CHAPTER 11

Stroke

Globally, strokes are among the most prevalent diseases and the leading causes of death. In the United States alone, approximately 795,000 individuals experience a stroke annually, making strokes one of the main reasons for loss of life in the country. Typically, a stroke is caused by the occlusion of a blood vessel in the brain, although cerebral haemorrhages can also be a less common cause. This blockage and the resulting circulatory disruption deprive a part of the brain of its vital oxygen supply. Typical indications of a stroke include unilateral paralysis, speech difficulties, loss of consciousness, dizziness, nausea, and visual disturbances such as sudden double or blurred vision, or even a complete loss of vision within a certain field.

Because a stroke usually does not cause pain, the seriousness of the situation is often dismissed and immediate medical intervention is not sought. However, the most critical response to a stroke is to get to a hospital as swiftly as possible. The longer the delay in receiving adequate treatment, the more extensive the potential brain damage. Every minute counts. When calling for emergency medical services, it is vital to clearly express the suspicion of a stroke. Additionally, the precise time when the initial symptoms emerged should be noted, as medical interventions to clear blocked blood vessels are most effective within the first few hours of symptom onset – any delay can be detrimental.

While a stroke may seem to strike suddenly, transient disruptions in the brain's circulation often trigger warning signs days or even months prior. These can include mild dizziness, flickering vision, transient paralysis, or speech difficulties. As these minor episodes usually dissipate within minutes or hours, most individuals tend to downplay their

significance. However, the appropriate response to such occurrences is immediate medical consultation.

Surviving a stroke usually leads to moderate to severe disabilities, which may be temporary but often become chronic. Consequently, a stroke represents a severe personal crisis for the individual, eliciting a range of emotional responses such as sadness, a sense of impending disaster, hopelessness, frustration, or even aggression. However, in the weeks and months following a stroke, the brain works tenaciously to rectify and compensate for the damage. This effort leads to substantial changes within the brain: it forms new synapses, generates new blood vessels, and develops new brain tissue, albeit not new nerve cells. Furthermore, the nerve cells neighbouring the damaged area or those in the opposite hemisphere strive to take over the functions of the lost cells.

These neurological changes can be significantly influenced by music. The most compelling evidence for the therapeutic effects of music has been produced for therapies administered following strokes. The brain's adaptive changes necessitate practice – and the more enjoyable the process, the more effectively the brain can reorganize itself. The emotional effects of music have a tangible impact on brain chemistry, creating positive implications for the healing processes within the brain. Moreover, the brain can reorganize more proficiently when engaged 'multimodally', such as when movement exercises are paired with moving to music.

When patients actively participate in their exercises, they can positively steer their healing trajectory. Furthermore, rehabilitation measures that incorporate music often outperform those without such inclusion. Up until recently, it was widely believed that post-stroke assistance was often very limited. However, in many cases, the appropriate rehabilitation measures had simply not yet been discovered. Some of the most promising, effective therapeutic measures have emerged from the domain of neurocognitive music therapy.

DURING THE ACUTE PHASE

Approximately fifteen years ago, a groundbreaking study by Finnish doctoral student Teppo Särkämö captivated the medical community.

He revealed that stroke patients who had listened to music during their hospital stay exhibited superior mental faculties and fewer depressive symptoms in the months following their stroke, compared to a control group of patients who had listened to audiobooks.[1]

In his research, Särkämö classified patients afflicted with middle cerebral artery strokes into one of three groups within a week of hospitalization: a music group, an audiobook group, or a passive control group. Participants in the music group were given a CD player featuring their favourite tunes, while those in the audiobook group received CD players with their selected audiobooks. Conversely, participants in the passive control group received neither music nor audiobooks. Teppo instructed the first two groups to listen to their respective CDs for at least one hour per day over the subsequent two months, whether they were in the hospital or at home. Both of these groups devoted about the same amount of time to their listening exercises during this period – on average one and a half hours per day.

Six months post-stroke, all three groups exhibited cognitive improvement – a testament to the brain's intrinsic ability for recuperation. However, a fascinating distinction emerged: the individuals in the music group exhibited a greater increase in their verbal memory and concentration test scores than those in the other two groups. In the verbal memory test, patients were asked to recall a list of ten words, while the concentration test challenged them to solve mental arithmetic problems. Notably, these improvements in the music group were most pronounced among patients with left-hemispheric strokes – likely because music stimulated the 'musical' right hemisphere more effectively.

Thus, the mere act of daily music listening enhanced the recuperation of particular cognitive functions in stroke patients. Furthermore, those in the music group reported feeling less depressed and less disoriented – in other words, less forgetful, uncertain, and unfocused – in evaluations conducted three and six months post-stroke. Consequently, the emotional state of the patients in the music group was noticeably

[1] Särkämö, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., Autti, T., Silvennoinen, H. M., Erkkilä, J., Laine, M., and Peretz, I. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. *Brain*, 131(3), 866–876.

more positive at both the three- and six-month intervals than that of the patients in the other two groups.

In addition to the observed effects of music listening on cognitive functions and mood, Teppo also noticed differences in the brain's reorganization.[2] Through MRI data, grey matter in the brain was measured one week and six months post-stroke. The results indicated that the music group experienced a significantly stronger increase in grey matter within the *healthy* hemisphere compared to the audiobook group. The latter, in turn, demonstrated a slightly more pronounced grey matter increase than the passive control group. Thus, it became apparent that music listening markedly bolstered the reorganization of brain functions within the hemisphere unaffected by the stroke.

What, then, accounts for the salutary effects of music listening on cognitive recuperation and cerebral reorganization? Music, it appears, activates an array of brain functions: perception, attention, memory, sensorimotor skills, along with emotion, intelligence, and language – particularly when the music includes lyrics. Therefore, music triggers a plethora of processes within the brain, stimulating numerous regions, including the area surrounding the lesion and its 'partner areas' in the unaffected hemisphere. Such stimulation not only triggers nerve cell activity but also enhances blood flow within the region. This augmentation aids in the compensation of functions from damaged areas, forming new synapses, dendritic spines, capillaries, and new tissue supporting nerve cells. Depending on the brain area, reorganization can even result in the settlement of new nerve cells. These processes particularly flourish in an environment that is gentle, pleasant, and emotionally positive, ideally engaging multiple sensory channels and cognitive functions – simultaneously as music so readily does.

The emotional benefits of music listening also encompass that patients worry less, focus on the music, relax more, and experience greater joy. This regulation of emotion impacts brain chemistry, affecting

[2] Särkämö, T., Ripollés, P., Vepsäläinen, H., Autti, T., Silvennoinen, H. M., Salli, E., Laitinen, S., Forsblom, A., Soinila, S., and Rodríguez-Fornells, A. (2014). Structural changes induced by daily music listening in the recovering brain after middle cerebral artery stroke: A voxel-based morphometry study. *Frontiers in Human Neuroscience*, 8, 245.

neurotransmitters such as dopamine, serotonin, and glutamate, as well as messengers of the immune system. Furthermore, emotions in the brain generate hormonal and vegetative effects in the body, including positive effects on blood pressure – which must not become too high post-stroke.

So, following medical emergency care upon hospital admission, music listening can provide substantial aid. It draws attention towards the music, away from worries, and promotes positive effects on brain regeneration. Therefore, family members, doctors, and nursing staff are advised to encourage stroke patients to listen to music (also see the box below). The specific genre of music appears unimportant, as long as it provides enjoyment and pleasure to the patient. The music selection in Teppo's study primarily consisted of popular genres (pop, rock, rhythm and blues), although some patients opted for classical, jazz, folk, or meditation music. Listening to music with vocals is particularly advantageous, as it also engages the brain's language functions.

However, it is crucial to prevent any overwhelming exposure to stimuli when listening to music, as this could create undue stress that would be counterproductive during this vulnerable period of recovery. In the weeks and months following a stroke, the brain is exceptionally receptive, aiding in its reorganization but also rendering it particularly sensitive.

Notably, during the acute phase, several stroke patients – especially those with right-hemispheric strokes – may develop *amusia*.[3] This means that patients frequently struggle to hear or understand music properly. While amusia can sometimes improve, it can also persist over the long term. Nonetheless, Teppo has shared with me that even when patients have difficulty perceiving the melody or the sound of the music, they can often still appreciate other aspects of it, such as rhythm or emotional expression. Moreover, music can often evoke memories in these patients. Therefore, even for patients with amusia, music can still hold significance, and listening to it can still be a beneficial activity.

[3] Särkämö, T., Tervaniemi, M., Soinila, S., Autti, T., Silvennoinen, H. M., Laine, M., Hietanen, M., and Pihko, E. (2010). Auditory and cognitive deficits associated with acquired amusia after stroke: A magnetoencephalography and neuropsychological follow-up study. *PLoS ONE*, 5(12), e15157.

Recommendations for the Immediate and Subsequent Phases after a Stroke

- Initiate music listening as soon as is feasible after receiving emergency medical treatment. However, there's no rush – music continues to offer benefits even days or weeks post-stroke.
- Family members should equip the patient with a device for playing music, perhaps along with headphones if they are sharing a room with other patients. Only play music that the patient enjoys or requests, using what you know they enjoyed before their stroke. If the patient struggles to express themselves, observe their reactions attentively to prevent any music-induced stress. If needed, adjust the volume, experiment with different genres, or switch the music off. When using headphones, always try them out on yourself first to check the volume. Note that safe listening levels for a healthy person might still be too loud for a stroke patient with heightened sensitivity. Consider headphones with volume-limiting features for additional safety.
- Exercise caution to prevent overstimulation or sensory overload, especially in the initial phases. Choose soothing music and introduce it gently. Opt for calming rather than stimulating music, and aim for a quieter rather than louder volume. Yet, it should remain engaging enough to provide a mental distraction. Keep in mind that, due to heightened sensitivity, music will sound much louder and more intense to the patient than usual.
- Include songs with comprehensible lyrics in the playlist, to stimulate both music and language processes in the brain.
- Let the patient listen to music for as long as they wish, ideally for at least one hour per day, over a period of no less than two months.
- When the patient is ready, encourage them to select and listen to their music on their own, or even begin making music again if they enjoyed playing an instrument before their stroke. Empowering patients to take an active role in music selection and creation can significantly enhance their recovery experience, providing both comfort and a sense of agency. The following chapters offer a wealth of recommendations and examples to help patients incorporate music into their recovery journey.

APHASIA: PATIENTS WHO SING EVEN WHEN THEY CAN NO LONGER SPEAK

Mrs N was in her late forties and staying in France when she awoke one morning to discover she had lost her ability to speak. Despite her capability to form sentences in her mind, she lost control over her speech-motor skills – she could no longer produce words. This harrowing ordeal, not unlike a nightmare, became her chilling reality. Fortunately, her husband acted quickly and ensured she was rushed to a hospital, where she was diagnosed with a stroke in the left hemisphere of her brain. Upon her subsequent transfer to a German clinic, she remained speechless – unable to voluntarily produce even a single vocal sound. Additionally, she suffered from hemiplegia, although this condition receded shortly after.

The stroke, coupled with the sudden inability to speak, plunged Mrs N into a deep well of distress and despair. She was frequently overwhelmed by bouts of weeping; although she could *hear* her emotional vocalizations, she remained unable to produce a single speech sound *intentionally*. Ultimately, she decided to pursue music therapy.

At a rehabilitation clinic, she encountered Claudia Dill-Schmölders, an experienced music therapist. Mrs N wept, and Claudia responded compassionately through music. Playing the piano, she improvised a tune for Mrs N, who gradually calmed down and began to synchronize her breathing with the rhythm of the music. Then, just before the final note of the melody, Claudia stopped playing – and to her surprise, Mrs N softly echoed the final tone. As the inaugural music therapy session progressed, Mrs N began to vocalize the melody's tones, one by one. She discovered that, although spoken language eluded her, she was still capable of singing tones. This realization evoked profound relief, along with a sense of potent internal liberation and relaxation. Finally, a glimmer of hope emerged for Mrs N. Within that very first music therapy session, she started to hum simple songs. Then, Claudia suggested she would *sing* the first syllable of the word 'hello', inviting Mrs N to complete the word with a sung tone. She voiced, 'Hel . . .' and Mrs N replied, with a fragile yet clear, '. . . lo'.

In the weeks that followed, Mrs N participated in both speech and music therapy. She attended a singing group specially designed for

aphasia patients, which incorporated not just singing but also breathing and rhythmic exercises. Additionally, she joined the 'therapeutic singing group', an initiative open to all patients in the hospital. Her extensive experience with choir singing proved beneficial, providing her with a broad repertoire of songs.

In music therapy, she began by learning to supplement words with singing, then progressed to singing whole words. This feat could only be achieved through *singing*; when she attempted to *speak*, she was unable to form sentences or even parts of words. Her attempts to speak were evident; she tirelessly sought a way to articulate speech sounds. However, barely any speech sounds emerged from her mouth, and those that did were scarcely audible and lacked resonance.

Consequently, Claudia worked with Mrs N on controlling her breathing, concentrating on eliciting speech sounds by way of singing – beginning with simple syllables and gradually advancing to entire words. It was highly effective to incorporate movements with the music or speech melody. They would tap along to the music with one hand or clap with both hands, for example. Additionally, music-therapeutic relaxation exercises on a soundbed assisted Mrs N in loosening her facial muscles.

Before long, she was capable of *singing* brief sentences, though she still found it impossible to replicate them while attempting to *speak*. In a mere span of two weeks, she progressively mastered singing words, parts of phrases, and, ultimately, entire phrases for a growing number of songs. She then embarked on melodious speaking, a fusion of singing and speaking. She had discovered that her voice could find flow through singing, which eased her effort to speak. Gradually, she began to initiate speech independently. After a period of three months, Mrs N had successfully regained her ability to articulate words clearly and bid farewell to the clinic.

Roughly a third of all stroke patients struggle with aphasia, a condition characterized by the loss of the ability to speak or understand language. When the left frontal lobe, particularly Broca's area, suffers damage, it often results in what is known as 'Broca's aphasia' or 'motor aphasia'. Interestingly, these patients retain the capacity to *comprehend* simple sentences spoken to them. They can think in words and

sentences, but they face a significant obstacle when it comes to *speaking*; typically, they can only babble one or a few sounds. One of the most compelling phenomena in neurology is that many of these patients preserve the ability to sing and, even more remarkably, to sing *with words*. I have encountered patients who have lost their capacity to utter the phrase 'happy birthday', yet they can melodiously voice 'happy birthday', with the words often articulated with such clarity and precision that it contradicts their speech impairment. This fascinating observation has catalysed the development of various therapeutic techniques that exploit this unique phenomenon.

MELODIC INTONATION THERAPY

One such approach is *melodic intonation therapy* (MIT). In this therapeutic framework, patients with motor aphasia are guided to sing simple sentences, using a rhythm and melody that mimic an exaggerated form of natural speech intonation. They might be directed to sing the phrase 'I-am-hun-gry' with just two pitches, where each syllable is sung for an equal duration. Unstressed syllables are sung on the lower pitch, while stressed ones take on the higher pitch. Concurrently, patients tap the rhythm of the sentence with their left hand, reflecting each syllable's beat. Along with the therapist, they start by singing phrases with simple rhythms on two or three notes, gradually transitioning to sing these independently. Over time, they learn to verbalize the phrases they have been singing and later expand this capability to singing or speaking entirely new sentences.

The act of singing inherently decelerates the pace of speech, making the production of words more manageable and less stressful. The rhythm proves vital in temporally structuring speech, and music's emotional uplift, brought about by the melody and the act of singing, motivates the patients. The early stages of therapy also place significant emphasis on using *speech formulas* – commonplace phrases such as 'How are you?', 'Good morning', 'Excuse me', 'I'm sorry'. These have been voiced countless times in one's life; therefore, we do not have to mentally construct or comprehend word by word each time. Speech formulas are uniquely represented in the brain, spanning *both* hemispheres. Hence, if the right hemisphere remains functional in aphasia patients,

its resources can aid in the verbalization of these formulas, facilitating the relearning of the articulation of new sentences.

Several studies have attested to the efficacy of MIT, not only during the subacute phase – a few weeks to a few months post-stroke – but also in patients with chronic aphasia, in whom language capabilities have not naturally improved or resurfaced with speech therapy.[4] In the subacute phase, initiating the therapy sooner tends to yield greater benefits, especially for those with more severe motor aphasia.

Owing to its straightforward and well-defined methodology, MIT serves as an excellent resource for both neuroscience and medical research. Neurologists are particularly interested in the underlying neurological mechanisms that contribute to the therapy's effectiveness. Gottfried Schlaug's team conducted an enlightening study with six patients suffering from chronic motor (Broca's) aphasia following a stroke in the left hemisphere. Despite ongoing speech therapy, they continued to struggle with speech even a year after the stroke.[5] These individuals participated in daily MIT sessions for fifteen weeks. MRI scans were used to map the brain's nerve fibres both before and after the therapy. Impressively, the study unveiled the formation of new nerve fibres, also known as 'axons', in all six patients' *right* hemispheres. Specifically, these axons transmitted information between the areas of Broca and Wernicke within the right hemisphere (as depicted in Figure 3.1). Furthermore, there was a marked improvement in the patients' speech fluency following the intervention. For instance, they demonstrated an increased vocabulary, using more diverse and complex words when tasked with describing pictures.

It is important to remember that language and music are processed in overlapping brain networks, with language predominantly processed in

[4] Van der Meulen, I., van de Sandt-Koenderman, W. M. E., Heijenbrok-Kal, M. H., Visch-Brink, E. G., and Ribbers, G. M. (2014). The efficacy and timing of melodic intonation therapy in subacute aphasia. *Neurorehabilitation and Neural Repair*, 28(6), 536–544; Merrett, D. L., Peretz, I., and Wilson, S. J. (2014). Neurobiological, cognitive, and emotional mechanisms in melodic intonation therapy. *Frontiers in Human Neuroscience*, 8, 401.

[5] Schlaug, G., Marchina, S., and Norton, A. (2009). Evidence for plasticity in white-matter tracts of patients with chronic Broca's aphasia undergoing intense intonation-based speech therapy. *Annals of the New York Academy of Sciences*, 1169(1), 385–394.

the left hemisphere and music in the right. In patients with Broca's or Wernicke's aphasia, the fibre tract connecting Broca's and Wernicke's areas in the left hemisphere is typically largely disrupted, and it is often significantly weaker in the right hemisphere than in the left. Therefore, the application of MIT can stimulate the growth of new nerve fibres, thereby strengthening the language functions of the right hemisphere.

I distinctly remember when Gottfried revealed these groundbreaking findings to me at a conference, before they were officially published. On his laptop, he displayed images of a centimetres-long neural pathway in the right hemisphere. This right-hemispheric pathway connected regions analogous to Broca's area in the frontal lobe and Wernicke's area in the temporal lobe of the left hemisphere. In the MRI images of a patient, I could discern each newly formed nerve fibre with incredible clarity. The significant increase in nerve fibres following the MIT intervention was immediately apparent. The brain's inherent ability to guide the growth of these new nerve fibres further underscored the incredible marvel that is the brain. While my anatomy students find it challenging to identify this specific neural pathway, the brain effortlessly navigates its growth, utilizing its innate ability. These compelling results were later reinforced by the same research team through an additional study involving five more patients.[6] The combined evidence indicates that individuals who have lost their speech due to a left-hemisphere stroke retain their ability to sing, utilizing their undamaged right hemisphere. This intriguing ability can stimulate the reorganization of language areas in the right hemisphere, aiding in speech recovery – even in stubborn cases where other therapies have proven ineffective in restoring fluency after a year.

Interestingly, this fibre tract is considerably more developed in musicians, in both the left and right hemispheres.[7] This suggests that musicians have a more facilitated path to recovery from aphasia following a stroke. It is also worth noting that the left-hemispheric dominance of

[6] Wan, C. Y., Zheng, X., Marchina, S., Norton, A., and Schlaug, G. (2014). Intensive therapy induces contralateral white matter changes in chronic stroke patients with Broca's aphasia. *Brain and Language*, 136, 1–7.

[7] Halwani, G. F., Loui, P., Rueber, T., and Schlaug, G. (2011). Effects of practice and experience on the arcuate fasciculus: Comparing singers, instrumentalists, and non-musicians. *Frontiers in Psychology*, 2, 156.

language processing is, on average, less pronounced in women than in men. While men commonly rely primarily on the left hemisphere for linguistic processing, women frequently utilize both hemispheres. As women already have more developed speech functions in their right hemisphere, they often recover more quickly from aphasia than men.

In conclusion, music therapy can play a pivotal role in restoring speech capabilities, particularly in cases of motor aphasia. When other therapeutic interventions fail and chronic aphasia develops, neurocognitive music therapy becomes a highly recommended approach. The likelihood of successful speech recovery increases when music therapy is individualized to the patient, incorporating MIT along with a variety of techniques tailored to their specific condition. Depending on the patient's ailment, this could involve different levels of singing, chant speech, breathing exercises, instrumental playing, or rhythmic exercises. Music therapists are also trained to look beyond the patient's functional needs; they value, as Claudia Dill-Schmölders succinctly put it to me, a holistic approach unifying music, body, and individual, considering their unique personality and emotions.

Recommendations for Speech Therapists and Family Members for Conducting MIT with Patients

If you are a speech therapist interested in incorporating MIT or elements of it into your routine, you can use these guidelines as a starting point. Family members can also use this method, particularly during lengthy waiting periods for speech or music therapy. Do not worry if you are not musically inclined; you can still follow these steps effectively. As long as the patient enjoys the process, and you follow these guidelines, you won't do any harm, and it is likely to be beneficial.

Patients with motor aphasia (also known as Broca's aphasia) are well suited for these exercises if they can understand spoken words, can sing songs with some understandable words, and possess the concentration and motivation to try this approach. Typically, these patients have suffered a stroke in the left hemisphere, not the right.

The exercises can begin a few weeks after a stroke, and you should perform them on a daily basis. Sit across from the patient at a table,

allowing them to observe your mouth during the exercises. For the initial session, opt for a selection of common words and phrases with two to three syllables. Examples include 'water', 'hungry', 'How are you?', 'Thank you', and 'Excuse me'. Then perform the following steps, explaining each one to the patient before performing it.

1. In the first step, only you will perform the actions. Choose a word to practise, such as 'hel-lo' or 'cof-fee', point to your mouth and hum the word first, then sing it twice. Use two pitches: accentuated syllables on the higher pitch, and the unstressed syllables on the lower pitch. Choose a *starting pitch* within the patient's vocal range. Typically, this is a comfortable pitch at which the patient can hum or sing. For instance, find out in which vocal range the patient can comfortably sing or hum 'Hey Jude' and start with that pitch. The *second pitch* should be about a minor third below the starting pitch. For those unfamiliar with these terms, the song 'Hey Jude' begins with a minor third, thus your second pitch can be the second tone of that song. Hum or sing slowly, at about one syllable per second. Start with simple rhythms, using the same length for each tone. (As you progress to short sentences, use longer and shorter notes as appropriate.) While humming or singing, tap gently on the patient's left hand with each syllable to coordinate the sensorimotor speech processes in their right hemisphere.
2. In the second step, sing and tap the word or phrase together with the patient in unison.
3. The third step is a variation of the second step: once the patient is comfortable singing and tapping the word or phrase together with you, allow them to continue to sing and tap solo, while you stop.
4. In the fourth step, you sing and tap the word or phrase first, and then have the patient repeat it while they tap with their left hand on each syllable.
5. The fifth step is a variation of the fourth step. You sing and tap the word or phrase first, the patient repeats it, but then you sing the question 'What did you say?', and the patient repeats the word or phrase again, singing and tapping.

6. Intersperse the sessions with well-known songs that you and the patient sing together. Over several weeks, as the patient improves, you can gradually introduce longer and more complex speech formulas and idioms, such as 'Every cloud has a silver lining', or 'When one door closes, another opens.' You can also transition to less common phrases.

Remember, it is crucial to perform these exercises only if the patient is willing and comfortable. Avoid inducing stress as it could be detrimental to the patient's recovery. Keep a close eye on their facial expressions and demeanour to catch any signs of distress or fatigue. Always aim to provide a calm, supportive, and cooperative environment to make the process enjoyable and foster a sense of progress and hope.

HEMIPARESIS: MUSIC'S THERAPEUTIC EFFECTS ON PARALYSIS

A stroke frequently affects only one hemisphere of the brain, thereby often causing weakened motor functions on the body's opposite side. Consequently, a stroke in the left hemisphere typically results in motor impairment on the body's right side, and vice versa. The severity of this impairment can vary: when patients retain some ability to move the affected arm or leg, this condition is termed *hemiparesis* (partial weakness), while a complete loss of movement is referred to as *hemiplegia*. Manifesting in approximately two-thirds of all patients, hemiparesis is a prevalent consequence of strokes. This condition significantly diminishes quality of life as it severely restricts one's independence and mobility. Therefore, it becomes paramount to offer aid to those struggling with motor difficulties, particularly in their arms, hands, or gait.

HEMIPARESIS OF THE LEGS: A RHYTHMIC THERAPEUTIC APPROACH

Among various interventions, *rhythmic auditory stimulation* (RAS) has emerged as a music therapy approach that is both remarkably effective

and ingeniously straightforward. The structure of a typical RAS session unfolds as follows: initially, the therapist determines the patient's natural walking pace. Music, either performed live or played from a recording, is then set to this tempo, and the patient walks in time with the music for a few minutes. Gradually, the tempo of the music is increased from one piece to the next, as long as the patient can maintain a stable gait. Subsequently, the patient practises manoeuvring across ramps and steps. The session culminates in periods where the music is purposefully faded out, providing the patient with practice in walking without rhythmic guidance.

Patients afflicted with hemiparesis commonly exhibit steps that are short, slow, and asymmetrical. Their gait often demonstrates rigidity, with little variation or flexibility between steps. Michael Thaut, a co-developer of RAS, documented marked improvements in the ambulatory abilities of hemiparesis patients following several weeks of RAS, surpassing the gains achieved through standard physiotherapy.[8] Thaut divided patients into two groups: one group received RAS, while the other was treated with physiotherapy following the 'Bobath concept'. (The average age of the patients was just below seventy years.) In both groups, therapy sessions, lasting half an hour each, were conducted daily over a span of three weeks. All patients had to have the capacity to take a minimum of five steps independently at the start of the therapy, which commenced four weeks post-stroke. After three weeks, RAS-treated patients showed significant progress, as they were able to perform more steps per minute and achieve larger and more symmetrical steps than those in the control group; they were able to perform an extra nineteen steps per minute and traversed an additional thirteen metres.

Thus, even a brief three-week course of RAS can yield dramatic improvements in a patient's gait. However, the pace of most patients remained approximately half as quick and less symmetrical than prior to the stroke, indicating potential for further improvement. Consequently, Michael Thaut's team doubled the intervention duration from three to

[8] Thaut, M. H., Leins, A. K., Rice, R. R., Argstatter, H., Kenyon, G. P., McIntosh, G. C., Bolay, H. V., and Fetter, M. (2007). Rhythmic auditory stimulation improves gait more than NDT/Bobath training in near-ambulatory patients early poststroke: A single-blind, randomized trial. *Neurorehabilitation and Neural Repair*, 21, 455–459.

six weeks, and applied RAS alongside conventional physiotherapy.[9] This integrated approach resulted in a markedly improved gait in patients compared to those subjected only to three weeks of RAS. Hence, an ideal treatment plan seems to be a combination of physiotherapy and RAS, extending over a period of at least six weeks, if not longer. Subsequent studies have consistently demonstrated RAS' effectiveness, not only during the subacute phase but also in patients experiencing chronic hemiparesis following a stroke.[10]

The biomechanics governing our upright gait are a marvel of intricate precision and synchronized dynamics. With every stride, a multitude of movements must seamlessly synchronize and coordinate. These individual actions need to be not only meticulously timed but also modulated in their acceleration and deceleration to integrate seamlessly into the overall kinetic sequence. Optimal performance arises when each movement segment is executed with just the right amount of force – neither excessive nor insufficient. When the brain, which serves as the command centre for this intricate walking mechanism, incurs damage, music emerges as a key tool. It assists in coordinating both isolated movements and complete kinetic sequences by providing a temporal framework. Consequently, music therapy interventions such as RAS can appreciably enhance the flexibility and fluidity of individual movements. Furthermore, music holds the power to motivate and bring joy, thus facilitating muscle relaxation and the smooth flow of movements – a universally applicable benefit for any muscular or movement issue.

Thanks to the simplicity and straightforwardness of the RAS principle, physiotherapists can proactively integrate music into their therapy regimen, rather than merely using it as an ambient background. For

[9] Thaut, M. H., McIntosh, G. C., and Rice, R. R. (1997). Rhythmic facilitation of gait training in hemiparetic stroke rehabilitation. *Journal of the Neurological Sciences*, 151, 207–212.

[10] Moumdjian, L., Sarkamo, T., Leone, C., Leman, M., and Feys, P. (2017). Effectiveness of music-based interventions on motricity or cognitive functioning in neurological populations: A systematic review. *European Journal of Physical and Rehabilitation Medicine*, 53(3), 466–482; Cha, Y., Kim, Y., Hwang, S., and Chung, Y. (2014). Intensive gait training with rhythmic auditory stimulation in individuals with chronic hemiparetic stroke: A pilot randomized controlled study. *NeuroRehabilitation*, 35, 681–688.

instance, they can choose music with an appropriate tempo and then explicitly instruct the patient to move in synchrony with it. This strategy aids significantly in the restoration of motor functions.[11]

Notably, patients themselves can directly apply RAS techniques (refer to the recommendations below). These music-assisted activities can also be organized within group settings such as day clinics, self-help groups, or residential homes. This approach not only makes therapy more cost-effective but also ensures its continued application long after hospital discharge or rehabilitation.[12] Furthermore, group therapy has the added advantage of fostering social interactions and facilitating mutual support. Regrettably, such group-based interventions are often in short supply across most institutions. As a result, I recommend that individuals unite with others undertaking a similar therapeutic journey, possibly sharing the financial responsibilities involved in hiring a qualified music therapist.

Recommendations for Patients with Gait Disorders

1. *Finding your walking pace with music.* First, calculate your steps per minute. Use online platforms such as YouTube or getsongbpm.com to find music that matches this tempo. For instance, if you take twenty steps per minute, multiply this by four to search for songs at eighty BPMs (beats per minute). Walk in time with the music, taking a step every four beats. If you take sixty steps per minute, search for songs at 120 BPMs and step every two beats. Have variations of music at slightly different tempos to adjust your pace as needed. Regularly walking to this music can significantly benefit you. (Also see 'Recommendations for Walking with Music for Parkinson's Patients and Therapists' in Chapter 13).

[11] Whitall, J., Waller, S. M., Sorkin, J. D., Forrester, L. W., Macko, R. F., Hanley, D. F., Goldberg, A. P., and Luft, A. (2011). Bilateral and unilateral arm training improve motor function through differing neuroplastic mechanisms: A single-blinded randomized controlled trial. *Neurorehabilitation and Neural Repair*, 25, 118–129.

[12] Jeong, S., and Kim, M. T. (2007). Effects of a theory-driven music and movement program for stroke survivors in a community setting. *Applied Nursing Research*, 20, 125–131.

2. *Consistency is key*. Make it a habit to walk to your chosen music consistently. This will help your brain form associations between the music and your walking pattern. If you find yourself in a situation where music is not available, you can mentally replay the tune to help maintain your walking rhythm.
3. *Explore partner dancing*. When it is safe to do so, consider gentle partner dancing to music. Start with simple steps. Face your partner with hands joined. The leader starts by taking a half-step forwards with the right foot, followed by the left foot. Then the leader takes a half-step backwards with the right foot, followed by the left, returning to the original position. The follower's steps mirror the leader's but start with the left foot moving backwards. Dancing with a partner can provide additional balance and reduce the risk of falls.
4. *Safety first in dancing*. Keep dance steps simple and avoid stepping more than a half-step backwards. The primary goal is to maintain balance and minimize the risk of falls. Dancing with a partner is not just fun but also therapeutic.

HEMIPARESIS OF THE ARMS: MUSIC-SUPPORTED TRAINING

Neurocognitive music therapists have also devised specialized methods for treating patients with arm hemiparesis. Sabine Schneider, Eckart Altenmüller, and Thomas Münte have pioneered an intervention, known as *music-supported training* (MST), that engages patients – even those who are not musically inclined – in creating music with their arms.[13] This groundbreaking approach utilizes two musical instruments to refine gross and fine motor skills respectively.

The first instrument, aimed at enhancing gross motor skills, resembles an electronic drum set. It comprises eight drum pads, arranged in a semicircular pattern around the patient, thereby making some pads

[13] Schneider, S., Schönle, P. W., Altenmüller, E., and Münte, T. F. (2007). Using musical instruments to improve motor skill recovery following a stroke. *Journal of Neurology*, 254 (10), 1339–1346.

easier to reach than others. A simple tap of the hand activates each pad, which produces a piano tone instead of a drum sound. This setup enables the production of a full major scale with the eight pads. The second instrument – a digital piano – is utilized to refine fine motor skills, focusing on only eight keys.

The level of patient engagement with each of the instruments during a session, in terms of difficulty and duration, is adjusted based on the extent of their hemiparesis. Some patients may interact solely with the pads or the piano, while others may alternate between both. Throughout this experience, the patient remains seated, either on a stool or in a wheelchair. The therapist models a note or a sequence of notes, which the patient then replicates. The music playing evolves from single tones to repetitions, eventually advancing to incorporate all eight tones in children's and folk songs. Initially, only the paralysed hand is used, before progressing to use both.

Much like the RAS concept, the brilliance of MST lies in its simplicity. The research team demonstrated its efficacy in a study involving patients at a rehabilitation clinic. These patients, who suffered hemiparesis in one arm, retained the ability to independently move the arm and index finger on the affected side. The participants were randomly assigned to either a conventional physiotherapy group or a group receiving both conventional therapy and MST. The conventional physiotherapy regimen consisted of nearly thirty half-hour sessions over three weeks, conducted individually or in groups. In contrast, the MST group partook in an additional fifteen music sessions, each lasting thirty minutes.

For those undergoing music therapy, the results indicated a substantial reduction in the severity of paralysis, along with marked improvements in the range and speed of movement. Additionally, these patients exhibited improved practical daily skills, such as moving more cubes from one box to another or inserting more wooden pegs into a pegboard. It is important to note that while the group receiving only conventional physiotherapy did not exhibit similar significant improvements, the study did not explore the full range of physiotherapy techniques, and a longer duration of physiotherapy might have resulted in comparable effects.

Interestingly, the study authors reported that some patients found the musical intervention particularly enjoyable – so much so that it became their favourite part of the therapy process. The enjoyment derived from such therapies is critical, as it fuels additional motivation – a crucial element for instigating plastic brain changes. These transformations are most pronounced when an individual finds the activity enjoyable or feels motivated to engage in it.

The marked improvements in hand and arm motor skills were not solely the result of the extra therapy sessions that the patients received in addition to their standard physiotherapy; rather, they stemmed specifically from the unique effects of the MST intervention. In a subsequent study, the research team discovered that the combination of conventional physiotherapy and MST significantly outperformed a fusion of conventional physiotherapy and another well-known therapy approach, *constrained-induced movement therapy*.[14]

While both conventional physiotherapy and constrained-induced movement therapy have established effectiveness, my aim is not to rank their efficacy but to emphasize that music serves as an additional, empirically validated tool in rehabilitation. Depending on the specific needs of patients, the integration of physiotherapy and MST often proves to be the optimal strategy. Given the simplicity of MST, therapists, whether they are physiotherapists or occupational therapists, can effortlessly incorporate it into their treatment methodologies, particularly if they personally enjoy music. MST is especially recommended for patients whose progress with traditional therapy is not satisfactory.

For patients with an affinity for music, this technique can significantly enhance enjoyment and motivation. However, it should be noted that it may not be suitable for patients with severe paralysis. Administering the method in a group setting can create an even more enjoyable atmosphere. Consider, for instance, forming a 'hemiparesis band' where the members play percussion instruments in sync with a stereo system's rock music.

[14] Schneider, S., Münte, T., Rodriguez-Fornells, A., Sailer, M., and Altenmüller, E. (2010). Music-supported training is more efficient than functional motor training for recovery of fine motor skills in stroke patients. *Music Perception: An Interdisciplinary Journal*, 27(4), 271–280.

In therapeutic contexts, the *emotional* aspects of therapy – such as enjoyment, relief, and relaxation – along with muscle relaxation and their associated neurochemical reactions in the brain are of vital significance.

Neither MST nor RAS constitute a miracle cure. Even with rigorous and sustained training, the hand may not fully regain its pre-stroke mobility. However, these methods can assist in restoring movement abilities to the greatest extent possible. Patients who enjoyed the musical activities during therapy and wish to sustain the associated benefits can continue these practices at home after their treatment has concluded. Further guidance for this continuation is provided in the recommendations below.

Guidance for Patients with Mild Arm Paralysis

- *Explore easy-to-use musical instruments.* This could be an excellent time to begin learning a lightweight musical instrument. Many affordable keyboards, for instance, come with built-in learning programmes featuring a broad range of music pieces. When selecting your instrument, make sure it accommodates simple songs and aligns with your musical tastes. A music therapist can offer advice on the most suitable instruments for you, and provide support throughout your musical journey.
- *Form a 'hemiparesis band'.* Gather a variety of percussion instruments such as bongo drums, djembes, egg shakers, tambourines, or claves. Your bandmates need not share your condition; this approach is adaptable to most neurological or psychological challenges. Healthy participants are, of course, also welcome. Assemble a playlist of dance music that all band members enjoy, play it on a stereo system, and then let everyone join the rhythm – the heat is on! This activity helps train both fine and gross motor skills and is guaranteed to be a fun and rewarding experience.
- *Engage with interactive music games.* Games such as *Guitar Hero* or *Rock Band* offer an accessible way to engage with music and improve motor skills. These games are played on consoles with toy instruments such as guitars and drums that resemble their real counterparts while being remarkably easy to handle. The games offer a wide

variety of styles, songs, as well as difficulty levels, and it is possible to play them solo or in a group. Before purchasing, ensure you can handle the instruments comfortably – for instance, you are able to bend your hand to grip the guitar neck, or hold drumsticks and strike a drum pad.