Apollo's Curse: Causes and Cures of Motor Failures in Musicians: A Proposal for a New Classification

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Apollo’s curse: neurological causes of motor impairments in musicians

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Abstract

Performing music at a professional level is probably one of the most complex human accomplishments. Extremely fast and complex, temporo-spatially predefined movement patterns have to be learned, memorized, and retrieved with high reliability in order to meet the expectations of listeners. Performing music requires not only the integration of multimodal sensory and motor information, and its precise monitoring via auditory and kinesthetic feedback, but also emotional communicative skills, which provide a “speaking” rendition of a musical masterpiece. To acquire these specialized auditory-sensory-motor and emotional skills, musicians must undergo extensive training periods over many years, which start in early childhood and continue through stages of increasing physical and strategic complexities. Performance anxiety, linked to high societal pressures such as the fear of failure and heightened self-demands, frequently accompanies these learning processes.

Motor disturbances in musicians are common and include mild forms, such as temporary motor fatigue with short-term reduction of motor skills, painful overuse injuries following prolonged practice, anxiety-related motor failures during performances (choking under pressure), as well as more persistent losses of motor control, here termed “dynamic stereotypes” (DSs). Musician’s dystonia (MD), which is characterized by the permanent loss of control of highly skilled movements when playing a musical instrument, is the gravest manifestation of dysfunctional motor programs, frequently linked to a genetic susceptibility to develop such motor disturbances.

In this review chapter, we focus on different types of motor failures in musicians. We argue that motor failures in musicians develop along a continuum, starting with subtle transient degradations due to fatigue, overuse, or performance stress, which transform by and by into more permanent, still fluctuating motor degradations, the DSs, until a more irreversible condition, MD manifests. We will review the epidemiology and the principles of medical treatment of MD and discuss prevention strategies.

Keywords

dynamic stereotype, motor control, musician’s dystonia, prevention of dystonia, treatment of dystonia

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Performing music at a professional level is one of the most complex human accomplishments. Playing an instrument requires the integration of multimodal sensory and motor information, the generation of appropriate action plans, the selection and retrieval of highly refined movement patterns from procedural motor memory, and the initiation of movement. In most instances, these movements are highly overlearned, and they depend on feed-forward programming of the anticipated—mostly audible—results and on real-time feedback.

Auditory and kinesthetic feedback is needed to improve, fine-tune and perfect the performance. Music making therefore relies primarily on a highly developed auditory-sensory-motor integration capacity, which has been conceptualized theoretically in the “common-coding” model by Prinz (1984). Simply put, in this model movements are represented as sound patterns, and sound patterns as movements (see for a review Zatorre et al., 2007). Subtle perturbations of this auditory feedback have a major impact on motor control. For example, playing on a keyboard with slightly delayed sound production affects the regularity of scale playing even in highly accomplished pianists (Cheng et al., 2013). Furthermore, the kinesthetic senses constitute another basis of high-level performance. They allow for the control and feedback of muscle- and tendon-tension as well as joint positions, enabling the continuous monitoring of finger-, hand-, or lip-position in the frames of body and instrument coordinates (e.g., the keyboard, the mouthpiece). Again, subtle changes in kinesthetic feedback result in an alteration of the motor program, and in some individuals long-term loss causes severe disturbances of the motor program and even focal dystonia (for a theoretical account and review on this topic, see Konczak and Abbruzzese, 2013).

In order to acquire these specialized sensory-motor skills, musicians must undergo extensive training periods over many years, starting in early childhood and passing through stages of increasing physical and strategic complexities. This process of practicing involves assembling, storing, and constantly improving sensory-motor programs through prolonged and repeated execution of motor patterns under the controlled monitoring of auditory and kinesthetic senses. To attain a professional level, as a rule of thumb, musicians have 10,000 h in 10 years of deliberate practice (Ericsson et al., 1993). Of course, time invested into the acquisition of motor skills alone is not sufficient for becoming an outstanding artist. Quality of practice as well as communication skills and expressive gesturing, rendering a speaking performance, are equally important in the process of artistic perfection of publicly acclaimed and valued interpreters (Hallam, 2014).

In music, learning through experience and training is accompanied by remarkable plastic adaptations of the central nervous system, which are not only reflected in modifications of the brain’s neuronal networks as a result of a strengthening of neuronal connections, but also in its overall gross structure. It is known, for example, that music practice enhances myelination, gray matter growth, and fiber formation of brain
structures involved in the specific musical task (for a review, see Chapter “Apollo’s Gift: New Aspects of Neurologic Music Therapy” by Altenmüller and Schlaug; Münnte et al., 2002; Wan and Schlaug, 2010). Gaser and Schlaug (2003) could demonstrate enhancement of gray matter density in cortical sensory-motor regions, auditory regions, the left dorsolateral prefrontal cortex, and in the cerebellum in professional instrumentalists as compared to nonmusicians and amateurs. Interestingly, these plastic adaptations depend on critical age periods: musicians who start playing their instruments before the age of seven do not display these structural adaptations of the brain, at least in the sensory-motor cortices and the callosal fibers; however, they seem to have an “early optimized network,” which allows superior performance of motor tasks without enlarged anatomical structures (Steele et al., 2013; Vaquero et al., 2014). In contrast, those who start after the age of seven do show the above-mentioned structural adaptations accounting for the effects observed in many morphological brain imaging studies (e.g., Bangert and Schlaug, 2006; Gärtner et al., 2013).

When discussing skilled motor behavior in music performance and its deterioration or even loss, it is first necessary to emphasize what is unique to making music and what renders it particularly challenging and fragile in terms of motor control:

1. Musical training usually starts very early, sometimes before age six, when the adaptability of the central nervous system is the highest. This feature is not unique to music, as other skilled activities, for example, classical ballet, also require an early start.

2. Making music is linked to sound production. As in speech, the auditory system provides a very precise feedback of the movement effects, with a temporal resolution superior to kinesthetic and visual feedback. Furthermore, in the frame of classical music, which is notated and available as sheet music, the target parameters, namely temporal accurateness (correct tempo, accuracy of rhythm, swing, beat, pulse, etc.), and spatial accurateness (correct key—or finger position on fingerboard, correct sound quality) are predefined. Therefore, a highly reliable reproduction of movements meeting these targets is required. This feature is unique to music: in classical ballet, for example, visual feedback is less critical in terms of temporospatial precision.

3. Most musicians work at the upper limit of their sensory-motor capabilities and strive to push their limits even further ahead in order to be faster, louder, and more expressive. Given the complexity of music, the demands of composers, especially in the last 100 years, and the role of outstanding peers as models—for example, the Chinese pianist Lang Lang, or the “record braking” violinist David Garrett—the theoretical limit of movement accuracy and speed is the temporal and spatial resolution of the auditory system. As musicians say, “there is always a colleague, who plays this piece faster, louder and more beautiful.” This is in part also true for sports, but in music, fine motor skills predominate. Therefore, musicians are frequently denoted colloquially as “small muscles’ athletes.”

4. The societal pressure and expectancies concerning the quality of musical performances have definitely grown over the last centuries: this is due, on the one
hand, to the ubiquitous availability of music recorded in the media, such as YouTube and CDs, but on the other hand, to collective learning processes leading to higher standards of music appreciation. This process augments anxiety, tension, and competition among musicians, making their lives increasingly stressful. Frequently even outstanding soloists have to cope with severe performance anxiety (Wilson, 1997).

5. Nevertheless, making music is frequently linked to highly positive emotions, to feelings of joy, satisfaction and even to strong emotional reactions, known as “chill responses” (Altenmüller et al., 2013). These qualities are known to enhance plastic adaptations of the brain and can even lead to a sort of addictive behavior, causing younger musicians to over-practice and ignoring their bodily limits, which are indicated by fatigue and musculoskeletal pain.

2 APOLLO’S CURSE: LOSS OF MOTOR CONTROL IN MUSICIANS

According to our new classification of motor control disturbances in musicians, we can distinguish five different types of deterioration of motor control in musicians (Altenmüller et al., 2014). The criteria for this new classification are (1) duration and development of the problem, (2) triggering mechanisms, (3) psychological profiles, (4) response to treatment, (5) accompanying symptoms, and (6) genetics.

2.1 MOTOR FATIGUE

Most musicians experience at some point a loss of motor control when playing their instrument. Frequently this phenomenon is short-term and bound to either lack of practice or overuse. It is accompanied by mental or bodily fatigue and obviously linked to reduced attention and insufficient movement monitoring. Usually, these deteriorations of movement coordination are short term: they disappear overnight and do not compromise overall performance. Although these incidents seem to be frequent, there is almost no scientific data available. A recent questionnaire study on German orchestral brass instrumentalists identified temporary crises of embouchure coordination in a percentage as high as 30% (Steinmetz et al., 2013). In clinical practice, the symptoms are lack of regularity in scales, trills, and other fast repetitive movements, and the wind-players complain of loss of sound quality and occasionally early fatigue. Pain is not usually reported. There is no information available as to whether any medical intervention other than rest is useful to treat this condition.

2.2 OVERUSE INJURY

In contrast to the former condition, overuse in the narrow sense of the word should only be diagnosed when pain is a dominating symptom and a history of either prolonged or unaccustomed practice exists. In this case, local inflammation of over-strained tissues, the release of pain-mediators, and spinal reflexes with
increased or occasionally lowered muscle tone may lead to a deterioration of motor control, mostly accompanied by relieving movements (Szeto and Lin, 2011). This condition may last a couple of days and, if the patient rests, subsides after a few weeks at the latest.

### 2.3 Choking Under Pressure

Another condition leading to a deterioration of motor control is “choking under pressure” (CuP). CuP figures widely in sports’ psychology literature but has not yet been adopted by experts in musician’s medicine and performing arts’ psychologists. In sports, the current definition characterizes CuP as an acute performance failure due to a perceived mismatch between the individual resources of an athlete and the demands of the situation (Hill et al., 2009). CuP describes the situation in which the individual perceives a subjectively unmanageable situation that is accompanied by fear of failure, anxiety, and increased arousal, leading to reduced motor control and worse performance outcome. In musicians, CuP is a relatively frequent experience, especially among performing novices, and is usually subsumed under the term “performance anxiety.” According to questionnaires, between 15% and 60% of performing musicians occasionally suffer from this condition (Brugués, 2011a; Steptoe and Fidler, 1987). It may lead to loss of agility, heightened muscular stiffness accompanied by increased cocontraction of antagonist muscles, and, as a consequence, reduction of temporo-spatial precision of movements and sound quality. This has been impressively demonstrated in pianists (Yoshie et al., 2009). In brass players, the so-called tongue stopper prior to an important cue is a typical manifestation.

### 2.4 Dynamic Stereotype in Musicians

If motor incoordination and lack of motor control persist for more than 4 weeks, despite the patient’s resting and careful rehabilitation under the guidance of a therapist or teacher has been attempted, one can assume that there is a graver alteration of sensory-motor networks leading to a deterioration of motor programs in the central nervous system. We have called this condition “dynamic stereotype” (DS), a term borrowed from the eminent Russian physiologist Pavlov (1951) (for a critical review, see Windholz, 1996). Originally, this condition can be understood as a reflection of fatal compensation strategies, which became automated. In the words of the exponents of Russian behaviorism, DSs are defined as a type of integral activity performed by the cerebrum of higher animals and man and manifested by a fixed, or stereotyped, succession of conditioned reflexes. The DS is influenced by external factors that are repeated in a certain order. Accordingly, the DS is the most vivid manifestation of the extremely subtle analyzing and synthesizing activity of the cerebral cortex and is the product of very complex interactions between the areas of the cortex. It can at least partly be conceptualized as a consequence of long-term CuP when these dysfunctional movements are stored in procedural memory traces,
possibly as a consequence of conditioned reactions to the previous choking experiences and procedural memory formation under stress (Klämpfl et al., 2013; Lobinger et al., 2014).

In many aspects, the phenomenology of DS resembles focal, task-specific dystonia (see below). However, in contrast to the latter, it seems to be more modifiable and more fluctuating, especially during stressful performances. Sometimes they experience sudden improvement and complete motor control occurs— but only for hours or a few days. DS responds occasionally to sensory trick maneuvers, such as alterations of either tactile input from the body parts affected by dystonia or alterations of auditory input, for example, by delay of the produced sound. We could demonstrate that the improvement in motor control when the patient plays with a latex glove is related to a better outcome of retraining and behavioral therapies (Paulig et al., 2014). It should be mentioned, however, that responses to sensory tricks and objective improvement are rare and highly variable (Cheng et al., 2013). Therefore, we prefer to consider this phenomenon a “soft-sign” with respect to the classification of motor control problems.

2.5 FOcal Dystonia in Musicians

The most severe movement disorder among instrumental performers is task-specific musician’s dystonia (MD) (Altenmüller, 2003), also known as musician’s cramp. Commonly, two major forms are distinguished: focal hand dystonia (FHD) and embouchure dystonia (ED). This movement disorder is characterized by persistent muscular incoordination or loss of voluntary motor control during task-specific highly trained movements, such as playing a musical instrument (Altenmüller, 2003; Jankovic & Ashoori, 2008). In most cases, pain does not accompany the disorder; occasionally, some muscular strain can occur when patients attempt to compensate for the dystonic movement by overactivating the antagonist muscles; however, lack of pain distinguishes it from the above-mentioned overuse injury. It is important to make this distinction while bearing in mind that prolonged pain syndromes may lead to symptomatic dystonia. MD frequently terminates professional careers and is highly disabling among musicians (Altenmüller, 2003; Altenmüller & Jabusch, 2010; Brandfonbrener and Robson, 2004; Lederman, 1991).

Various symptoms can mark the beginning of the disorder: subtle loss of control in fast passages; finger curling (cf. Fig. 1); among woodwind players, a lack of precision in forked fingerings; irregularity of trills; fingers sticking to the keys; among string players, an involuntary flexion of the bowing thumb; and among woodwind and brass players, the loss of control of the embouchure in certain registers. At this stage, most musicians believe that the reduced precision of their movements is due to a technical problem or lack of practice. As a consequence, they intensify their efforts, but this reaction often exacerbates the problem. The loss of muscular coordination is frequently accompanied by a cocontraction of antagonist muscle groups. For example in pianist’s cramp, the coactivation of wrist flexor and wrist extensor muscles is frequently observed, and we have documented a case of a task-specific dystonia in
the leg of a bass-drummer, leading to pronounced coactivation of ankle flexor and extensor muscles (Lee and Altenmüller, 2014).

There are special cases of task-specific loss of motor control in musicians, which should be mentioned here, as they are strongly related to MD or even constitute subgroups: dystonic tremor is characterized by task-specific tremulous movements of the supporting arm in woodwinds or in the bowing arm of string players (Lee et al., 2013, 2014). A very rare condition is a task-specific inability to recruit motor programs required for a specific overlearned movement, termed “negative dystonia” (Mezaki, 2007).

According to the recent estimates, 1% of all professional musicians are affected (Altenmüller and Jabusch, 2010). In contrast, in the general population, the prevalence of focal dystonias, including writer’s cramp, blepharospasm, and cervical dystonia, is estimated as 29.5 per 100,000 in the United States and 6.1 per 100,000 in Japan (Nakashima et al., 1995; Nutt et al., 1988). In comparison to other activities producing dystonic movements, such as writing, playing golf (the “yips”), or playing darts (dartism), classical musicians have the highest risk of developing focal dystonia (Frucht, 2009).

Demographic data demonstrate a preponderance of male musicians with a male/female ratio of about 4:1 (Lim and Altenmüller, 2003). Hereditary factors play a role in the etiology of MD, as a positive family history of dystonia exists in up to 36% of affected musicians (Schmidt et al., 2009). According to the epidemiological data, the probability of developing MD depends on the instrument played: guitar players, pianists, and brass instrument players have the highest risk of developing dystonia.
(Altenmüller and Jabusch, 2010). Repetitive use, controllability of motor actions, tempo-spatial demands, and extratemporal fine motor burdens, such as writing, are triggering factors (Altenmüller et al., 2012; Baur et al., 2011). Furthermore, those musicians who start practicing after age 10 are at a much higher risk of developing MD (Schmidt et al., 2013).

While there is probably a certain overlap between MD and the above-described DS, each of these disorders is distinct from the other. Generally, focal dystonia is more severe, and the dysfunctional movements are more obvious and more resistant to any attempt to correct them voluntarily. Furthermore, movements respond to a lesser degree to the above-mentioned sensory tricks. Sudden spontaneous improvements are rare exceptions, and psychological stressors do not influence the loss of motor control to a major degree. Finally, in contrast to DS, MD has a tendency to spread from the specific movement when playing the instrument to general, daily-life movements. For example, MD may first show only in the ring and little finger of the pianist when playing scales, as depicted in Fig. 1, but later extends to typing on a computer keyboard and to buttoning up a shirt, and in the end may lead to permanent cramping of the hand. In neurology, this condition is termed “dystonic cramp” and it seems to affect about 35% of musicians suffering primarily task-specific dystonia (Rosset-Llobet et al., 2007). Along the same line, loss of motor control may progress from the forearm to the upper arm, leading in rare cases to segmental dystonia. When dystonia spreads from one hand to the other, which is the case in about 3% of the musicians suffering from FHD, a bifocal dystonia has to be assumed (Rosset-Llobet et al., 2007).

2.6 SYMPTOMATIC TASK-SPECIFIC DYSTONIAS IN MUSICIANS

Symptomatic task-specific dystonias in musicians form a rare heterogeneous group of dystonias. Per definition, the leading symptom is isolated deterioration and loss of motor control when playing a musical instrument. In contrast to the above-mentioned “idiopathic” focal dystonias, the disorder is caused by an underlying neurological or psychological pathology. For example, in rare cases it may mark the beginning of Parkinson’s disease, albeit we have to acknowledge that we have only seen two MD patients who later developed Parkinson’s disease. When taking our present group of 850 MD patients into account, this incidence rate of Parkinson’s corresponds to that in the general population of Germany. Furthermore, in neurological textbooks, Morbus Wilson, Huntington’s Chorea, and other neurodegenerative diseases have been mentioned as causes of symptomatic dystonia; however, to our knowledge an isolated task-specific loss of motor control in these conditions, specifically when playing the instrument, has not yet been described.

MD is sometimes triggered by bodily trauma. Here, it is unclear whether the lesioning of peripheral nerves and the concomitant sensory degradation or the trauma-induced rest or change in practice schedules, playing postures, and so on constitutes triggers. We have seen two flutist patients who suffered from inferior
alveolar nerve lesion and numbness of the lower lip and who then developed ED (unpublished clinical data).

Psychogenic dystonias in musicians are extremely rare conditions. We have never suspected any musician of malingering, probably due to the rewarding nature of music and the lack of secondary benefits when loosing the ability to perform. However, fluctuating or longer lasting loss of motor control when playing an instrument may occur in some psychiatric diseases, such as schizophrenia, obsessive–compulsive disorders, and constraint and anxiety disorders. In schizophrenia, long-term consequences of antipsychotic drugs have to be considered as a cause. In obsessive–compulsive disorder, dysfunctional working behavior and, as a consequence, motor fatigue and overuse may be the underlying pathogenic mechanisms. Anxiety has frequently been found to be a risk factor in MD (see below). This might hypothetically be linked to chronic CuP, as we discussed in Section 2.4.

Finally, psychogenic MD in the narrow sense of the word is, as far as our experience goes, extremely rare. The underlying theory assumes a conversion disorder, which in turn is caused by fundamental unresolved psychological conflicts, leading to subconscious alterations of motor behavior that may express the nature of the underlying conflict in a “converse” manner. It is very difficult to diagnose and therefore frequently subsumed under the term, unexplained medical conditions (Lang and Voon, 2011). As a rule of thumb, musicians suffering from psychogenic dystonia usually have a history of previous physical or psychological trauma or disorder, show the symptoms in an exaggerated, speaking manner, seem to be more emotionally distant from the motor disorder, and display less despair than do musicians with normal MD. Sometimes a triggering event can be identified, and in the follow up, fluctuating symptoms with prolonged periods of complete remission or miracle healing are suspicious for a psychogenic cause (Czarnecki and Hallett, 2012).

3 A HEURISTIC MODEL OF MOTOR DISTURBANCES IN MUSICIANS

Summarizing the previous paragraphs, we can classify the six types of motor disorders according to the duration of motor degradation, the accompanying symptoms, the underlying neurophysiological mechanisms, and the response to treatment. In Fig. 2, we depict a heuristic model which goes from a continuous worsening of motor control from temporary subtle awkwardness to increasingly unstable motor control and finally fully developed focal dystonia. Furthermore, we have added triggering factors, identified in our previous epidemiological studies (Altenmüller, 2003; Altenmüller and Jabusch, 2010; Altenmüller et al., 2013).

In the beginning, motor fatigue may cause a temporary degradation of motor skills, or, in highly skilled experts, additional/alternative recruitment of muscles contributing to dysfunctional movements. This mechanism has been convincingly demonstrated in skilled table tennis players (Aune et al., 2008) and most likely also applies to instrumental musicians. For example, in skilled piano players, fatigue
of the long flexor muscles in the forearm may be compensated by activation of the intrinsic muscles in the hand, which in turn results in dysfunctional movements in the metacarpophalangeal (MCP)-joints with lack of fine control of touch and degraded sound quality. These changes are accompanied by central nervous adaptations due to short-term plasticity, and they result in reduced amplitude of movement-related potentials and in an alteration of the topography of motor and premotor cortex activations (Dirnberger et al., 2004). Interestingly, in a study on musicians suffering from dystonia, a fatiguing muscular contraction significantly improved motor performance. In contrast, in healthy musicians, performance consistently worsened following fatigue (Pesenti et al., 2004).

In the overuse condition, dysfunctional CNS-plasticity might play an important role in motor degradation (Byl et al., 1996, see also Flor, 2012 for a review). Although in most instances prognosis is good and quick recovery common, under conditions with heightened anxiety and other stressors, such as high professional workload, these dysfunctional motor patterns may stabilize in procedural memory. Here, psychological stress might induce the cascade of emotionally induced memory consolidation, which has been previously described for different forms of memory: consolidation mainly relies on noradrenergic activation of the basolateral amygdala (BLA) (McGaugh, 2000; Packard et al., 1994). The primary motor cortex, which is essentially involved in the storage of motor memories (Karni et al., 1998), receives a basolateral amygdala projection (Sripanidkulchai et al., 1984). Thus, it may be
assumed that consolidation of these dys-coordinated movements as dysfunctional motor programs is a BLA-mediated process in the primary motor cortex (Jabusch and Altenmüller, 2004). This may also be the link to conditions, which we discuss in Sections 2.3 and 2.4.

CuP is common in sports and has been investigated in golfers suffering from the yips. This condition is defined as involuntary movements during the execution of putting strokes, resulting in a serious decrease in the success rate in putting. It has been classified by some authors as a task-specific focal dystonia (Adler et al., 2005); however, many authors believe that the yips are more related to CuP (Lobinger et al., 2014). The following are arguments against the classification as a focal dystonia:

1. The yips occurs not only in professionally trained golfers but also in golfing beginners. This renders a pathophysiological mechanism similar to that of MD very unlikely. In musicians, we could demonstrate that dysfunctional brain plasticity induced by prolonged practice leads to distorted topographies of receptive fields in the somatosensory cortex, which in turn leads to the observed degradation in motor control due to abnormal somatosensory feedback (Elbert et al., 1998).

2. The yips look more like a sudden jerk, or an anticipating tremor prior to hitting the ball. In MD, reduced inhibition in the motor output is another proven cause of dysfunctional movements, leading to prolonged coactivation, and typical dystonic postures—for example, the curling of fingers in Fig. 1.

3. The Yips are relatively frequent in the golfing community with the rate of prevalence between 16% and 24% (Klämpfl et al., 2013). This is unusual for any kind of dystonia. As of now, the most common task-specific dystonia is MD, which affects 1–2% of professional musicians.

In music, the term CuP, has not been applied, but the phenomenon clearly exists. The above-mentioned tongue stopper in brass players, or the short-action bowing tremor in violin-players, playing soft notes with the tip of the bows, is good example. Here, most probably anxiety-induced “reinvestment” leads to cognitive interference, resulting in dysfunctional movements due to the attempt to prevent or even correct feared errors. In an EEG-study on highly trained professional pianists, we could demonstrate that their brain anticipates errors of motor execution, and that these “pre-error”-related brain waves arise about 50 ms prior to the wrong key-stroke (Herrojo-Ruiz et al., 2009). Such a rapid error-anticipating mechanism cannot be cognitively controlled; rather it is highly susceptible to disturbances via cognitive control. Therefore, it is plausible that reinvestment and CuP may lead to a deterioration of motor control.

DS is characterized by a more permanent reduction of motor control. As outlined earlier, it differs from focal dystonia only gradually, but is more likely linked to psychological triggering factors than to underlying genetic causes (Ioannou and Altenmüller, 2014). In terms of underlying neurophysiological mechanisms, we speculate that these musicians have a deficit in the so-called limbic loops of the basal
ganglia, linking movements, and motor control to emotions. However, this question remains to be addressed in future investigations in a patient population, which is correctly classified a priori (Ioannou and Altenmüller, 2014).

MD can be distinguished from the former by the more pronounced worsening of motor control, the lack of “islands” of wellbeing, and the tendency to progress to dystonic cramps. The pathophysiological basis of MD can only briefly be summarized. For more details, we refer to a review by Altenmüller and Jabusch (2010). Numerous studies have revealed abnormalities in three main areas: (a) reduced inhibition in the sensory-motor system, (b) altered sensory perception, and (c) impaired sensorimotor integration. In recent years, an increasing number of brain imaging studies among musicians—and other focal dystonias—have demonstrated that these alterations are probably not task-specific. Functional connectivity (Moore et al., 2012), cortical activation patterns (Haslinger et al., 2010), and basal ganglia anatomy (Walter et al., 2012) have proven to be abnormal, although behavioral tests are more in favor of task-specificity when testing musicians in other skilled motor tasks (Rosset-Llobet et al., 2007). We argue that musician’s focal dystonia is the product of a hereditary susceptibility, probably related to a general lack of central nervous inhibition and the above-mentioned triggering factors. This leads not only to task-specific functional alterations of CNS-networks—as we predict in patients suffering from a DS—but also to structural alterations found in the above-mentioned studies.

In the previous publications, we have emphasized psychological conditions as an underlying triggering factor. In several questionnaire studies, we found elevated anxiety and extreme perfectionism in MD patients (Altenmüller and Jabusch, 2009; Enders et al., 2012). According to Jabusch et al. (2004), these psychological characteristics had already been present before the onset of dystonia according to personal recall. We now argue that musicians with a major psychological burden can most likely be subsumed under the classification of a DS. We are presently conducting a study, which addresses the impact of stress and anxiety on motor performance in musicians suffering from loss of motor control who show signs of either high or low psychological burdens. Subsequently, we will apply specific interventions aiming at improving psychological conditions and preventing dysfunctional reinvestment in order to improve motor control in those musicians who suffer from DSs.

4 CURING APOLLO’S CURSE: TREATMENT OF MOTOR DISTURBANCES IN MUSICIANS

What do psychological and neurophysiological findings imply for the differential treatment of motor disturbances in musicians? We have already mentioned that motor fatigue is best treated with rest, although no scientific data are available to verify the results. For the treatment of overuse injuries, besides rest, pain medication, muscle relaxants, and physiotherapy with gentle stretching exercises have proven to be
useful (for a review, see Helliwell and Taylor, 2004). For these pain syndromes, a prompt intervention is required to avoid dysfunctional plastic adaptations of the central nervous system seen in chronic pain conditions (Jensen et al., 2013). CuP in musicians is probably best prevented by mental training and specific cognitive strategies which are already being applied in sports psychology (e.g., “hemispheric priming” Beckmann et al., 2013). Efficient treatment probably includes cognitive behavioral therapy, mindfulness-training, and various breathing and relaxation techniques (for a review, see Brugués, 2011b). As medications, beta-adrenergic receptor blockers (such as propanolol) and benzodiazepines are potentially helpful. Both drugs prevent dysfunctional motor memory formation (Soeter and Kindt, 2013).

As far as the treatment of DS is concerned, we predict that psychological techniques, such as the prevention of dysfunctional reinvestment and cognitive interference, will be helpful. The latter, for example, could be influenced by guiding attention from an internal (body-related) to an external (sound-related) focus. These techniques have been shown to be efficient in complex motor studies with normal and patient groups (Wulf, 2007, for an overview). Furthermore, psychotherapeutic techniques reducing anxiety and perfectionism will probably improve the condition. Specific interventions are learning-based sensorimotor training, based on re-defining spatial and temporal processing capacities in the sensory and motor cortices in order to restore task-specific skills (Byl and McKenzie, 2002). Prolonged pedagogical retraining has been successfully applied to pianists suffering from loss of motor control (van Vugt et al., 2014). Useful medications include selective serotonin-reuptake inhibitors (e.g., escitalopram) to overcome reinvestment, overfocussing, and depression; anticholinergic drugs to reduce dysfunctional motor memories; and finally, as a symptomatic treatment, local injections of botulinum toxin into the cramping muscles (Schuele et al., 2005). These medications are also applied in MD.

Finally, treatment for MD is mostly symptomatic and depends on the type of dystonia. Psychological interventions seem to be less effective for the treatment of MD than for DS. Various oral medications have been used, and the anticholinergic drug trihexyphenidyl has proven to be the most effective agent (Jabusch et al., 2005). Occasionally, patients may benefit from baclofen or antiepileptic drugs such as phenytoin, primidone, or rivotril. Chemical denervation using botulinum toxin has been used for many forms of MD with considerable success. Botulinum toxin blocks the transmission of nerve impulses to the muscle and weakens the overactive muscles involved. Results in musician’s cramp depend on the dystonic pattern, on the injection technique and on the precise localization of the dystonic muscles. In our series, injections of botulinum toxin were applied to 71 musicians suffering from hand dystonia. Fifty-seven percent patients reported long-term improvement (Schuele et al., 2005). A new promising therapy is bihemispheric transcranial direct current stimulation during the execution of functional movements at the instrument. In a double blind randomized prospective trial, we could demonstrate that stimulation with inhibition of the dysfunctional network of the “dystonic” motor cortex and the activation of the “healthy” network of the contralateral motor cortex improved performance significantly (Furuya et al., 2014).
Since successful treatment is still a challenge, preventing MD is important. On the basis of the heuristic model outlined in this chapter, which assumes a progression of increasing motor disturbances from fatigue, pain, anxiety to dysfunctional motor memories, and finally to MD with structural memory consolidation and brain adaptations, we now have the theoretical means at hand to intervene at an early stage. From the first lesson on, music educators should strive to create a friendly, supportive atmosphere, introduce reasonable practice schedules, teach proper techniques, and prevent overuse and pain by including mental practice and variations of movement patterns. By avoiding mechanical repetitions and hence frustration, teachers can help maintain students’ motivation. Students should be taught to adopt healthy living habits, including warm-up and cool-down exercises, regular physical exercise, sufficient breaks, and sleep as the cornerstones of healthy musical practice.

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REFERENCES


Lobinger, B., Klämpfl, M., Altenmüller, E., 2014. We are able, we intend, we act—but we do not succeed: a theoretical framework for a better understanding of paradoxical performance in sports. J. Clin. Sport Psychol. in press.


