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Music and the Brain

Creativity in music and the skills to play and appreciate music are uniquely human characteristics. All mammals seem to enjoy a tune but only human beings show true musicality and ability to communicate through music. The brain composes music to please itself: one can learn much about how the brain works by studying its responses to music and music-making.

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About the book:

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This book is written as three parts:

The first part discusses what brain does with music, that is: how music is sensed and perceived, processes grouped together as the basis for 'perception of music'. We follow musical tones as they are transformed in the inner ear from airwave vibrations into neuro-electrical signals, which are processed by brain structures in a series of fascinating steps of neural processing until we finally experience the processed signals as music.

The second part describes what music does to the brain: how it affects it's functioning and enables it to change – effects known as manifestations of neuroplasticity. The authors then go on to analyse the characteristics of 'the musician's brain' – the brains of musicians have shared features that set them apart from other people's brains. We take a closer look at what the musical experiences do to the brain and what effects they have on its structure and function.

In the third part, the authors give an account of the ways in which the brain-changing effects of music can be used to aid recovery after blows to the head and to treat neurological and related disorders such as dementia, Parkinson's disease and mental illnesses. We are taken through the arguments that support music as a sometimes effective form of therapy in a many types of acute and chronic neurological illnesses.

This book is for those who want to know more about how our brains respond to music and is changed by it.

Sample translations from Music and the Brain
Translated from Norwegian by Anna Paterson

Music and the Brain: Introduction

Our brain doesn't look all that impressive: it is a soft, grey mass weighing in at a little over one kilogram, with a ridged and grooved surface, and situated in the moist darkness inside the back of the skull, apparently isolated from the rest of the body. Nonetheless, everything that is human has been generated by this unassuming structure: all culture and building of communities, all our thoughts, hopes, plans and dreams, all human joy, sadness, love and despair – and, naturally, all music that has ever been composed, played and listened to throughout the history of mankind.

All this emanates from the grey lump of matter that we all have between our ears. So, no surprise then if the brain turns out to be endlessly more complex than it might look at first glance. Actually, it is a fact that the human brain is *the* most complicated structure we know of in the observable universe.

The brain consists of around 80 billion nerve cells (neurones), each one of which is connected to, on average, 7000 other nerve cells. The other cell types in brain tissue must not be forgotten: the so-called glia cells, for instance, are essential for the brain to function. No one knows for certain how many glia cells there are but probably just as many as nerve cells – at least. Together, they form an unimaginably complex system of cellular networks which, so far, we have barely begun to understand. New methods to represent the structure and function of the brain are constantly being developed and our knowledge about our brain, whether in terms of single neurones or cellular networks, has increased at great speed during the last couple of decades. Still, the elusive complexity of the brain remains a great mystery that we can hardly ever hope to understand since, as we study it, the brain is actually studying itself. It is paradoxical: if the brain were simple enough for us to understand, we would be too simple-minded to understand it!

In the past, the brain wasn't highly thought of; it was just about the only organ that the ancient Egyptians didn't bother with as they went about preserving body parts for bringing along into the afterlife. Music is different: its status has always been high. The ancient Greeks thought that the soul entered the body through music. No music, no soul. Similar ideas have been part of many cultures and, as a matter of fact, all cultures we know of have developed forms of music. Making music is a fundamental human activity and musicality an inescapable human trait. Many animals, probably including all the mammals, show aspects of musicality: for instance, wolves howling in chorus and whales singing to each other – as do most birds, of course. Such vocalisations have parallels in human musical communication but there are no other creatures who communicate with music in the same way as human beings.

The oldest musical instruments we know of are about 40,000 years old, matching the age of the early cave paintings. It is perfectly possible that, 100–200,000 years ago, members of Homo sapiens were fashioning simple instruments such as drums and flutes. We assume that they played together to boost social cohesion, communication and collaboration. Some of the researchers in this area also think that early music may have been important in the development of language. Even newborns recognise and discriminate between different rhythms, intervals and series of tones. They can pick out acoustic characteristics of voices and the melodic patterns of languages (prosody). Young children use the musical route into communication by language.

One of the most fascinating features of the brain is its capacity for change. Everything we do, experience and learn leaves a physical trace in our brains – throughout its life, the central nervous system is in a state of on-going change. When you go to bed at night, your brain is a little different from what it was in the morning: its changeability is called *neuroplasticity*. Thanks to neuroplasticity, you are able to learn new things at all times.

Music is able to stimulate a range of feelings and to transmit precise emotional information, characteristics that make it a perfect tool for studying how the brain generates emotion. Music can activate the reward centres in the brain, suggesting one way in which it exerts its unique ability to change how whole cell networks operate. There are actually few if any human activities that can change the brain to the same extent as practising music, instrumental or vocal – you can read all about this in Chapter 7. So, it's not a complete surprise that the brains of professional musicians have certain distinctive characteristics. The typical features of 'the musical brain' are, in a sense, the outcomes of an ideally conducted experiment in natural conditions. We can observe what happens to your healthy brain if you spend something like 8,000 hours on intensive music practice. More details are presented in Chapter 9.

Nowadays, music belongs to everyone, an easily accessible asset that we come across every day and listen to more or less attentively. How does this new availability of music affect us? Does its capacity for changing the brain have any practical value apart from pure musical satisfaction, and can music be put to therapeutic use? Section 3 of the book is devoted to trying to answer these important questions.

Above, we have summarised the themes we discuss in this book. We have decided to group music-related subjects in three sections. The first section is an account of how the brain handles music, the second deals with what music does to the brain and in the third section explains something about what we know about using music as part of the therapy for people with various functional deficits.

Here, we will go through the contents of each section in more detail:

Section 1

So, you thought your ears do the listening? Not really –listening happens in your brain. The sounds are fluctuations in air pressure that have a long way to go, from nerve signal to consciousness, before you experience the music.

- *From wave of pressure changes into sound*: How do the ears transform air vibrations into electrical signals that the brain can work with?
- *From sound to tone:* What is the difference between a sound and a tone/musical sound? A pure tone is produced when a string or other (resonating) object is vibrating in a regular pattern, something that is rare in nature. It is critical for making music and we will show how the brain perceives different characteristics of tones to 'hear' what we call pitch (frequency), loudness, and 'timbre' (quality or colour of the tone).
- *From tone to colour, chord and harmony…* We will describe the physical basis for consonance and dissonance in the structures that pick up sounds and transmit them for processing in the brain.
- *…and on to melody, rhythm and movement…* Melody and rhythm are created when series of tones are combined into distinctive timed and harmonic patterns. These combinations, which depend on our ability to perceive time and movement, involve several brain structures including parts of the basal ganglia and the cerebellum, as well as 'hearing areas' in the cerebral cortex. These are known as primary and secondary (associative) areas and

are fund in the temporal and parietal lobes, and in certain prefrontal areas[1]. When it comes to perceiving and experiencing music, practically the whole brain is engulfed in a wave of activity. Music is "a time-related variation of sequences of sounds" as is the spoken language. The brain has to cope with several challenges in order to perceive and analyse music. It is a case of grasping sound patterns as you hear them (simultaneously) since quality and colour of tones (pitch and timbre), and the sequences or chords exists only for a few moments and must be analysed there and then. At the same time, there is a musical structure, composed of harmony, melodic line, rhythm and temporal variations, that unfolds over time and about which the brain must collect information and subject to sequential pattern analysis. Simultaneous and sequential patterns are then combined into a coherent experience of the music.

- *…and emotions*. Music has a rare capacity for evoking a wide range of emotions, from fear, to joy, to sorrow. The emotional states are accompanied by physiological changes in functions such as heartrate and skin galvanic response, and triggering of reactions such as involuntary muscle contractions (shivering) and 'hair standing on end' (goose bumps). Investigating people listening to music they are fond of, while using brain imaging techniques such as magnetic resonance imagining (MRI) and positron emission tomography (PET) scans, it is possible to detect changes in brain cell activity states in some regions (e.g. nucleus accumbens, hippocampus) associated with – among other things – a sense of reward. If, on the other hand, people listen to music they dislike, there is activity in parts of the brain associated with dread and fear (e.g. amygdala and certain areas of the insula).

Section 2

In this section, we review what music does to the brain, especially in musicians; what structural and functional changes can be observed in musicians and what might be the significance of such changes.

When a pianist listens to music played on a piano, nerve cell activity increases sharply in the finger areas of the brain. Many pianists report that their fingers start moving when they listen to scores they themselves have played. During both the production and the perception of music, there is, in other words, a great deal of co-activation between the brain's auditory and motor systems. If a non-musician is asked to practise playing a simple piano piece, it takes no more than 20 minutes practising every day for 5 days before you see the same effect as in a professional: activity is increasing in the finger areas when the person listens to the piece being played. This is just one example of very fast neuroplastic changes – so, what changes would one find in the brain of someone who has spent at least 8,000 hours working to reach a professional standard on his or her instrument?

Section 3

This last section of our book is all about 'Music as Medicine'. There are different approaches to the use of music as therapy for illnesses affecting the brain and the rest of the central nervous system. In cases of Parkinson's disease, rhythmic music and dance tunes have immediate effects: the patients move more quickly and with greater ease. Presumably, it is the predictability of rhythms that drives the facilitation of movements: the rhythmic pattern sets up a 'feed-forward' link that engages the Parkinson patients and gets them going. Music activates all the brain's motor systems. For instance, it supports walking practice, not only in Parkinson cases but also in stroke patients.

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[1] Translator's comment: I have looked through some recent papers and can't find any confirmation that auditory sensory-motor processing takes place only in the **right** parietal lobe.

Corresponding responses are seen some patients with speech defects such as aphasia due to stroke or other trauma to the brain's speech areas: words in a text are expressed more like normal if sung rather than said. In cases of aphasia, this observation has led to the therapeutic use of singing as well as listening to music as part of retraining spoken language. The resulting neuroplastic changes are likely to have long-term benefits.

Research confirms that cognitive training can reduce the risk of dementia and also that learning to play an instrument as an adult has positive side effects on a whole array of cognitive skills. The results of a twin study, in which one of the adult twins learnt to play music, supported the idea that music practice protects against dementia. It would seem, then, that being engaged in music can slow cognitive decline and hence dementia. There are also plenty of studies and anecdotal evidence to back the finding that people with various forms of dementia respond positively to music. It seems to have stimulating effects on the brain, alerting the patients and improving their ability to communicate.

If you are interested in how music affects and changes the brain, this book is for you! Starting out, we follow the fascinating processes as tones – air wave vibrations – are recorded as electrical nerve signals and, in the end, perceived as music. We go on to discuss the effects of music on brain structures and functions. Finally, we review what makes music such positive component of the treatment of many acute and chronic conditions affecting the brain.

Chapter 12

Music and strokes

The brain is, beyond comparison, the most important organ in the body. It operates not only as the overall 'command centre' but also as sole source of our thoughts, emotions and memories. Brain-dependent processes build our individual identities: you define your aware self as the sum total of all your capabilities and life experiences.

But while the brain is outstandingly important, it is also uniquely vulnerable. Most other organs respond to acute injury by more or less effective self-repair – forming new organ-specific cells, including new blood cells to replace blood loss – but damaged brain tissue has only very limited potential for healing. True enough, the neurons in the brain are able to regenerate throughout life, as we have already seen, but the process is neither quick nor consistent. Recovery from the functional disturbances caused by strokes and other trauma depends to a large extent on the brain's *neuroplasticity* rather than on tissue regrowth and repair. It has been shown that, after a traumatic event, the brain's capacity for neuroplastic change actually increases, with other brain centres taking over from the injured area, previously weak connections being reinforced and new lines of communication formed. We have also noted previously that music has strikingly positive effects on the brain's neuroplasticity. Unsurprisingly, it has followed that the supportive effects of music on the brain's recovery processes in cases of stroke have been very thoroughly investigated.

A crucial reason for all the research into stroke is that the condition is so very common and has such very troubling consequences for society at large as well as for the individual. Worldwide, stroke is one of the most prominent causes of functional decline and death. In Norway, around 12,000 men and women are afflicted by stroke every year, which amounts to more than 30 incidents on every single day. Most of the patients are elderly: three in every four are over 70 years old. Having said that, the annual incidence of strokes in people under 50 years of age is about 1,000 and, rarely, the condition can also hit young people and children. Per year, the costs associated with stroke have been calculated to be around 7-8 billion Norwegian kroner.

What is stroke?

A 'brain attack' or stroke can be described as a sudden, more or less destructive event caused by defective blood circulation in a part of the brain. There are two main types: infarction or *ischaemic* stroke, in which the specific cause is a blockage of the local blood supply, and a bleed or *haemorrhagic* stroke affecting a part of the brain tissue. The bleeding can also be into the space around the brain. Most strokes (80-90%) are due to infarctions, and the majority of the rest to localised bleeding.

Typically, infarctions follow when a blood clot impacts in asmall artery, and cuts off the supply of blood to the cells in that particular area. Unlike most of the cells in other tissues, neurones are very intolerant to being without their normal blood supply and begin to die within a few minutes of the blockage. The outcome is irreversible damage – an ischaemic stroke. If the blockage is due to a blood clot (rather than any other debris in the blood stream), it may be resolved when normal processes cause the clot to disintegrate. If the local blood flow recovers in time, the symptoms will fade away. This kind of passing infarction is called a *transient ischaemic attack* (TIA) or mini-stroke. 'Mini' it may be, but it should be taken seriously. It is essential to find the cause quickly as a TIA is often a forewarning of later and perhaps more devastating strokes.

A haemorrhagic stroke is the outcome of one of the brain arteries springing a leak. The uncontrolled blood flow into the surrounding tissue causes local pressure changes, which in turn trigger a series of cell-killing biochemical reactions, and the local neurones in the area of the bleed will start to die.

The major risk factors for all kinds of stroke are the same: high blood pressure, diabetes, being a smoker or overweight or, simply, old. Many of these factors are related to the person's lifestyle, which is presumably the reason why the incidence of stroke is declining as public awareness of healthy habits is rising. However, the total number of cases will continue to grow for years to come because the population of old people is growing proportionally larger and old age is *the* most important risk factor.

Because the symptoms of a stroke are due to nerve cell death in an area of the brain, they will vary according to the precise area in which the damage has been done. For instance, if the infarction has affected clusters of nerve cells in the motor area, the patient will find it problematic to use the part or parts of the body controlled by these neurones. Strokes in the area of language generation and comprehension will result in the patient having trouble with aspects of language and speaking. If any of the areas associated with vision is affected, one or several of the patient's visual functions will be disturbed – and so on. The conclusion is that the symptoms of a stroke can be very varied, even though the underlying cause is the same.

Treatment

The immediate treatment of a stroke depends on the first cause. In haemorrhagic strokes, treatments aimed at stopping the bleeding don't seem to be very effective. The reason is that the actual bleed happens so quickly and, when it takes place inside the brain tissue, local pressure changes tend to stop the blood from flowing after a few seconds or minutes. It is however crucially important to deal with high blood pressure to reduce the risk of further haemorrhages coming soon after the first. Sometimes, surgery during the acute phase is an option: the idea is to remove the blood in the tissue. It is not a routine intervention because the damage to the brain is already done and, generally, little is gained by removing the blood afterwards.

After a brain infarction, the most important step is to remove the blood clot, or thrombus, as soon as possible. The aim, in other words, is to restore the local blood circulation to normal and reduce the threat of a lasting lack of blood that would lead to further injury of still viable brain tissue. One common form of treatment is injecting into the blood stream a substance with the property of breaking down blood clots. Such substances are known as *thrombolytic* agents: once the agent reaches the brain, it would do the job locally. To be effective, the treatment must be carried out quickly – ideally within 4 hours of the diagnosis. In some cases, mechanical removal of the clot is a possibility: it can be 'fished out' via a catheter introduced via the large femoral artery in the groin and advanced up into the blocked brain artery.

Once the acute treatment is complete, the clinical team must identify the risk factors for that particular patient in order to avoid further strokes. The next stage is the painfully slow but crucially important rehabilitation period, when the patient sets to work in dedicated in-hospital stroke units to recover lost or damaged functions. Here is where music can play a role.

Disturbances to language

Troubled speech after a stroke or other form of trauma has two main variants: *aphasia* and *dysarthria.* Aphasia means that the generation of language and/or the understanding of it is affected; the patient finds it difficult to grasp what is said or to actually produce comprehensible language, spoken and written. Combinations of these problems are common. Dysarthric patients have normal understanding and production of the spoken language but can't articulate the words or else speak them with poor articulation. In dysarthria, the symptoms can have different causes: it could be a matter of loss of neurones in the areas of motor cortex in control of the muscle groups in throat, palate or tongue that help to shape spoken language, or it could be local injuries in the head or the neck. A person with dysarthria but not aphasia is able both to understand written language and express herself normally in writing but can't deal easily with oral expression. Someone with aphasia finds both written and spoken language problematic. To summarise, putting it simply: aphasia knocks out the brains ability to produce language, while dysarthria interferes with the ability of the mouth and throat to produce words. It matters greatly to be able to discriminate between the two dysfunctional states, because of the different types of patient disability require different therapeutic interventions.

Aphasia is a very common symptom after a stroke; data from Denmark indicate that the incidence after any kind of stroke is about 40% of all cases. The French neurologist Paul Pierre Broca (1824–1880) was the first to describe aphasic patients systematically. Ultimately, he realised that in very many of the cases he had examined, a posterior part of the left frontal lobe was affected. It became known as *Broca's area*, and damage there makes it hard to produce words. The patient will often understand spoken words quite well but be wholly or partly unable to speak, a condition called *expressive aphasia.* The words are uttered slowly and in bursts, the sentences are short, too, and occasionally marred by verbal errors. Some of these patients may have lost all ability to express themselves or else able to say only yes or no. The other main type of aphasia is known as *impressive aphasia* and entails inability to grasp meaning. The patient may well speak fluently but the content is incoherent.

From song to speech

There is a remarkable, fascinating observation that has been known for more than a hundred years: some people with little or no ability to speak are still able to sing the lyrics of songs. The Norwegian documentary film *Folk from the Fjord* (*Folk ved fjorden*) by Øyvind Sandberg records one example: an elderly lady with right-sided hemiparesis and aphasia that has reduced her to saying only yes or no when speaking with her daughter. When she sings hymns, however, she pronounces the words clearly and precisely. One of us authors, Geir Olve, was so intrigued by this phenomenon that it triggered his interest in music therapy. Then Torun Einbu got in touch with him about the development of a project idea for her Master's thesis in the area of speech and language therapy. Torun is a speech therapist who uses music to treat her patients and is also an excellent singer. Geir and Torun agreed that they both were keen to investigate the ability shown by some stroke patients to sing the words in a text. The first question was: how common is this? Everyone who has worked with aphasic stroke patients knows of such cases. Torun found in her research that of all she had examined, two out of every three uttered more words when they sang than when they were asked to say the words of the text or recite them from memory. The effect of singing was not as marked in all the patients but it was not at all unusual: most aphasics were able to pronounce more words when they sang than when they spoke. Fortunately, there was no correlation between increased word production and the musical quality of the singing – that is, the correctness or not of the melody and rhythm. The degree to which the patients felt they were benefiting from singing also had no influence on the number of words produced. Trying to sing the words was enough to enable them to express themselves better. The conclusion is that most aphasic patients can produce more words when they sing than when they speak. In day-to-day communication, the usefulness of this effect is probably limited but, as we shall see, it matters in the rehabilitation of language-related functions.

Melodic Intonation Therapy

Melodic Intonation Therapy (MIT) is a systematic approach to speech training, which uses song-based techniques to stimulate word production and uses rhythm to make the spoken language flow more easily. MIT has caused some controversy but several recent studies have shown that aphasic patients who have received music- or song-based therapy manage spoken language better than those given more conventional training in language and speech. For instance, Haro-Martinez and his colleagues have published a randomised, controlled study of 20 Spanish patients with aphasia in which the results point to general improvements in communication skills compared with the control group. True, the tests for degree of aphasia did not show any significant differences between MIT exposed patients and the control group. However, the groups were small and the results should be investigated in a bigger population. In another study, aphasic patients were scanned before and after MIT using *magnetic resonance imagining* (MRI scans) to record any effects on the *arcuate fasciculus,* one of the major nerve pathways linking the anterior (Brocka's) and posterior language areas. It had grown thicker after the therapy, especially on the right (undamaged) side of the brain. Again, the group of patients was small and they acted as their own controls (Schlaug et al, 2009). Still, results such as these indicate that MIT is associated with plastic changes in the language system in the brains of people made aphasic after a stroke. Besides, taken together with the many patients with aphasia who were able to sing texts, the effects of MIT confirm that the human forms of communication, speech and music, are tightly linked in the brain – as we have seen earlier in this book.

Music to treat cognitive and emotional problems

Strokes affect not only motor control and speech but can cause difficulties by harming any kind of brain function, depending on where in the brain the original lesion occurred. Between a third and a half of all stroke patients will, to a lesser or greater extent, show cognitive deficits that affect memory, attention and other executive functions. They are also prone to emotional problems, including fatigue and depression. As we have seen earlier, music connects to both the cognitive and emotional systems in the brain – it could follow that music would be helpful for people with such problems and make them feel better. Marie Tervaniemi in Finland has done pioneering research on this idea and study was published in the highly respected journal *Brain*. Her group had carried out an experiment in which patients listened for one hour daily to their favourite music, picked in collaboration with a music therapist. They did this for the first two months after their stroke and were compared with patients who been offered either standard language training or sessions listening to audio books. The 'music treatment' led to relatively greater improvements in cognitive functions such as verbal memory and focused attention. The effects persisted when the patients were tested again six months later.

So, it seems that simply listening to music you like can help your brain reorganise and repair during the stroke rehabilitation stage. The Finnish group went on to show in a later study that, after stroke patients had been listening to music, the volumes of the frontal lobe cortex, certain limbic system regions and parts of the basal ganglia had all increased. They used MRI scans to measure the changes, which were correlated with improvements of the verbal memory, attention and language characteristics associated with frontal lobe functioning. Changes in the limbic system, which is involved in emotional states, correlated with certain but inconsistent degrees of recovery from depression. On the basis of this work, it would appear that music contributes improvements in cognitive functions, presumably due to neuroplasticity. Sadly, there is still a lack of other good, clinical evidence of the effects of music on the cognitive disturbances associated with stroke. The Cochrane organisation, which carries out overviews of evidence-based studies in all areas of medicine, made a systematic review (2017) of the effects of music on cognitive problems after strokes and concluded that the benefits were not proven. Whether the reason for this is simply a lack of good, well-designed studies can only be shown by carrying out more good studies in the future!

Music for better movements

Hemiparesis – it entails movement problems affecting one half of the body – is the most common symptom after a stroke. It is present in varying degrees of severity in about 70% of patients. As we have seen earlier, music has a power of its own to stimulate movements and can activate all the motor areas on the brain. Nowadays, music is increasingly used in the treatment of movement deficits following a stroke. The best studied effects are on walking in response to rhythmic music or rhythmic auditory stimuli generally: *rhythmic auditory stimulation* (RAS). Most of the studies use different stimuli and the point is to coordinate body movements with the stimulus. We discussed earlier people's almost automatic need to move in response to rhythmic music – to beat out the rhythm with hands or feet, to stamp one's feet, clap and nod and rock the body. It is this urge to move to music that is being recruited by RAS techniques.

Gait

Our walking is a function that has developed and been finessed over millions of years in order to provide optimal balance between conscious control and automatic movements. We would hardly be able to move around at all without the automatic component of walking. In itself, walking is such a hugely complex physiological function that to make yourself organise the simplest few steps across the floor is way beyond the data processing power of our aware mind. But, at the same time, walking needs to be under conscious control to enable us, for instance, to adjust speed and stride length to fit different conditions and situations. The muscular contractions in legs, hips, arms and back must be reset moment by moment as we stand still, or swing our legs forwards and back. The smooth coordination of these automatic adjustments is carried out by groups of linked areas in the spinal cord, brainstem and cerebellum, where the rhythm generating centres for normal gait are also found. You can investigate this by propping up a baby on a smooth surface so that the body weight is supported by the feet: the baby's legs will start moving rhythmically in a 'walking' pattern. Later in life, as the gait control system matures, cerebral centres will be recruited and take overall control of features such as the speed required and how to cope with irregular surfaces. Once set up, the pattern of the gait will be maintained by the rhythm generators.

In cases of hemiparesis after strokes or other traumas, one or many features of normal gait will be disturbed. The centres in cord, brainstem and cerebellum will usually be intact because strokes rarely affect these 'lower' parts of the central nervous system.

We have tried to outline the theoretical basis of rhythm-training for stroke patients with gait disturbances. There are many RAS studies showing that, in such cases, the tempo, stride length, foot displacement and balance are improved in comparison with the outcome in patients offered only standard physiotherapy. With the exception of balance, which is usually not included as a variable, the Cochrane overview (cf. above) indicates that RAS is an effective treatment of gait deficits in stroke patients and that the best results are seen when a skilled music therapist has matched the training to the individual's needs.

Functions of the arms

Music-based interventions to treat dysfunctional arms have also had encouraging results. Various forms of music therapy have been tried, from RAS to learning to play an instrument with the affected hand. In a study by Tong and his colleagues, patients were taught to play the piano for four weeks but one group practised on a piano that made no sounds. Overall, the group with a normal, 'sounding' piano did significantly better in tests of hand- and arm-functions than those taught on a soundless one. The result suggests that the music is a more important factor than the exercises in pressing the right keys. As we have suggested previously, the effect of music is probably to increase motivation via heightened dopamine release in the brain's reward system, leading to stimulation of neuroplasticity and improved motor control.

A promising, relatively new approach is known as *music sonification therapy* (MST), which entails patients making fairly large movements matched with corresponding sounds. The patients get instant sound (music) feedback on the success of a movement. This is intended to compensate for the lack of proprioceptor information coming back into their brains from sense organs in joints, tendons, skin and musculature. Instead, the brain is trained to listen in order to get an idea of what the arm or the foot is doing. Scholz and colleagues (2016) distributed stroke patients between two groups of 25 members, one of which received MST and the other a sham variant, in which the music had no relationship to their movements. The results showed better outcomes in the 'real' group compared to the 'sham' group, which is further confirmation that music is important in stroke rehabilitation. However, the study was small and the effects not very marked, so – again – more and larger investigations are needed to ascertain just what the role of music is for improvements in arm movements after a stroke.

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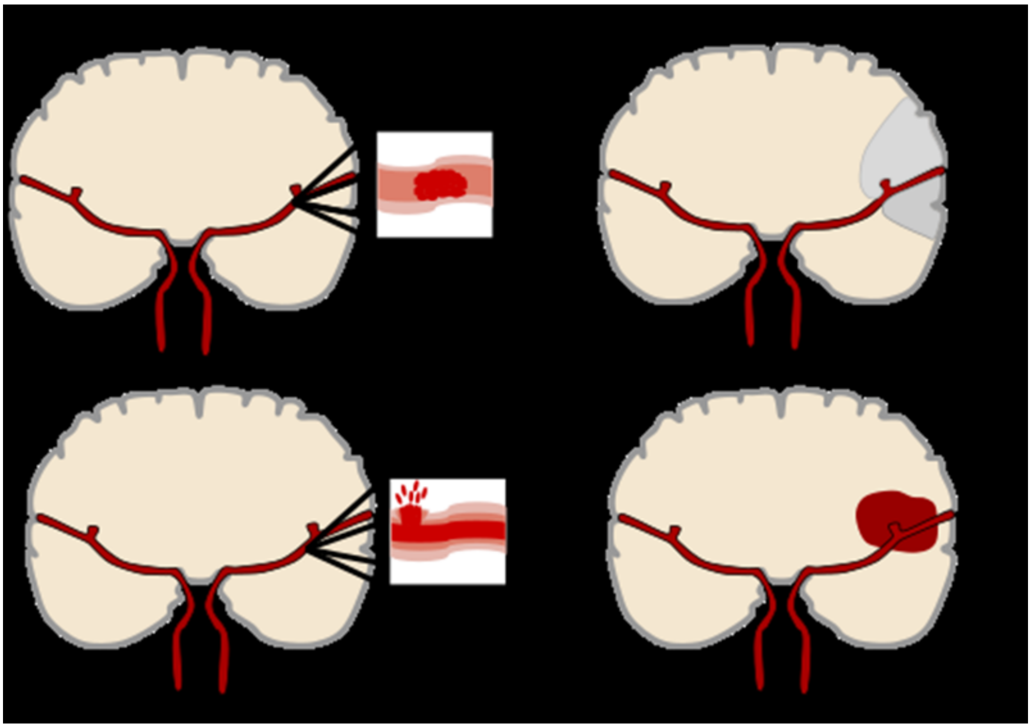

Caption: There are two different forms of stroke. Both lead to destruction of nerve cells (neurones) in the affected area of the brain. The top diagram on the left shows a blood clot impacted in one of the arteries supplying an area of the brain. The area will not get any blood, the tissue will become ischemic and the neurones will die, as shown in the top diagram on the right.

The lower left diagram shows a ruptured artery. The lack of oxygenated blood will lead to neuronal death in the area of the bleed, as shown on the lower right diagram.