be more rapid and/or successful in conveying the information. The patient may also experience frustration, embarrassment, and/or make incorrect word choices during active attempts to speak, all of which may further disincentivize spontaneous speech attempts. Additionally, as with other central nervous system sequelae (e.g., Elbert, Flor Birbaumer, Knecht, Hampson, et al, 1994), it is plausible that cortical areas corresponding to speech and language production may contract, which would further confound such attempts. The extent to which each of these factors contribute to learned nonuse likely varies from patient to patient. Nonetheless, these factors likely conspire to discourage the patient from making spontaneous attempts to speak. Eventually this suppression of conversational speech becomes habitual, and more disability may be exhibited than what may actually exist. In Figure 1, we suggest how these factors may conspire to produce learned nonuse in people with motor speech impairments. To our knowledge, this is the first conceptual model of learned nonuse in motor speech impairments. However, it should be noted that the model is based on understandings of how learned nonuse is thought to transpire in stroke-induced hemiparesis.

The Current Paper

In response to the above clinical and behavioral challenges, intensive (e.g., Pulvermuller et al, 2005; Pulvermuller et al., 2001) and high duration (e.g., Bakheit, Shaw, Barrett, et al,

2007; Hinckley & Carr, 2005) therapy regimens have been proposed. Such approaches have been suggested to be efficacious by increasing the amount of time a person spends in therapy (for a review see Code & Petheram, 2011), and/or the number of repetitions of a targeted language skill accomplished during a particular block of therapy time (e.g., Bhogal, Teasell, & Speechley, 2003). Moreover, they are believed to overcome the learned nonuse phenomenon via operant conditioning (Pulvermuller & Berthier 2008), with some studies (e.g., Pulvermuller, 2001) reporting that such use facilitates functional cortical reorganization. However, the efficacy and clinical practicality of these approaches vary considerably, and these regimens may not be feasible in some clinical environments. Financial restrictions also sometimes exist, creating an additional barrier to needed post-acute speech/language services. Thus, there remains a need for efficacious, easily-administered, interventions for stroke-induced language and motor speech impairments.

Mental practice (MP) involves the cognitive rehearsal of physical movements in the absence of physical, voluntary attempts (e.g., Guillot & Collet, 2005). Because MP does not involve physical rehearsal, it can be performed without direct supervision, with minimal expense, and with no equipment. While used for decades in sport and exercise settings, our team was the first to apply MP to increase learning and outcomes in stroke (Page, 2000), showing that MP use increases affected upper extremity use and function (e.g., Page, Levine, & Leonard, 2005; Page, Levine, & Leonard, 2007). Most recently, this work has revealed that MP use causes the same cortical changes as physical practice in stroke (Page, Szaflarski, Eliassen, Pan, & Cramer, 2009).

Given promising MP neurobiological and behavioral efficacy data with the stroke-affected upper extremity, we have been exploring MP use in other neurological impairments, with our most recent efforts focusing on post-stroke motor speech disorders. The previously-mentioned shortfalls associated with other speech and language approaches, and MP's noninvasive, straightforward application in many environments, make it appropriate to inform clinicians about this promising treatment. We also encounter clinicians who aspire to use MP, but are uncertain how to effectively implement the technique. For example, a speech language pathologist and physical therapist associated with a "stroke recovery center" with which one of the authors worked, as well as several websites, have claimed that they possess MP protocols suitable for use with stroke survivors. However, these protocols lack many of the essential elements known to make MP efficacious from decades of research. Such claims can be misleading to patients and their care partners, as well as to well-intentioned professionals who may emulate these protocols for their own clinical use.

Our overall goal is to increase the evidence-based use and understanding of this promising mind-body technique. Given shortfalls of some conventional speech rehabilitative techniques, diminished amount of clinical time available to implement them, and uncertainty regarding optimal MP implementation, this paper introduces the neurophysiologic bases for MP, the evidence for MP use in stroke rehabilitation, and discusses its applications and considerations in patients with stroke-induced motor speech impairments. To our knowledge, this is the first paper to suggest the application of MP to motor speech impairments.

Neuroplasticity After Stroke and Motor Speech Impairments

Emboldened (and, some would argue, initiated) by Broca's work (e.g., Broca, 1861) the neurosciences were dominated by localizationist concepts for decades. Central to this paradigm was the belief that specific brain regions primarily controlled specific functions. It had also been a common clinical tenet that the central nervous system was "hardwired" and/or that change could only occur in younger individuals, or as a result of spontaneous

recovery occurring soon after ictus. Yet, it was also known that, although particular cells serve specific functions, there is considerable sharing and overlap among cells in the functional representation of motor control. For example, movement representations can vary from moment to moment at a particular site, as first shown by Leyton and Sherrington (Leyton et al, 1917). Similarly, many had demonstrated that individual neurons subserve a myriad of functions (e.g., Bach y Rita 1964; Hebb, 1949).

With the advent of noninvasive functional neuroimaging it was discovered that the human motor system is modified by use, and that this use – or activity dependent plasticity – plays a major role in recovery of function after stroke (e.g., Butefisch, Davis, Wise, et al., 2000). For example, Jenkins and colleagues (Jenkins et al, 1990) showed that repeated tapping training with the 2nd, 3rd, and 4th, fingers caused expansion in the cortical representations corresponding to these areas, and correlative motor improvements. Karni and colleagues (Karni et al, 1995) similarly reported enlargement in human primary motor cortices engaging in daily practice of several motor tasks, while Classen and colleagues (Classen et al, 1998) showed that even simple thumb movements repeated over a short period of time induce lasting cortical representational changes. Others have repeated this finding, using a number of practice scenarios (e.g., Elbert et al, 1995; Liepert, Terborg, & Weiler, 1999). From these data, it is clear that entire groups of cells can reconfigure quickly in response to behavior. “Neuroplasticity” refers to the capability of such cells or groups of cells to alter function and/or structure according to repetition and demand.

After stroke, a reduction in motor cortex excitability and a decrease in the size of the cortical representations of paretic muscles each occur (e.g., Cicinelli, Traversa, & Rossini, 1998; Liepert, Bauder, Sommer, et al, 1998). These cortical changes are likely attributable to reductions in use, whether that “use” may refer to diminished integration of the affected upper extremity in functional tasks, less weightbearing the affected lower extremity, and/or diminished use of speech combined with increased use of cueing, gesturing, or other strategies due to aphasia. Regardless of the particular impairment, it now appears that when repetitive, task specific practice (RTP) is provided, the size of the cortical areas representing the particular capacity being used increase, and correlative functional changes are seen. Importantly, this plasticity is brought about only when learning and repetitive use occur. Plasticity is not typically observed when non-functional, repetitive use, and/or attempts to increase strength (e.g., a muscle) or volume (e.g., voice) are undertaken. (for a recent review, see Nudo, 2006).

Johansson (2000) argued that plasticity constitutes the principal process involved in stroke recovery. The prospect of plasticity being “the” fulcrum for stroke recovery has several implications for clinical stroke rehabilitation, including broadening the ways in which “recovery” is measured to include brain-based techniques, and the increased use of programs emphasizing restitution of function. Regarding the latter, a common clinical tenet has been that function cannot substantively increase through rehabilitative efforts. This sentiment, combined with the longstanding sentiment that the maximal period of recovery may be just a few months (e.g., in aphasia, it has been suggested to be as little as 2 months {e.g., Holland, 1989}), often causes clinicians to focus their efforts primarily on compensatory strategies to “work around” clients' deficits (e.g., provision of assistive/alternative communication in patients with non-fluent aphasia; one-handed shoe-tying in patients exhibiting upper extremity hemiparesis). While more research is needed to identify the patients most likely to benefit from particular interventions, the discovery of use-dependent plasticity - even years after ictus - justifies that rehabilitative efforts instead place greater emphasis on restitution of function in at least some of these patients.

Neurophysiological Foundations of Speech Rehabilitation

Within aphasia rehabilitation, there has been debate as to whether restorative (as described above) or compensatory therapy techniques are more efficacious. Some rehabilitation programs emphasize functional communication ability without actual restitution of function. Examples include the “promoting aphasics communicative effectiveness” (PACE) program (Davis & Wilcox, 1981), and other “pragmatic” approaches in which the therapist and patient are put in “real” communicative situations (e.g., Springer, Huber, Schlenk, & Schlenk., 2000). As discussed in the next paragraph, constraint induced aphasia therapy requires subjects to actively communicate in appropriate and specific ways with other people with aphasia in the context of a card game. Through participation in such programs, patients can learn appropriate, contextually-relevant, cues and communication behaviors allowing them to be successful in particular situations (e.g., using compensatory behaviors to order food in a restaurant), without restitution of lost functions in the purest sense.

While the above programs have shown some success, it is also now apparent that neuroplastic changes and correlative recovery of language function may occur in some patients by adopting cognitive strategies that mimic the RTP conditions described previously. Similar to PACE, these strategies still place patients in contextually-relevant scenarios. However, these “restorative” programs force patients to actively attempt to produce and reacquire language that is contextually and semantically appropriate while in these situations. Use of gestures, familiar utterances, or other strategies that typify learned nonuse are discouraged in favor of new language production, all within a supportive environment using positive reinforcement and appropriate progression as skills are mastered. For example, a patient may initially be asked to identify a noun that is on a card during a game of “Go Fish” played with his therapist (e.g., “This is a bench.”). As he masters production of this noun, additional challenge may be added by using cards featuring nouns with descriptors, such as colors (e.g., “This is a brown bench”). Subsequently, the patient may be presented with more complex/high context scenes (e.g., “The man is sitting on the brown bench by the tree”), may be asked to do so in group settings, and/or may be asked to do so in more complex settings (e.g., a hospital cafeteria) as additional progressions.

When such strategies are adopted, “real” language functional recovery has been reported, with new brain areas assuming function of damaged areas. The oldest hypothesized mechanisms for this reorganization is by Gowers (1895), who asserted that homologous, contralateral areas may take on function of damaged areas subserving speech. The particular idea that speech restitution may be related to in the contralesional/right hemisphere (also known as “Henschen's axiom” {Henschen, 1920–1922}) has been echoed by other researchers throughout the decades, with Nielson (1946) arguing that the extent of neurologic recovery is directly related to the capacity of the right hemisphere to take on language functions.

It now appears that cortical areas adjacent to the site of the lesion may also assume functions of damaged speech and language regions. For example, it appears that the three sub-regions comprising Broca's area (BA) (i.e., pars opercularis {BA 44}, pars triangularis {BA 45}, and pars orbitalis {BA 47}) perform in a hierarchical fashion - and in collaboration with right, homologous regions - to assist with spoken language. Specifically, the posterior portion of the lateral prefrontal cortex in both hemispheres assists in selection of discrete actions that are relevant to the immediate context, whereas more anterior regions integrate the actions into goal oriented behaviors that are less temporally fixed (e.g., Koechlin & Jubault, 2006). Such findings can inform the clinician by allowing determination of where the patient's spoken language may be “breaking down,” and guide intervention strategies. For example, lesions in BA's 44, 45, and 47 appear to be more involved in tasks requiring syntactic and semantic processing (see Bookheimer, 2002, for a review); therapists treating

patients lesions in these areas may, thus, use interventions targeting these processes, such as semantic feature analysis.

In the case of MP, our laboratory is particularly interested in whether repeated activation of the above networks via MP may (a) recruit new cortical areas to assume functions of the ones damaged by stroke or (b) enhance activation in regions that are part of the “normal” speech and language networks. We hypothesize that this use-dependent plasticity may overcome the loss of portions of this hierarchical executive network after stroke, and ultimately improve speech production. From a scientific perspective, the discoveries of the above-mentioned, hierarchical networks also warrant a shift away from an emphasis solely on side “dominance” or lesion laterality, and toward greater monitoring of the distributed networks and the regional contributions of those networks. Our team is using techniques such as diffusion tensor imaging (DTI) to examine the integrity of the underlying networks, and their changes concurrent to improvements in speech capabilities in people with motor speech disturbances.

Mental Practice As A Restorative, Neuroplastic, Strategy in Stroke

For decades, authors have reported improved movement quality when MP is combined with physical practice (e.g., Bachman, 1990; Yaguez et al, 1998). Although individuals do not voluntarily move during MP, widespread muscular activations occur during MP as if the activity is being physically performed. Indeed, in one group's words, MP produces “an identical, minute innervation in localized muscles activated during the same overt movement” (Hale, 1982). Evidence for this finding first came from Jacobsen (1931), who reported activations in the biceps brachii of participants who were asked to visualize bending their right arms. More recent studies have confirmed Jacobsen's findings using electromyography (EMG). (e.g., Bakker, Boscher, & Chung, 1996), and have shown that vegetative responses (e.g., heart rate, oxygen consumption) during MP are consistent with degrees of imagined effort on a particular task. (Decety, Jeannerod M, Germain M, & Pastene, 1991). In other words, an imagined task that is physically more strenuous would elicit greater physiologic responses than one that is less strenuous.

While the neuromuscular processes associated with MP have long been known (e.g., Jacobsen, 1931), improved neuroimaging techniques have elucidated the neural substrates subserving MP (e.g., Decety, 1996; Kosslyn, Ganis, & Thompson, 2001). Indeed, motor evoked potentials, EEG activity, and increased cerebral blood flow to cortical areas that are used during physical performance of a particular task, are all observed during MP (e.g., Salford, Ryding, Rosen, et al, 1995). Although beyond the scope of this review, it is also interesting to note that the time needed to mentally execute actions is nearly identical to the time needed to physically execute them. (Decety, Jeannerod, & Prablanc, 1989). This evidence has led researchers (Decety, 1996) to conclude that imagined actions rely on same neuromuscular substrates as physical movements, including after neurologic injury (e.g., Lacourse, Orr, Cramer, & Cohen, 2005).

The above attributes make MP especially well-matched to the needs of patients with stroke, and the increasingly challenging environments in which rehabilitative services are rendered to these patients. In particular, given that the amount of therapist-client contact time is diminishing and that stroke patients spend large amounts of time alone and inactive (Bernhardt, Dewey, Thrift, & Donnan, 2004), the ease and cost with which MP can be carried out as an alternative or adjuvant practice strategy make it advantageous. MP is also likely to be useful in clinical situations in which safety precludes physical practice (e.g., balance) (Linden, Uhley, & Smith, 1989) and/or when physical factors (e.g., pain, fatigue) make physical practice difficult (e.g., Pan, Morrison, Ness, Fugh-Berman, & Leipzig, 2000). For example, walking is, perhaps, one primary goal after stroke (e.g., Lord, McPherson,

McNaughton, Rochester, & Weatherall, 2004). Yet, practicing walking in one's hospital room or one's home is unwise for most patients, especially if they lack substantive care partner support. In such situations, MP constitutes a viable, safe method of practicing walking, since skills are cognitively rehearsed without actual, physical practice (e.g., Dunskey, Dickstein, Marcovitz, Levy, & Deutsch, 2008). As alluded to previously, work conducted by our team (e.g., Page, Levine, & Leonard, 2007) has shown that RTP efficacy is significantly increased when augmented by the addition of MP. As with other forms of practice discussed previously, we have shown that learning and use-dependent cortical plasticity is observed following MP + RTP participation (e.g., Page et al., 2009) in chronic stroke patients (> 1 year post ictus). We have begun to apply these findings to other stroke-related impairments, and at a variety of times post stroke (e.g., in the days and months post ictus).

MP Applications to Motor Speech Disorders

Based on promising neuroimaging and behavioral data in stroke and spinal cord injury, we are investigating the efficacy of MP as a restorative treatment technique in stroke-induced motor speech impairments. Acknowledging that there are numerous variants of post stroke speech disorders, our work is focusing on apraxia of speech as well as other motor speech disorders. In addition to the practical reasons to use MP that were stated at the beginning of this paper, there is a strong neurological basis to the use of MP in people with aphasia. For example, it had been shown that observation of others' movements caused the activation of so-called "mirror neurons" (e.g., Grezes, Armony, Rowe, & Passingham, 2003; Iacoboni et al., 1999). These findings were recently replicated in language models, showing activations of the mirror neurons located in Broca's area during observation of speech (e.g. Buccino et al., 2004) and during communicative and mouth gestures (e.g., Ferrari, Gallese, Rizzolatti, & Fogassi, 2003). It is likely that mentally imagining functional, appropriate speech performed by others from a third person perspective would enact the same network of mirror neurons. Additionally, language studies have shown that the motor frontal cortex is involved in both the generation of action-denoting verbs and motor representations of the same actions (e.g. Pulvermüller et al., 2005; Tettamanti et al., 2005). Concurrently, a number of studies have shown impairments in processing of action-related words (in most cases verbs) in neurological patients for whom the conceptual representations of action were also impaired (e.g., Peran et al., 2003; Silvani & Ciccarelli, 2007). Collectively, these data point to a network that is shared – or at least partially shared – by both language and movement production. It is already known that MP activates this shared network to produce movement-related changes; it is hypothesized that repetitive use of language via MP will, likewise cause use-dependent cortical changes in these networks that will produce language changes.

To investigate the above hypotheses and optimize MP for clinical aphasiology use, we are investigating three different applications of MP in people with non-fluent aphasia. We present these below for readers who may be considering applying this clinically-practical strategy in their own environments: (a) as an augmentative treatment: in most cases, MP will not take the place of physical practice. In fact, there is considerable evidence suggesting that regimens combining physical and mental practice are most effective in increasing physical performance and skill acquisition (e.g., Hird, Landers, Thomas, & Horan, 1991). This is likely due to the fact that a performer needs to have some kinesthetic memory of the activity (i.e., how it feels to perform the activity) to then effectively imagine performing it. Consequently, we are examining the efficacy of MP when provided adjunctively before or after physical practice of functional communication strategies. Working closely with our rehabilitative team, the MP used in these scenarios recapitulates the physical practice that occurred during supervised sessions with the speech-language pathologist. In some ways, the MP has the ability to complement or even go beyond the scope of the physical practice

sessions. For example, the MP sessions may enable the patients to rehearse pragmatic scenarios that cannot be physically approximated in the speech clinic, and/or for which there may not be time given the limited amount of contact time with the speech staff. Whereas half-hour outpatient sessions may focus on the client's technique and articulatory precision of particular words/phrases, we may collaborate with the staff so that the MP focuses on applying these techniques to appropriate use in a particular hobby or environment valued by the patient (e.g., ordering pizza in his/her favorite restaurant); (b) as a stand-alone treatment: MP has been shown to be more effective than no practice at all, and may be especially useful when it is infeasible to physically rehearse. Likewise, there is some evidence in stroke rehabilitative contexts suggesting that MP without formalized physical practice is efficacious (e.g., Dunskey et al., 2008). This finding may be applicable to community-based clients retaining non-fluent language deficits, but who have no reimbursement to cover much-needed therapy visits. In particular, we suspect that the use of MP may be better than the alternative of no guided practice at all (which constitutes the standard of care for most discharged stroke patients). To test this hypothesis, we are examining whether home-based MP of particular naming and semantic tasks is efficacious among individuals with non-fluent aphasia who have previously (but are not currently enrolled in) communicative therapy regimens. (c) as a "virtual" treatment: A large number of our clients are not able to attend regular, therapist-administered, treatment sessions due to lack of transportation, cost associated with use of public transportation, support needed to attend the sessions (e.g., grooming, self-care, community mobility to/from session), and/or other difficulties associated with matriculating to a major medical center for rehabilitative therapy participation. To address these challenges, one of the most intriguing applications of MP lies in its administration over the Internet. As we alluded to earlier, observation of an activity triggers the mirror neuron system, facilitating the encoding of motor engrams (e.g., Celnik et al., 2006) and the retrieval of motor responses (e.g., Brass, Bekkering, & Prinz, 2001). We have developed the capacity for our clients to watch videos of a speaker announcing common words and phrases. These videos will be presented remotely to community-dwelling patients with non-fluent aphasia. This capacity has the advantage of diminishing the number of occasions on which the patients have to matriculate to supervised therapy sessions, while also allowing us to provide a well-controlled, easily-modified, individualized speech regimen to each client from virtually anywhere in the community with Internet access (e.g., a coffee shop; a library; a senior center). The use of a password protected website allows us to monitor the frequency, duration, and activities during patients' site use. Consequently, we can examine the quantity and quality of compliance with the regimen as well as dose-response issues (i.e., the extent to which quantity of use correlated with outcomes from the program).

In all of the above cases, we are using pragmatic models discussed earlier as a framework for the presentation of our MP scenarios. As discussed earlier, such models require that subjects rehearse activities that simulate participation in "real world" communicative situations. In the case of MP, a hypothetical patient may begin by being presented with a list of words and phrases that would be used in a typical conversation (e.g., "hello"), and/or specific nouns or numbers needed in daily conversation for stroke survivors (e.g., "toilet;" "food"). The patient would engage in MP, in which he envisions himself or another individual saying these words (for reasons described earlier, this MP may be effectively augmented or even replaced as needed by video presentations of an individual saying the word or phrase). Moving forward, the progression for MP work with this patient could include using more complex words or phrases (i.e., more descriptors; use of verbs), with eventual mental rehearsal of these complex phrases simulated in more complex environments. For example, we have begun the 8-week intervention phase with the subject physically and mentally rehearsing initiation of common, conversational entry points with the therapist (e.g., "Hello; how are you?"). Over time, we have layered on a therapist reply

that requires an in-kind, subject response (e.g., the therapist says, “I’m fine; how are you?”). The therapist may also throw in a “curve ball” as the training progresses (e.g., “I’m not great; my car broke down and I had to walk to work today”). Such responses require the subject to fabricate a new, appropriate reply (e.g., “I am sorry to hear that.”). As is the case with MP used in other contexts (e.g., preparing for a sports performance), the mentally rehearsal allows the subject to think through various communicative scenarios that he/she may encounter when initiating a conversation. The subject also can use the MP to repetitively reflect on and problem solve through facets of the physical practice session with which he/she may have had difficulty.

In addition to modifying the complexity of the conversational content, we will also increase the interpersonal and environmental difficulty levels as the intervention period progresses. To progress the former, we may have the subject physically and mentally rehearse the same conversational scenario, but do so with his spouse, on the telephone, and, eventually, in a social situation (e.g., ordering food from a waiter at a casual restaurant). This takes advantage of the abundance of positive research showing the efficacy of partner training for people with non-fluent aphasia (e.g., Simmons-Mackie, Raymer, Armstrong, Holland, & **Cherney**, 2010); however, we also hope to abate some of the apprehension encountered when communicating with increasingly significant others. Progression of the latter may occur by increasing the noise of the ambient environment in which the subject must initiate conversation and/or the speed at which the subject must initiate the conversation and make his/her needs known (e.g., the hospital cafeteria when no one else is behind him in line versus ordering food when there is a line behind him). The therapist or care partner is always by the subject's side to shape the behavior through positive encouragement and incremental increase in the challenge, as described elsewhere (e.g., Pulvermueller et al., 2001). Irregardless of the specifics of the scenario, details are described with high specificity on the audiotapes, and depicted with high specificity in the video-based rehearsal strategies.

To confirm that participation in these regimens impacts change in domains relevant to real world functioning, we typically administer a variety of measures examining speech and language impairment (e.g., Aphasia Quotient of the Western Aphasia Battery; Apraxia Battery for Adults II), function, and the amount and quality of language use in “real world” scenarios. The latter is particularly important given the well-established relationships between use, neuroplasticity, and function (e.g., Heddings, Friel, Plautz, Barbay, & Nudo, 2000; Nudo, 2006). This team also probes the individual to assure that the practicing of these words is improving, using untrained words as a “control” scenario. Use of neuroimaging can also be used longitudinally to ascertain how cortical changes may co-occur with MP use, and how MP-induced cortical changes may resemble cortical changes reported in other language retraining programs.

Clinical Application of MP

MP is conceptually straightforward and is used in a variety of performance contexts (e.g., athletics, musical performance). Perhaps because of these reasons, many underestimate the considerable science and great care that goes into the construction of an effective, carefully-progressed, MP regimen. The genesis of entire journals, textbooks, and scientific conferences dedicated entirely to MP, as well as decades of scientific studies discerning the ingredients that optimize MP administration, are evidence of the high degree of knowledge and specialization that is required to implement an effective MP regimen. The need for precision and the potential difficulties associated with administering MP are heightened when working with clinical populations such as stroke. Below, we briefly highlight two of the most vexing factors that must be considered in implementing a MP program.

When?—A fundamental question is when MP should be most effectively delivered. We have usually administered our MP programs targeting the affected arm, ambulation, and language directly after supervised physical practice (i.e., clinical) sessions. However, administering MP directly after physical practice also has inherent disadvantages, including patient fatigue and distractibility associated with having just participated in a tiring language regimen. In such situations, it is plausible that MP may be best practiced as a “bolus” of therapy in the evening (e.g., in the patient’s hospital room and/or as a home exercise regimen), or as a “warm-up” strategy just before patients begin their clinical therapy sessions. The optimal timing of MP in relation to physical practice in clinical settings – and the patient and diagnosis-related factors that affect this timing – is an important area for future research.

With Whom?—As stated earlier, we frequently encounter clinicians who wish to apply MP to patients encountered in their clinical loads, and/or scientists who wish to opportunistically expand MP use to other diagnoses or impairments. Like any clinical approach, MP will not be efficacious in every client, and the efficacy of this approach will depend somewhat on the etiology and location of the injury. For example, patients with parietal and premotor strokes may have difficulty with imagining certain tasks, such as pointing to an item (e.g., Sirigu et al., 1996; Tomasino & Rumiati, 2004). Such difficulties would preclude inclusion of MP scenarios that incorporated gesturing as part of the communication strategies.¹ Likewise, certain mental operations that would occur during imagery of movements (e.g., mental rotation) are typically lateralized to the right hemisphere (e.g., Corballis & Sergent, 1989). Consequently, patients exhibiting left hemisphere lesions (i.e., people with non-fluent aphasia) would likely not be impacted by this finding; however, it would affect other sub-groups, such as patients with right-sided lesions involved in our other MP programs targeting object manipulation using the affected upper extremity. Like any area of specialized therapeutic expertise, clinicians interested in MP must stay current with MP research to ensure its cost effective, appropriate implementation.

The “in whom” considerations associated with MP are not limited to being familiar of lesion type and/or location. Other patient-related factors will also strongly influence the effectiveness of the regimen. Like any form of exercise, MP is a multi-faceted ability that varies from individual to individual (e.g., Isaac & Marks, 1994). Consequently, the inherent ability to execute MP will also vary. For example, the ability to mentally imagine oneself or others performing tasks and/or the vividness with which the images appear in the “mind’s eye” may vary greatly. Scales such as the Motor Imagery Questionnaire (MIQ) (Hall & Pongrac, 1983) can be used by clinicians to determine how adeptly a patient is able to mentally picture him/herself performing such skills, with some data suggesting a relationship between this ability and skill acquisition. This possible relationship, as well as the possibility that individuals can increase the quality of their mental images through practice (e.g., Hamel & Lajoie, 2005), make this a worthwhile construct to monitor in patients involved in MP programs. It also remains unclear whether the vividness with which stroke patients image is related to the quality of the imagery given that the relationship between subjective scores of imagery and objective measures of visuo-spatial manipulation is rather loose (e.g., Lequerica et al., 2002). It is also conceivable that the subjective measure of vividness of mental imagery is driven by disinhibition caused by subcortical lesions.

¹A possible “workaround” for such patients may be the use of computer-based MP strategies as discussed earlier in this manuscript. Rather than having to produce the mental images themselves, this would allow patients to observe others performing the movements, enacting the “mirror neuron” cortical network that likely subserves both MP and passive observation of movements.

Conclusion

Mental practice (MP) is a promising mind-body intervention that is supported by decades of studies that demonstrate its efficacy and inform the elements that optimize its use. Most recently, MP studies have included neuroimaging evidence that identify the cortical networks activated during MP tasks. Results of some of these studies also suggest that motor and language cortical areas are both activated during mental and physical practice, as well as during passive, third person observation of physical practice by others.

Because of the extensive body of literature now available on MP, much is known about the populations in whom it works, and the considerations that must be taken into account when constructing MP scenarios. Consequently, while MP itself can be cost effectively and easily administered in a variety of settings, clinicians interested in administering MP should collaborate with an experienced MP provider to optimize its appropriate, effective implementation.

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Figure 1.
Hypothesized Development of Learned Nonuse Among People with Motor Speech Impairments