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In plain language:

This article describes an amateur musician's retention of piano playing skills following a severe stroke. Emerging evidence of music-induced neuroplasticity and the potential neuro-protective role of musical skills is outlined to support the discussion of a musical recovery bias in this single case. Music therapy is relatively well established within traditional neurorehabilitation models and this article proposes to expand on this knowledge by considering the importance of rehabilitating musical skills within the model of functional rehabilitation.

Clinical reflection

Musical expertise as a consideration for post-stroke rehabilitation: A retrospective clinical case example

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Abstract

Functional areas addressed within a best practice multidisciplinary rehabilitation framework typically encapsulate mobility, communication and activities of daily living for stroke survivors. Traditionally reported rehabilitative music therapy interventions contribute to this functional model. This retrospective clinical case describes the retention of musical skills following a severe diffuse bilateral stroke and explores the value of rehabilitating musical skills as a target for functional rehabilitation, in an individual with pre-morbid musical expertise. This case illuminates the concept of a musical recovery bias in a stroke survivor and presents an argument for the consideration of musical skills as an important focus for individuals with pre-morbid musical expertise.

Key Words: pianist, stroke, neurorehabilitation, music therapy

Background

Rehabilitation following stroke. Stroke is an acute neurological event, resulting from a disruption of blood flow, that causes the death of brain tissue. Despite medical advances, stroke remains a leading cause of death and disability worldwide (Warlow et al., 2008). Recovery from stroke is a complex heterogeneous process with several factors impacting rehabilitative potential, including the type and location of the stroke, the volume of brain tissue damaged, and the pre-morbid

health and functioning of the stroke survivor (Warlow et al., 2008).

Rehabilitation following stroke is broadly defined as treatment or therapies that maximise an individual's capacity to "achieve and maintain optimal functioning" within their current health status and lifestyle choices (Gutenbrunner, 2011, p. 768). Evidence supports that rehabilitative therapies should commence as early as medically possible following stroke onset as early response and recovery are considered prognostic for long-term rehabilitative potential (Bernhardt, Chan, Nicola, & Collier, 2007; Paolucci et al., 1998). Current adult rehabilitation practices aim to maximise daily functioning and quality of life (Gutenbrunner, 2011). Recovery of mobility, communication and activities of daily living

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(ADLs) account for approximately 75% of functional goals targeted by multidisciplinary teams during inpatient rehabilitation (Plant & Tyson, 2018).

Music therapy in neurological recovery.

Currently, the vast majority of reported music therapy services in stroke rehabilitation use musical interventions to positively contribute to the rehabilitation of the functional, non-musical areas described above (Magee, Clark, Tamplin, & Bradt, 2017). In this context, many music therapy interventions, including Neurologic Music Therapy (NMT) methods, are supported by the current evidence describing the neurological processing of music in musically untrained individuals and the relationship between musical and non-musical functions (Särkämö, Tervaniemi, & Huotilainen, 2013; Thaut, 2005). More specifically, as a complex auditory stimulus, music is made up of many components (pitch, timbre, harmony, melody, rhythm, etc.) that are perceived as a complex whole. The perception and production of music activates a complex global network of cortical and subcortical neural regions (Altenmüller & Schlaug, 2013; Koelsch, 2009; Peretz & Zatorre, 2005) including neural areas also responsible for emotional, motor, memory, speech and language functions. The extensive nature of the musical neural network strongly suggests the potential for retention of basic musical functionality, even in the presence of significant brain damage following a neurological event such as stroke (Gentle, Barker, & Bower, 2015). The ability to meaningfully process music, and the vast neural activation stimulated by this processing, is not reliant on musical expertise or systematic musical training (Herholz & Zatorre, 2012).

Targeted music therapy methods have been found to improve functional recovery for

individuals with various brain injuries, including stroke. In a recent Cochrane Review, Magee and colleagues reported that music and music therapy interventions may be directly beneficial for gait rehabilitation, communication rehabilitation and quality of life (Magee et al., 2017). However, evidence supporting the positive role and mechanisms of music in rehabilitation of cognitive skills such as attention and memory is still under-researched and poorly understood compared to physical and speech counterparts (Magee et al., 2017). The music therapy interventions included in this review targeted the functional areas of recovery that Plant and Tyson (2018) reported make up the majority of inpatient rehabilitation goals. Positive outcomes following participation in music therapy are not thought to be dependent on pre-morbid musical expertise. Indeed, limited exploration of the role of pre-morbid musical expertise is presented in the current literature that explores the rehabilitative potential of music for individuals who sustain a neurological insult, including stroke.

Music as a neuro-protective factor following stroke. Learning to play a musical instrument proficiently may be one of the most neurologically demanding tasks a human being can undertake (Altenmüller & Schneider, 2009), and instrumental training has been shown to result in structural changes in the brains of musicians when compared to non-musicians (Herholz & Zatorre, 2012; Merrett, Peretz, & Wilson, 2013; Schlaug & Chen, 2001). For example, the anterior corpus callosum has been found to be larger in pianists. The corpus callosum is a vital communication pathway that connects the two hemispheres of the brain and is essential in the successful execution of bimanual motor tasks like playing the piano. It has been suggested that an increase in the size of the corpus

callosum may lead to greater inter-hemispheric communication in musicians, particularly in those who commenced instrumental training from childhood (Münste, Altenmüller, & Jäncke, 2002). Structural differences in musicians have also been observed in many other areas of the brain, with increased grey matter volumes compared to non-musicians seen in the primary motor cortices, auditory cortices, premotor and cerebellar cortices in addition to frontotemporal white matter connections (Omigie & Samson, 2014; Schlaug & Chen, 2001).

Although still in the early stages of investigation, the neuroplastic changes seen in musicians (particularly instrumentalists), may influence non-musical cognitive and motor functions (Omigie & Samson, 2014). In adults, the neuro-anatomical differences seen in musicians overlap with neural areas associated with higher cognitive processes including language, memory, attention, planning and problem-solving (Moreno & Bidelman, 2014; Tervaniemi, 2017). It has been hypothesised that the neuro-anatomical changes seen in individuals with a long history of musical exposure and practice creates a greater chance of preserved substrates, connectivity and corresponding behavioural/cognitive functions following neural damage (Omigie & Samson, 2014). As the musical brain is adept at recruiting a widespread network of neural functions, this may also result in increased availability to recruit alternate functional pathways following localised damage to neural tissue (Omigie & Samson, 2014). In short, there is a growing body of compelling evidence to suggest musical training represents a neuro-protective

factor for increased recovery potential following adult brain injury, including stroke.

Music therapy addressing musical rehabilitation following stroke. It is the experience of the authors that the assessment and rehabilitation of musical skills following brain injury, in clinical music therapy practice in Australia, is an ancillary consideration compared to the rehabilitation of motor, speech and other non-musical capabilities in acute and sub-acute hospital settings. Given the body of emerging evidence supporting musical training as potentially neuro-protective for a range of functions following brain injury, the value of a thorough assessment of musical history and greater attention to musical functioning therapeutically as a way of promoting and aiding goal-based recovery cannot be underestimated.

The following retrospective clinical case study presents an early exploration of the value of assessing and rehabilitating musical, specifically instrumental, skills post stroke in an individual with pre-morbid musical expertise. Music therapy was utilised to access meaningful responses earlier in recovery than seen in other therapies, with musical skills being overtly used earlier in the recovery process compared to speech and complex motor skills. The clinical case offers an expanded understanding of how music may facilitate earlier access and therefore greater potential for recovery for both musical and non-musical functions.

Retrospective Case Study: Wendy

Wendy¹, a 63-year-old female, suffered a series of severe strokes following vascular surgery that was complicated by

¹ A pseudonym has been used. Patient, family and institutional consent was gained for publication of this case study.

intra-operative bleeding. Wendy was admitted to the intensive care unit (ICU) following surgery with a fluctuating consciousness. Electroencephalogram (EEG) performed on day 10 post-surgery revealed a non-convulsive status epilepticus, which is a state of continuous seizure associated with significant impairment and death. At that time, magnetic resonance imaging (MRI) showed multiple septic emboli (clots). Wendy remained in the ICU for three weeks before being admitted to an acute general medical ward for another three weeks with a continuing state of decreased consciousness. Imaging studies at this stage revealed an emergent complex neurological insult that resulted in lasting periventricular white matter changes (reduced connectivity). There were multiple areas of cell death (infarct) throughout her cortical and subcortical neurons (grey matter), particularly in the frontal lobes and noticeably in the right hemisphere. Significant areas of infarct were also noted in Wendy's left parietotemporal white matter. These imaging results indicated a significant global brain injury, with damage seen in bilateral cortical and subcortical regions of Wendy's brain. Following medical and conscious state improvements, Wendy was transferred to an inpatient sub-acute specialist neurorehabilitation ward.

On admission to the sub-acute rehabilitation facility, Wendy remained grossly functionally impaired. Her awareness, responsiveness, speech and motor skills were extremely impaired; she had a dense left hemiparesis (paralysis on one side of the body) and was minimally responsive to external stimuli. Wendy's treating team were concerned about her potential for meaningful recovery due to the length of time that had elapsed since stroke onset and her limited responsiveness at that time point.

Music therapy program. Music therapy interventions commenced on Day 10 of Wendy's admission to the sub-acute neurorehabilitation ward (Day 52 post stroke onset). Wendy was referred to music therapy because of her low-responsive state with the goal of eliciting repeated, meaningful, cortically mediated responses to stimulate early cognitive recovery. Musical background information was gathered from Wendy's family before the initial music therapy contact. Wendy came from a musical family where both her grandmother and mother were proficient pianists. Wendy received formal piano lessons between 8-15 years of age. Wendy continued to play the piano for leisure almost daily throughout her adult life. Her musical preferences included classical music and hymns.

Wendy received 2-3 music therapy sessions per week of 30-60 minutes duration, facilitated by an experienced registered music therapist (RMT) who has additional training in NMT. The primary music therapy methods used are briefly described below and were clinically selected to maximise functional recovery while supporting Wendy's emerging musical capabilities.

Musical sensory orientation training. Musical sensory orientation training (MSOT) is an NMT technique that utilises live or recorded music to stimulate arousal, orientation and facilitate meaningful response (Thaut & Hoemberg, 2014). As consciousness improves, MSOT may include engagement in simple musical exercises to increase basic attention. In this case, a full-sized keyboard was introduced for stimulating awareness and intentional responses, as it was a pre-morbidly familiar musical instrument to Wendy.

Therapeutic singing. Therapeutic singing (TS) is an NMT technique that uses singing activities to facilitate the initiation and

articulation in speech in addition to improving function of the respiratory apparatus (Thaut & Hoemberg, 2014).

Oral motor and respiratory exercises. Oral motor and respiratory exercises (OMREX) is also an NMT method, and utilises vocal exercise and the playing of wind instruments to increase the strength of the musculature required for speech.

Therapeutic instrumental music performance. Therapeutic instrumental music performance (TIMP) is an NMT technique in which the playing of musical instruments is utilised to simulate functional (non-musical) movement patterns. Musical instruments may be frequently utilised in non-traditional ways to facilitate motor rehabilitation including range of motion, strength, endurance and coordination (Thaut & Hoemberg, 2014).

Table 1 below presents the timeline of Wendy's inpatient recovery, primary music therapy interventions utilised to support functional rehabilitation, and progress during the music therapy program.

Outcomes

As outlined in Table 1, Wendy's music therapy program portrays a use of music therapy interventions to address non-musical domains of functional recovery over 15 weeks. This aligned with the rehabilitation goals developed by the multidisciplinary team. Throughout weeks 2–6 pre-morbidly familiar songs were sung by the RMT with a simple guitar accompaniment, a standard application of MSOT to increase arousal and awareness in an individual presenting with limited behavioural responses to external stimulation. A simple homophonic musical texture was initially used as it was determined by the RMT to be less demanding for Wendy's emerging cognitive processes. As Wendy's recovery and rehabilitation

progressed and she was observed to be increasingly responsive, she was encouraged to more actively engage in the MSOT interventions through singing along or playing hand-held percussion instruments.

Two significant and unexpected outcomes occurred during Wendy's inpatient rehabilitation. The first occurred in Week 5 when her preserved ability to play the piano became evident. Wendy was assisted in her wheelchair to sit in front of an electronic piano as part of the extended MSOT intervention to address her emerging arousal and awareness. She was verbally encouraged to play and was able to play a culturally well-recognised Christmas carol that was suggested by the RMT. She played from memory with her right hand only, as at this stage of her recovery her left hand remained significantly affected by hemiparesis. Initially she played the song tentatively, with a large number of melodic errors. However, she was able to self-correct these errors, demonstrating awareness, insight and adaptive learning skills and during this single session she progressed to playing 'Jingle Bells', 'Silent Night' and 'Away in a Manger' with her right hand. Wendy further demonstrated the ability to *play by ear* when the RMT sang a melody and she was able to reproduce this melody on the electronic piano. In doing this, she demonstrated preserved musical functioning including relative pitch and rhythm. Wendy also demonstrated skills in audiation, which is being able to hear and comprehend music mentally. Wendy's piano playing ability improved in accuracy during the following weeks and, as she progressed, she was encouraged to self-generate songs to play rather than always playing the songs suggested by the RMT. She was able to generate the musical information required to play songs that had been pre-morbidly familiar, not just songs that had been played

Table 1.

Timeline of Wendy's inpatient music therapy program and recovery during the same time period

Time (Sub-acute admission)	Documented functional recovery	Music therapy interventions	Progress in music therapy
Weeks 1–3 (7–8 weeks post stroke onset)	<ul style="list-style-type: none"> ▪ Nil eye contact ▪ Nil verbal/gestural communication ▪ Inconsistently attending to objects in left visual field ▪ Used comb appropriately in therapy 	MSOT	<ul style="list-style-type: none"> ▪ Non-verbal ▪ No observed behavioural response to familiar music
Week 4	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Writing with inconsistent legibility ▪ Able to write yes/no responses 	MSOT	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Increased eye contact ▪ Cried when listening to a pre-morbidly familiar song
Weeks 5–6	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Writing with inconsistent legibility ▪ Demonstrated basic comprehension when writing 	MSOT	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Played songs suggested by RMT on piano, from memory (right hand only) ▪ Improved accuracy of songs with repetition ▪ Perseveration evident in piano playing
Weeks 7–9	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Increased attention span in therapies ▪ Recalled important dates/events ▪ Increased complexity and legibility of writing 	MSOT	<ul style="list-style-type: none"> ▪ Non-verbal ▪ Initiated playing of variety of different songs on piano ▪ Able to write song titles of the songs played
Week 9	<ul style="list-style-type: none"> ▪ Spontaneous return of speech – recited a prayer ▪ Verbally answering open-ended questions (e.g. name, address) ▪ Following two-stage commands ▪ ++ response time for verbal instructions ▪ Limited verbal initiation 	MSOT TS	<ul style="list-style-type: none"> ▪ Singing familiar songs ▪ Increased volume during singing compared to speaking ▪ Continued improved accuracy of songs on piano with repetition ▪ Decreased response time for instructions related to piano playing compared to ADLs
Weeks 10–15 Discharge from sub-acute facility	<ul style="list-style-type: none"> ▪ Significant improvement in ADLs (dressing, showering, etc.) ▪ Improved movement and strength of left upper limb ▪ Increased initiation and engagement in conversation 	TS TIMP OMREX	<ul style="list-style-type: none"> ▪ Improved left upper limb strength. Able to play drum independently with bilateral arm/hand movements ▪ Increased voice volume and articulation accuracy during singing

during previous music therapy sessions, for example playing Haydn's 'Surprise Symphony - No. 94' during one of her final music therapy sessions. This ability to play pre-morbidly familiar songs indicated a notable retention of intact memory and motor functions. This retained musical ability was extremely unexpected given the severe nature of Wendy's brain injury.

A second surprising outcome of Wendy's recovery and rehabilitation was observed in Week 9 when Wendy's speech returned spontaneously while attending a familiar cultural event with her family. Following this, Wendy was able to verbally communicate in all contexts, although responding time was slow and her voice was very soft. TS was then introduced to facilitate and encourage verbal output with an increased volume and intelligibility of vocalisations. Pre-morbidly familiar songs were used with adjustments to tempo and pitch to match/scaffold Wendy's emerging abilities. OMREX was added to the music therapy sessions to further support Wendy's speech rehabilitation through increasing the strength of the muscles required for speaking. TIMP was utilised to support Wendy's emerging upper limb function, and incorporated simple grasping activities, progressing to a focus on more complex coordinated bilateral arm movements.

Discussion

Wendy was an amateur musician (pianist) who suffered a severe diffuse bilateral brain injury as a result of multiple strokes at the age of 63, with greater damage evident in her right hemisphere. Wendy's early functional recovery was minimal and she was initially given a poor prognosis. It was almost 10 weeks post stroke onset before Wendy consistently presented with a behavioural response to sensory stimulation, which

indicated awareness and some ability to organise a meaningful behavioural response. However, just one week later Wendy was able to play pre-morbidly familiar songs from memory on the piano, with her right hand, and she was observed to have retained complex musical skills despite her profound brain injury, hemiparesis, nonverbal presentation, very slow processing and poor motor skills. Music therapy began 52 days post stroke (Week 1 of the music therapy timeline reported above in Table 1) initially as standard practice to facilitate arousal and awareness, but it then became apparent that this was a key therapy in eliciting major functional changes and re-emergent skills, often before they were reliably present in other therapies. It may be described that Wendy displayed an obvious recovery bias towards her previous musical skills.

It should be noted that without functional brain imaging of Wendy's musical neural correlates, it is beyond the scope of this case to draw finite conclusions as to why Wendy's brain displayed such a strong bias towards musical recovery. However, based on existing evidence it is possible to hypothesise that Wendy's pre-morbid daily piano playing from childhood had resulted in protective neuroplastic changes compared to what could be expected in a non-musician (Omigie & Samson, 2014). While obviously not performing at her pre-morbid level, she was able to execute complex musical tasks despite being severely impaired in non-musical areas. Additionally, Wendy's return to musical functioning was observed to precede return of functioning in non-musical domains. Again, it is beyond the scope of this article to postulate the recovery relationship between her neurological musical and non-musical functions, however this finding does add greater weighting to Omigie and Samson's

(2014) hypothesis that musical expertise may result in an increased likelihood of retained function and enhanced recovery following brain injury via increased capacity for alternate neural pathways to functionality. It may be possible that Wendy's pre-morbid musicality and her engagement in keyboard playing post stroke stimulated her brain to recruit alternate intact neural pathways to access language, motor and other cognitive skills (Omigie & Samson, 2014).

Post discharge from the rehabilitation facility, Wendy did not continue with music therapy in the community. However, Wendy's remarkable response to music therapy in the early stages of recovery through to discharge raised questions about the ongoing role of music in the chronic phase of stroke recovery (6+ months post stroke) to maintain skill recovery. Given that current evidence supports: a) beneficial brain changes through participation in enriched environments in late stage recovery following stroke (Janssen et al., 2012), b) neuroprotective music-induced brain changes in musicians (Omigie & Samson, 2014), and c) potential positive effects of musical training on recovery of other cognitive functions (Merrett et al., 2013), it is worth considering a music education aligned model of long-term rehabilitation as a unique opportunity to stimulate the brain in alternative ways to achieve greater functioning, not just in musical abilities, but across the spectrum of human functioning.

Conclusion

Rehabilitative therapies post stroke target the restoration and compensation of function (Gutenbrunner, 2011), typically in the motor and communicative domains (Plant & Tyson, 2018). For individuals with pre-morbid musical expertise, it is becoming increasingly

apparent that the assessment and rehabilitation of musical skills should be considered a priority. Music therapists working with individuals with acquired neurological conditions who have pre-morbid musical experience should be mindful of cases like Wendy in their approach to therapy and expectations/goals for recovery. Wendy's recovery bias towards musical functioning highlights the increased potential for pre-existing musical skills to be targeted as a gateway to access other functional skills. Further systematic exploration would add weight to this shift in clinical practice. Finally, whilst an early exploration, this case points towards the need for a subtle expansion in the focus of rehabilitative music therapy interventions for stroke survivors, away from the sole use of music-based interventions in hospital to address non-musical recovery, and towards the utilisation of targeted music therapy interventions to address music as a unique and valuable recoverable skill both in hospital and throughout the recovery trajectory.

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