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Neuroplasticity and Functional Recovery: Training Models and Compensatory Strategies in Music Therapy

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Abstract

New research developments in the recovery of function following neurological trauma as well as basic and applied research relevant to music perception and production, seem to point to the suggestion that specific music therapy interventions that directly address the restoration of function as opposed to developing compensatory mechanisms, in certain circumstances, may now be a more appropriate treatment approach. We will address the issue of appropriate timing for the introduction of each strategy and discuss potential outcomes of each approach. As one might imagine, much of this research is published in the neurological journals, which music therapists may not regularly consult. It seems challenging enough just to keep abreast of new music therapy literature. Further, there is so much neurological research that the music therapy clinician often finds it difficult to know where to begin. This text provides an overview of a growing concept related to recovery known as neuroplasticity, and how specific training models in music therapy utilize this relatively recently identified phenomenon. Also, a framework will be provided to help guide the practicing clinician when attempting to build a lineage of systematic thought relevant to the use of music in neurorehabilitation, as well as discuss the frequently employed concept of behavioural compensation. Some music therapy literature that relates to these different concepts is outlined. Discussions surrounding the decision to use either of these two approaches are presented in relation to stages of recovery and the clinical presentation of the client.

Keywords: neuroplasticity, compensation, Neurologic Music Therapy, Rational-Scientific Mediating Modell.

Introduction

A dilemma facing many music therapy clinicians working with people with neurological conditions is whether the focus of therapy should be to develop compensatory functional skills based on the spared function, or to focus on addressing the restoration of function (reducing the impaired function in order to return it to normality, or as close as possible to that). Diverse music therapy literature in this area certainly falls into both of these approaches but what has not been discussed is why and when each approach should be adopted. More than likely this relates to stages of recovery, the dynamics of client progress, the functional needs of the client, and perhaps the individual music therapists' own philosophical stance. However, there is growing evidence from the field of neurology and neurological recovery that the practice of developing compensatory skills based on spared function without attempting to minimise the deficits resultant from injury, may actually inhibit the clients' restoration of normal function. Recent information regarding how the central nervous system responds to injury and how individuals regain lost functioning through training models has produced promising new approaches. Taub, Uswatte, and Elbert (2002), state in their preface that "cortical reorganization after a lesion, central nervous system repair, and the substantial enhancement of extremity use and linguistic function by behavioural therapy, support this emerging view" (p. 22). Nevertheless, there are certainly situations when focusing on compensatory skills as a means of developing function other than specifically targeting the deficit is implicated. The purpose of this paper was to raise music therapy clinicians' awareness of the need to address restoration of function as a first priority with compensation function employed as an alternative when restoration of function does not occur. This text will explain these ideas with references to previous music therapy literature. The concepts of compensation and cerebral reorganisation (neuroplasticity) shall be explained to highlight the necessity to consider which approach is appropriate in any specific situation.

While there is increasing experimental evidence of the existence of neuroplastic processes within the medical field, there is yet to be any music therapy studies evaluating the effect of music therapy programs on cerebral reorganisation. This falls in line with the general finding that there is a paucity of music therapy literature within the neurorehabilitation area, particularly experimental research. Likely explanations stem from the enormous costs involved in employing technology such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), which could evaluate the effects of music therapy[1]. Given this, this paper attempts to connect knowledge emerging from studies of neuroplasticity as a way of explaining some outcomes reported in music therapy. Similarly, music therapy studies reporting on developing compensatory function were identified to illustrate how music therapy can be framed within this philosophy of practice.

Compensatory Function

Behavioural compensation suggests that the individual adopts and develops the use of skills, which were not used prior to the injury in order to engage in and complete tasks. This is not to be confused with compensatory strategies, which imply the use of an intervention to stimulate the restoration of normalised function. In the case of compensation, the undamaged brain systems are engaged and the client uses novel tactics or unusual behaviours to carry out acts of daily living. It often involves new learning and requires the individual to use an alternative means of task performance to the preferred (or so-called normal) approach, which has become more difficult or impossible due to the impairment or disability sustained (Dixon & Bäckman, 1999; Prigatano, 1999).

The concept of compensation has its roots in Emerson's (1933) concept of the process of regression or egression to the norm. This process describes the human organism as a dynamic, variable, adaptive, and self-correcting system that has the tendency to return to normalcy (Dixon

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[1] An fMRI (or functional magnetic resonance imaging) scan is a radiology technique which uses magnetism, radio waves, and a computer to produce images of body structures. An MRI scan can be used as an extremely accurate method of disease detection throughout the body. In the head, trauma to the brain can be seen as bleeding or swelling. Other abnormalities often found include brain aneurysms, stroke, tumors of the brain, as well as tumors or inflammation of the spine.

Positron Emission Tomography (PET) is a tool used to diagnose brain functions and disorders. PET produces three-dimensional, colored images of chemicals or substances functioning within the body. These images are called PET scans.

& Bäckman, 1999). This idea holds that for every gain there is a corresponding loss, and therefore, for every defect or deficit, there is some way to recover.

Kurt Goldstein first developed the concept of compensation in 1933, when he stated that recovery occurs as a consequence of a change in strategy rather than the amelioration of the deficit (cited Benton & Tranel, 2000, p.11). Goldstein argues that rehabilitation should be focused on establishing situations in which the patient may succeed in performing tasks through intact capacities rather than decreasing the impairments per se. Examples of compensation include the use of physical tools such as walking sticks and electronic wheelchairs, modified kitchen equipment, diary/day planners, augmentative communication devices, or electrical appliances activated by specifically designed switching devices. Similarly, the clients themselves can alter what they do as a means of achieving the task – dressing themselves whilst sitting down, consciously taking a large breath before speaking, using positive self-talk before commencing challenging tasks. In all these cases, the clients would make use of their spared capacity.

Music Therapy and Compensatory Function

The idea of using spared capacity as a means of redeveloping functional skills is not something new to music therapy. Here, music therapy programs provide opportunities for clients to learn alternative means for undertaking daily tasks to accommodate for the neurological impairments inhibiting their function. The clients' strengths or capabilities are identified and then used to develop new skills to compensate for what is now lost.

Within the music therapy session, the client might take up opportunities to practice using tools introduced to them in other allied health treatment programs. Such tools could include augmentative communication systems whereby the music therapist incorporates compics to be learnt by the client "pictorial representations of objects, feelings, etc." into specifically composed songs (Baker, 2003; Livingston, 1996). For a client learning to utilise a diary as a strategy to compensate for poor memory, the music therapist may set tasks for the client to complete between music therapy sessions to encourage the use of this tool in a variety of mediums (Lee and Baker, 1997).

Music therapy programs can also aid clients in their effort to complete tasks when an alternative means of approaching task completion is indicated. For example, for a hemiplegic client, a music therapist may focus on the unaffected upper limb in an attempt to strengthen its function. This is particularly important when the affected limb was pre-morbidly the dominant limb. In Erdonmez's (1991) case study, her client developed functional control of his unaffected (and also nondominant) left upper limb. Within a supported environment, Erdonmez provided music instruction to assist the man with re-engaging in music playing. Functional outcomes were evident in the man's re-engagement in painting. Here he used his left hand to paint, an activity previously enjoyed by him pre-morbidly.

Further evidence of compensatory approaches was reported by Lucia (1987). She described how the implementation of a music therapy program helped hemiplegic patients maximise their use of the unaffected side of their bodies. In collaboration with an occupational therapist, Lucia's clients performed a series of 14 exercises, which were set to music. Songs were selected to ensure that they matched the sequence of movement. She proposed that pairing the singing of pre-morbidly learned familiar songs with the movements of the exercise might enhance the acquisition of new movement patterns that were previously activated by the affected limb.

Livingston (1996) and Lee and Baker (1997) adopted compensatory strategies to help clients with memory difficulties learn new information. For example Lee and Baker described a client who had safety issues when using her wheelchair (for example, forgetting to apply her breaks, attempting to use the wheelchair to go down stairs). The treating music therapist composed a song surrounding the problems this client had, consequently, the client used the song as a cue to safety when using her wheelchair. In this example, the client was unable to utilise memory in the normal fashion and therefore compensated for this by using music as a cue.

Restoration of Function

Until recently, it was generally believed that the adult brain (cortex) was structurally static. In recent years however, there has been growing evidence to suggest that the human brain is capable of self-modification and considerable reorganization following neurological trauma (Kolb & Gibb, 1999; Robertson, 1999; Mateer & Kerns, 2000; Stein, 2000). This notion of reorganization stems from the idea that the brain can reorganize itself to enable an individual to do *more with less* (Kolb & Gibb, 1999). This means that the brain makes use of the remaining brain tissue and reorganises its function to enable the individual to participate in daily life.

The earliest concepts of cerebral reorganisation were reported in 1868 by Jules Cotard (cited Benton & Tranel, 2000, p. 5). He reported that children with congenital or earlyacquired atrophy to the left hemisphere did not grow up to be aphasic. Even though these children were gradually losing their *language centres* of the brain, their brain seemed to be able to adapt or reorganise itself so that the language centres were adopted by a differing area of the brain. This lead to the idea that partial or complete recovery may be a product of neural substrate reorganisation, now referred to as neuroplasticity.

Hughlings Jackson, a pioneer in neurology in the 1870s, contributed important findings to the concept of neuroplasticity. He showed that the rate of development of a lesion (rapid – as in a stroke, or slow – as in a tumor) determined the resulting symptomatology. Here, a rapid lesion produced a greater disability than a slower developed lesion. This suggested that for the slower developing brain lesion, there was time for the brain to reorganise itself to prepare for the pending and gradual loss of function. Such time was not available in the event of a stroke or traumatic brain injury with a dramatic loss of brain tissue occurring.

Nudo, Barbay, and Kleim (2000), Kolb and Whishaw (2000) and Bacj-Y-Rita (2000) highlighted that whilst they see the potential for the endogenous reorganisation of remaining circuits following trauma, they assert that it is unlikely that a localised structure like the cerebral cortex could undergo a whole-scale reorganisation of cortical connectivity in the adult. They understand that the extensive recovery that some people demonstrate must be the result of additional factors including compensation. However, they believe that in the developing brain, full-scale reorganisation may be possible. Kolb and Whishaw (2000) understand neuroplasticity as a process involving changes at the synaptic level, particularly the changes in the structure and number of glial cells[2]. They state that when neurones lose synapses (through brain trauma), there is a retraction of dendritic arborisation; conversely, when neurones gain synapses, there is an

[2] Glial cells play an important role in modifying synapses and have been examined in studies of laboratory animals to understand the location and nature of changes in neurones and their synapses.

extension of dendritic arborisation. If a cerebral injury is followed by an increase in dendritic space, there is a good functional outcome, whereas if an injury leads to atrophy of dendritic space, there is a poor functional outcome. This leads to a logical assumption that if dendritic growth can occur, functional recovery should be enhanced. This raises the question as to how one can provide the greatest potential for an increase in dendritic space, that is, how can therapy contribute to dendritic growth.

With the developments in positron emission tomography (PET) and functional magnetic resonance imaging (fMRI), studying the changes to functional organisation has been possible and is fuelling the developments in understanding neuroplasticity. It is now possible to examine the changes of cerebral reorganisation following the exogenous application of different treatments. Kolb and Gibb (1999) and Kolb and Whishaw (2000) showed that treatment can facilitate plastic changes in animals. For example, Kolb and Gibb (1999) studied changes in number and size of glial cells, neurones and synapses, in animals following experience. When animals were placed in complex environments filled with toys that they could interact with – so called enriched environments – there was a marked increase in the number and size of glial cells. This change in the glial cells is correlated with the changes in neuronal morphology and it is thought that the glial cells played an important role in stimulating the neuronal changes.

Researchers observed rats who had received controlled neurological damage to ascertain whether they were able to reach out and obtain their food after they had sustained physical impairment. They noted that after some time and effort, the rats were again able to obtain their food. This suggested that some neural modification occurred with time, which enabled them to achieve the required behaviour (to take the food). However, Kolb and Gibb (1999) acknowledged that some behavioural compensation occurred, as evidenced by the rats' modified behaviour used to grasp their food. Kolb and Gibb (1999) concluded that some animals can adapt to cortical injury by using other remaining circuitries. In addition, Kolb and Whishaw (2000) showed that in rats, following tactile stimulation, there was an unexpectedly large reduction in behavioural deficits, which was associated with a reversal of the atrophy of cortical neurones normally associated with these lesions. This was evidence of the brain's reorganisation following *treatment.*

Similar changes in neuronal morphology have been found in humans. For example, in professions such as a typist, a machine operator, and an appliance repairman, a high level of finger dexterity developed over a long period of time. When examining brain structures, it was noted that they had especially large differences in trunk and finger neurones in their brains, when compared with other people (Kolb & Gibb, 1999). Further, the digit fingers in string players showed increase in cortical representations when compared with the left thumb, yet they found no such difference in the cortical representation of the right hand (Elbert, Pantev, Wienbruch, Rockstroh & Taub, 1995). This suggests that intense or repetitive experience in one area can increase the cortical representation of that function in the brain.

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With respect to people with functional deficits, there is also ample evidence to indicate similar potential for reorganisation in humans with regard to recovery from disturbances in attention, memory, language, and executive functions (Kolb & Gibb, 1999; Mateer & Kerns, 2000; Robertson, 1999). Studies such as those by Pascual-Leone et al. (1993), O'Leary, Ruff, and Dyck (1994) and Elbert et al. (1995) highlight that the brain can reorganise itself quickly dependent on situation and experience. Pascual-Leone et al. (1993) reported an increase in cortical representation of the index finger used in reading by blind Braille readers. Similarly, within a few weeks, it was shown that the cortical representation of the hand and fingers in humans was altered following surgical separation of webbed fingers (O'Leary et al., 1994). These studies provide compelling evidence that dynamic reorganisation is possible in the cortical topography of adult humans.

Studies with aphasia have provided some evidence that therapy facilitates cortical reorganisation in humans. One good example is the study by Musso et al. (1999). Their study supported the role of specific training in influencing functional reorganization in the treatment of aphasia (auditory comprehension). They provided a short-term, intense, and effective training program (11x 8-minute sessions) for language comprehension, with PET scans completed before the first session and then after each of the 11 sessions. Following different interventions, comprehension improved in patients with a significance level of $p<0.0001$. They also compared a non-specific stimulation condition (TV, writing, speaking, listening to the radio), which did not improve the performance of the patients (over the same time span). PET scans found that improved language performance correlated with fast modification of the activation pattern in a bilateral cortical network comprising brain regions directly or indirectly related to language. Most of these areas are related to language processing under normal conditions, suggesting that the brain reorganized itself as a consequence of training rather than exposure to non-specific stimulation.

Mateer and Kerns (2000) and Robertson (1999) also support the concept of plasticity and that the reorganization of lesioned brain systems is induced and dependent on experience rather than purely natural recovery. They argue that substantial literature supports the view that experience-dependent changes occur in the brain throughout the lifespan through modification of synaptic activity, changes in synaptic firing, dendrite arborisation, and axonal sprouting, with the underlying theme of cells that fire wire together (Mateer & Kerns, 2000, Schallert et al., 2000). Connections between cells stimulated to fire in synchrony are strengthened, whereas non-synchronous firing inhibits connectivity. With regard to recovery from neurological trauma, improvements are viewed as natural extensions of normal learning and experience-dependent processes. Here, repeating the experience strengthens the connections, thereby enhancing recovery.

Mateer and Kerns (1999) further argue that varying the types of experiences will shape synaptic interconnections and further influence recovery. Similarly, Nudo et al. (2000) propose that rehabilitation must be varied and not repetitive. They state that if physiologic plasticity in cortical maps is critical for functional recovery, then therapy should aim to progressively develop increasingly difficult motor skills. Tasks that require simply moving the limb repetitively in the absence of skill acquisition will not facilitate reorganisation. They argue that changes in the cortex are driven by the acquisition of new motor skills, not simply by motor use.

Music Therapy and Restoration of Function

Cortical reorganisation is about developing new connections in perhaps new regions of the brain, which can be used to undertake tasks no longer able to be performed by the person. This indicates that therapy concerns redeveloping the same skill rather than finding alternative means of achieving a task (that is, compensation). Therefore, music therapy programs that focus on restoring deficit areas could be viewed as instigating neuroplastic processes.

Arguably, the most recent and efficacious advancement in the use of music for functional treatment of individuals with neurologic disorders would be those techniques and protocols associated with the Neurologic Music Therapy (NMT) model (Thaut, 2000). Treatment protocols related to the NMT model are based on both basic scientific and clinical research related to the perception and production of music and its subsequent effects on brain and behavior functioning. These strategies are the end products of a systematic lineage of inquiry, which Thaut (2000) has described as the Rational-Scientific Mediating Model (R-SMM). Before discussing clinical research, it is important to note that within the context of the R-SMM, three levels of inquiry precede studies related to clinical outcomes with diagnosed populations.

The first level of research involves investigations of the physiological, neurological, and psychological systems related to music perception and production within the affective, cognitive, and sensor-motor domains. Within the context of the motor domain, which to date is the specific area with the most substantial body of empirical research, areas of understanding to be investigated at this level would include audiospinal facilitation, auditory-motor arousal, and rhythmic synchronization. Studies by Platel et al. (1997) describing the functional anatomy of music perception and Rossignal and Melvill Jones (1976) describing rhythmic movement synchronized to auditory stimuli provide information at the foundational level for understanding the influence of organized auditory stimuli on brain and behaviour functioning.

The next level of investigation is concerned with the more broad perspective of how we learn new motor skills, rehabilitate after injury, and how the brain functions to control movement after damage to recover lost abilities, all in the absence of music (Thaut, 2000). This step in the R-SMM attempts to establish or identify parallel processes between musical and non-musical behavior through comparative analysis. Studies that utilize brain scanning technology such as fMRI data to show the correlation between motor improvements and rehabilitation therapy (Johansen-Berg et al., 2002), as well as PET data to reveal the functional anatomy of stroke patients (Chollet et al., 1991), are examples of relevant literature used at this level to build knowledge leading toward the functional application of therapeutic music experiences.

The final step before engaging in clinical research would be to study the influence of music as a mediating stimulus on non-musical behaviour. The purpose of research at this level is to utilize the similarities between brain and behavior function, in and outside of music, which were identified in the second step, and build a good rationale for future studies of the therapeutic application of music. Again, within the motor domain, one area of interest at this level would involve the effect of auditory rhythm on simultaneous motor functioning (McIntosh, Prassas, Kenyon, & Thaut, 1998; Thaut, Rathbun, & Miller, 1998; McIntosh, Brown, Rice, & Thaut, 1997; Brown, Thaut, Benjamin, & Cooke, 1993). This level of research is fundamental as it establishes the data necessary to build rational hypotheses, regarding the influence of music on non-musical functioning, to be tested in clinical research models.

Upon arrival at level four, clinical outcome research, given the first three stages of inquiry have been established, the researcher would then already lie on a bed of scientific understanding gleaned from a systematic approach to understand the influence of music on non-musical brain and behaviour functioning. This level of research has shown substantial promise and evidence for the use of music to retrain motor functioning after brain injury or deterioration, much of which is based on cortical plasticity and training models. The focus of research in step 4 is on the functional lasting change generated or facilitated through music-based interventions. Three standardized treatment protocols for neuro-motor rehabilitation have resulted from this line of inquiry and include: rhythmic auditory stimulation (RAS), therapeutic instrumental music performance (TIMP), and patterned sensory enhancement (PSE) (Thaut, 2000). Gait training under the influence of auditory rhythm, previously referred to as rhythmic auditory stimulation (RAS), has shown to be therapeutically beneficial for patients with traumatic brain injury, (Hurt, Rice, McIntosh, & Thaut, 1998) for patients who have experienced a stroke, (Thaut, McIntosh, & Rice, 1997) and for patients with Parkinson's disease (Thaut, McIntosh, Rice, & Miller, 1996). Research in this area, within the motor domain, is not limited to gait as evidence is also mounting for the use of music, or specifically, rhythmic cuing, in the functional recovery of upper extremity abilities as well (Thaut, Kenyon, Hurt, McIntosh, & Hoemberg, 2002). In all cases, the emphasis in research and clinical application is on meaningful and enduring recovery of lost function.

In reviewing the clinical work reported in the literature, several examples of stimulating recovery of lost function is evident. The earliest music therapy example of this comes from a text by Fields (1954). Fields reported on four subjects she studied where the music therapy session aimed to improve the client's use of the affected limb. Familiar music was selected and modified accordingly so that the client was able to perform the desired movements on musical instruments. In doing this, every time a movement is performed, it strengthened any neural connection made, gradually ensuring that the task becomes easier with each attempt.

Livingtson (1996) described her work with clients who had received an acquired brain injury. She used keyboard-based activities to facilitate improvements in finger coordination and dexterity and eye-hand coordination. Livingston also illustrated how the culturally and age appropriate headbanging to rock music assisted one client to strengthen his neck muscles, allowing him to be able to lift his head up and visually interact with people. Livingston explains that the music provided clear cues to help the client with the tempo of his movements. Like Fields (1954), Livingston's music therapy programs were focused on recovering the deficits.

Glassman (1991) utilised the technique of music therapy and bibliotherapy to facilitate improvements in cognition for a girl with brain injury. Her client initially began listening to songs, which reflected the client's inner feelings. Following this, the client began to substitute her own words for some words in other popular songs, to reflect the feelings she was experiencing. Finally, her cognitive abilities improved so much that she was able to write her own lyrics independently. Whilst the primary focus was on the client's emotional exploration, the success of this method was gradual, which in addition simultaneously redeveloped cognition. Similarly, Wit, Knox, Jutai, and Loveszy (1994) reported on a project, which used electroacoustic music for *training* brain-injured adolescents' attention. Wit et al. (1994) used the motivational factor of music to encourage the subjects to practice various attentional skills. The four treatment subjects improved in their attention, whereas the control subject made only slight improvements. In both of these citations, the focus of the program was to help clients regain lost functions.

Gervin (1991) and Claeys, Miller, Dallow- Rampersad, and Kollar (1989) used pre-composed songs to assist with compensating for impairments in memory and direction following. Gervin (1991) composed and sang a song about *getting dressed* to assist a man to regain this lost functional task. He demonstrated problems in initiating, motor planning, and sequencing his ability to dress in a reasonably acceptable time frame (25-28 minutes). Gervin stated that external cues (song lyrics) with accompanying tempo for pacing could address disorders in initiation, sequencing, motor planning, and problem solving (p. 88). Over the course of ten sessions (two weeks), the man was able to dress himself in 10-11 minutes. In this example, the song provided prompts to compensate for the impairments; however, this was employed to restore function rather than develop compensatory skills.

Magee (1999) described a case in which a music therapy program was used to enhance the client's communication potential. A man with aphasia at eight months post-injury was seen for an intense music therapy program comprising three sessions per week. At one point, Magee introduced singing exercises and a modified melodic intonation therapy program (MIT), which enabled the man to generate some phrases in the *out of the music therapy session* situation. Similarly, Baker (2000) provided a detailed outline of her modified MIT program, which was provided to two clients. The basis for this technique was that the music aimed to function as a mnemonic device, with the clients using the melody as a trigger to generate the words/phrases they chose to communicate. When the clients had difficulty generating the word they wished to use, they could self-generate their own melodic cues. These are examples of where the music was initially functioning as a tool to compensate for the deficit but where long-term restoration of function was the long-term goal achieved by these clients.

With regard to vocal function, several music therapy citations indicate that music therapists have attempted to ameliorate the problems rather than establish compensatory strategies. Music therapy programs that have targeted either increased vocal range, vocal intensity and breath control, and rate of speech (Cohen & Masse, 1993; Cohen, 1992; Livingston, 1996; Cohen, 1988; Lucia, 1987) also directly focus on promoting the reparation of the deficit, supporting the potential for cortical reorganisation to occur.

Mateer and Kerns (1999) recommended that treatment should be varied in order to encourage interconnections, which lead on to further recovery. Certainly music therapy programs not only provide a different medium from the other therapies through which clients can develop these neural interconnections, but the music therapy programs can employ varied activities which further encourage neural and synaptic interconnections.

Adopting the Right Approach at the Right Time

This brief review of the music therapy literature indicates that some music therapy programs have focused on developing compensatory skills and others on restoration of impaired function. Both approaches have demonstrated positive outcomes, which were translated into functional improvement. This leads to the question of how one may determine when either approach is implicated or perhaps which approach is more effective in facilitating enhanced independence. It was previously stated that particularly in older brains and brains that have severe/large lesions, complete reorganisations are unlikely. This may suggest that both compensation and plasticity processes may be appropriate. In the developing brain, research suggests that a full-scale reorganisation in the brain is possible. In these cases, when working with young children, reducing the deficit is certainly implicated. This idea may challenge some music therapists whose philosophy of practice may be to allow these children to use their strengths rather than to strive for the redevelopment of lost skills.

This notion has been supported further by Mateer and Kerns (2000) who warn that encouraging clients to acquire compensatory skills can be detrimental to the clients' recovery process, not only for children but for adults as well. Their recent research has identified that residual functioning of a damaged system can be suppressed, masked or dominated by the functioning of other systems which remain intact. This suggests that the development of compensatory skills not only can deter the utilization of partially lesioned circuits, but they may also actively inhibit such utilization via inhibitory circuits and imply that these processes can be contraindicated. Restitution of function in damaged circuits may actually be hindered by compensatory adjustments which may support adaptive function in the short term, but which result in long-term inhibition of the activity of damaged circuits (Mateer & Kerns, 2000). This occurs because the brain is developing stronger connections to the new or novel method of completing an activity as practised in the development of compensatory skills, and simultaneously inhibiting the connectivity of the traumatised neural circuits.

This finding certainly has serious implications for the way music therapists may practice in this field. Providing music therapy programs which allow or even encourage clients to make use of their intact abilities may actually limit their recovery or brain reorganisation processes. For example, when a person who has sustained lesions within the brain has a resulting hemiplegia on one side of the body, providing him with music therapy activities whereby he is strengthening the unaffected side of the body so that it can perform the roles that the now affected side can no longer do (particularly the upper limb), may actually prevent the recovery of the affected limb. Similarly, by assisting an aphasic person to communicate by developing a new means of communication (such as writing, using computerassisted programs etc) within the music therapy program, the recovery of verbal communication may actually be disencouraged.

Durham's client (Pavlicevic, 1999, pp. 97-112) had displayed minimal change over a long period (two years). Therefore, she allowed the client to develop an alternative means of communication, a compensatory skill to enable her to have interaction with others. Any chance of further restoration was limited due to the minimal longterm changes in function and therefore supporting the development of a compensatory communication skill was appropriate.

These findings point to the possibility that compensatory skills should not be employed at all. However, there are situations when this approach should be adopted. For example, when a client has not responded to the initial trial of decreasing the deficit area and is clearly not making any functional gain in the target area of functioning, alternate solutions should be sought. When considering the articles by Livingston (1996), Lee and Baker (1997), Erdonmez (1991), and Lucia (1987) it is unclear as to how long postinjury the clients described were. Perhaps their clients' impairments were long standing and restoration of normal function had not occurred. However, the client in Magee's article (1999) was only 8 months post-injury (a point in recovery where neuroplastic changes are likely to be active) when she began to see the client. Therefore, targeting restoration of function was appropriate for this client. The same point is evident in Baker's (2000) clients who were two and three months post-injury when they were referred to music therapy.

From the field of neurorehabilitation, Nudo et al. (2000) supports the idea that compensation is a necessary part of functional recovery. They proposed that recovery is not based solely on the process of neuroplasticity but rather comprises at least three separate but interactive processes: the resolution of diaschisis (the initial swelling and neural shock that temporarily inhibits neural circuits that have survived the trauma), restoration of function and, finally, compensation. They state that short-term recovery (hours and days following the trauma) may be explained at least partially by resolution of pathology (such as diaschisis) in the acute stages. However, following this period, long-term recovery (weeks to months) is likely to involve neuroplastic changes in the anatomy and physiology of intact cortical (and subcortical) tissue. Further, longerterm functional recovery may eventually require the development of new and novel ways of completing tasks, that is, the development of compensatory skills.

Conclusions

The most recent developments in theories and models of recovery, including neuroplasticity, cortical plasticity models, and training models, seem to point toward the need for music therapy programs to focus on the amelioration of deficits during the initial stages of recovery from brain trauma. However, when clients are consistently unable to achieve the preferred mode of performing a skill, then encouraging compensatory skills should be considered. Many questions regarding neuroplasticity remain unanswered, which may affect the choice of music therapy program design. Firstly, does the degree of severity and/or location of lesion influence the point in time when music therapy programs should consider restoration of function or encouraging the development of compensatory skills? For example, should music therapy programs for clients with severe brain injury who are considered unlikely to regain any lost function, focus immediately on developing compensatory skills? Much is known about cortical areas activated by music and some initial information seems to indicate that earlier musical experiences can somewhat insulate or provide a foundation for recovery for a person following brain trauma (O'Callaghan, 1999). However, how music therapy treatment may reactivate, reconnect, or recruit new cortical areas remains to be an area in need of replicated research. It is important to remember that this field is continuing to discover new aspects and it is important for the music therapist to keep abreast of these changes to ensure that the music therapy programs are informed.

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