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# **Music for the ageing brain: Cognitive, emotional, social, and neural benefits of musical leisure activities in stroke and dementia**

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## **Abstract**

Music engages an extensive network of auditory, cognitive, motor, and emotional processing regions in the brain. Coupled with the fact that the emotional and cognitive impact of music is often well preserved in ageing and dementia, music is a powerful tool in the care and rehabilitation of many ageing-related neurological diseases. In addition to formal music therapy, there has been a growing interest in self- or caregiver-implemented musical leisure activities or hobbies as a widely applicable means to support psychological wellbeing in ageing and in neurological rehabilitation. This article reviews the currently existing evidence on the cognitive, emotional, and neural benefits of musical leisure activities in normal ageing as well as in the rehabilitation and care of two of the most common and ageing-related neurological diseases: stroke and dementia.

## **Keywords:**

Music, singing, ageing, rehabilitation, stroke, dementia

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## Introduction

Different musical activities, ranging from music listening to active musical participation through singing, playing an instrument, and dancing, have been an essential part of human culture across history. Today, musical leisure activities are widespread and common; in fact, most of us engage or interact with music on a daily basis in one way or another. For most of us, music is present throughout the individual life-span, ranging from early childhood to old age, and can serve a variety of functions and needs in everyday life, be they emotional, cognitive, motoric, or social in nature. A key feature underlying all aspects of musical activity is the ability of music to evoke and regulate emotions and to provide pleasure, comfort, and aesthetic fulfillment (Saarikallio, 2011; Sloboda & O'Neill, 2001; Zatorre & Salimpoor, 2013). During the past years, these subjective experiences of the emotional and cognitive impact of music have received increasing experimental and scientific support that music can indeed evoke strong and diverse emotions, mediated by the autonomic nervous system and the neuroendocrine system (Chanda & Levitin, 2013; Juslin & Västfjäll, 2008; Zentner, Grandjean, & Scherer, 2008). For the human brain, music arguably ranks among the most powerful and diverse sensory, motor, cognitive, and emotional experiences. Evidence accumulated in the past 20 years of neuroimaging studies indicates that music activates extremely complex and wide-spread, bilateral networks of cortical and subcortical areas that control many auditory, cognitive, sensory-motor, and emotional functions.

The initial perception of the *basic auditory features* of music (e.g. pitch, intensity, temporal variation) takes place along the ascending auditory pathway, from the inner ear to brain stem and thalamus, and projecting to the auditory cortex (Hall, Hart, & Johnsrude, 2003; Skoe & Kraus, 2010; Zatorre, Belin, & Penhune, 2002), as well directly to limbic areas, such as the amygdala and the medial orbitofrontal cortex (LeDoux, 2010). After this initial encoding stage, the analysis and perception of *higher-order musical features* or constructs (e.g., melody, harmony, interval structure) that are based on rule-based syntactic analysis of spectral and temporal fluctuation patterns within the sound stream occurs in a network comprising inferior and medial prefrontal areas, premotor areas, anterior and posterior superior temporal areas, and inferior parietal areas (Alluri et al., 2012; Janata et al., 2002; Patel, 2003; Patterson, Uppenkamp, Johnsrude, & Griffiths, 2002). The *rhythm or beat of music* is additionally processed by a network of motor regions comprising the frontal motor/premotor cortex as well as striatal and cerebellar regions (Bengtsson et al., 2009; Grahn & Rowe, 2009; Zatorre, Chen, & Penhune, 2007). Keeping track of music as it unfolds over time activates the *attention and working memory* system located in inferior and dorsolateral prefrontal cortex, cingulate cortex, and inferior parietal cortex (Janata, Tillmann, & Bharucha, 2002; Jerde, Childs, Handy, Nagode, & Pardo, 2011; Schulze, Zysset, Mueller, Friederici, & Koelsch, 2011).

Familiar music also strongly engages the *episodic memory system* spread over multiple regions in medial temporal (e.g., hippocampus), parietal (precuneus, angular gyrus), and frontal (dorsomedial and inferior prefrontal) lobe (Ford, Addis, & Giovanello, 2011; Janata, 2009; Platel, Baron, Desgranges, Bernard, & Eustache, 2003). Episodic memory refers to long-term memory for episodes of experience, including the storage and recall of sights, sounds, location, time, and other contextual information that define an event (Voss, Bridge, Cohen, & Walker, 2017). Finally, the emotional impact of music and the pleasure derived from music is closely linked to a network of many dopaminergic limbic/paralimbic areas, including various midbrain areas, nucleus accumbens, amygdala, hippocampus, cingulate cortex, and orbitofrontal cortex, which together form the *reward system* of the brain (Blood & Zatorre, 2001; Salimpoor, Benovoy, Larcher, Dagher, & Zatorre, 2011; Koelsch,

2014; Zatorre & Salimpoor, 2013). The familiarity and emotional impact of music appear to be closely intertwined: the emotion-related limbic and paralimbic regions and the reward circuitry have been observed to significantly more active for familiar relative to unfamiliar music (Pereira et al., 2011).

The fact that musical activities are not only rewarding and motivating but also engage and stimulate a wide-scale, distributed neural network that is closely linked to many neurochemical systems regulating emotions, arousal, and cognitive functions make music a very potent tool to use also in neurological rehabilitation. Given the rapid ageing of the world's population (WHO, 2011) and the increasing societal and economical burden brought about ageing-related sensory, cognitive, and motor decline (Olesen et al., 2012), there has been increasing interest in the potential of music-based interventions to promote brain and cognitive reserve and emotional well-being during normal ageing. Similarly, in response to the growing prevalence of many ageing-related severe neurological illnesses, such as stroke (Feigin et al., 2014) and dementia (Prince et al., 2013), many music-based neurological rehabilitation methods have been developed to enhance recovery or sustain functioning in the cognitive, motor, language, emotional, or social domain.

Broadly speaking, these music interventions can be classified either as *music therapy*, which is implemented by a trained music therapist and follows an established music therapy protocol, or as *other music-based interventions*, comprising musical activities implemented by other professionals (e.g. nursing staff), the patients themselves, or family caregivers. This review article focuses on the latter category and provides an overview of the current evidence for the effects of musical activities, such as music listening, singing, instrument playing, and dancing, on cognitive, emotional, and neural functioning in normal (healthy) ageing as well as in the care and rehabilitation of persons suffering from ageing-related neurological diseases, particularly stroke and dementia.

## Musical activities in healthy ageing

### *Emotional and social impact of musical activities*

Although the emotional and social impact of music in adolescence as a means for constructing the self-identity, forming interpersonal relationships, and dealing with stress and negative emotions is often emphasized, music continues to play an important role also in adulthood and old age as a way for regulating mood, evoking memories, maintaining self-esteem, competence, and independence as well as reducing feelings of loneliness and isolation (Hays & Minichiello, 2005; Saarikallio, 2011). This latter function is of paramount importance given that loneliness and low social participation are known to be associated with the development of dementia in longitudinal cohort studies (Kuiper et al., 2015). Music listening is a common, everyday leisure activity for older adults that is linked to positive emotions and contributes to psychological well-being (Laukka, 2007). In a large Canadian sample (N =318) of seniors aged 60-100, 70% of the seniors reported listening to music daily and, overall, music was rated as being very important in life (Cohen, Bailey, & Nilsson, 2002). Recently, also participatory group musical activities, especially community or choir singing, have received increasing interest as potential ways of maintaining health and psychological well-being in ageing (Cohen et al., 2006; Coulton, Clift, Skingley, & Rodriguez, 2015; Johnson et al., 2013; Skingley, Martin, & Clift, 2016)

Overall, questionnaire/interview studies and more recent experimental studies of healthy older adults participating in community choirs have linked choir singing to multiple psychosocial and health-related benefits, suggesting that regular choral singing can bring about enjoyment, cognitive stimulation, better physical and mental health, and increased social interaction. In a large-scale questionnaire study, Johnson et al. (2013) explored the relationship between self-perceived benefits of choir singing and quality of life (QOL) and depressive symptoms in 177 Finnish older adults who sang in community choirs. The older choral singers reported few symptoms of depression as well as high overall QOL and satisfaction with health, and there was a significant relationship between the self-perceived benefits of choral singing and better QOL in the psychological, social relationships, and environmental domain (Johnson et al., 2013). Similarly, in a non-randomized longitudinal study, Cohen et al. (2006) compared 90 older adults participating in a 30-week choir program with 76 control older adults over a 12-month follow-up and observed that choir singing was associated with better self-rating of health and morale, less loneliness, and higher level of activity.

Recently, the long-term efficacy of community singing has also been evaluated in a randomized controlled trial (RCT) in the UK. In the pioneering RCT, Coulton et al. (2015) followed a large group (N = 258) of healthy older adults, half of whom participated in 3-month community singing intervention, for six months using measures of QOL, mood, and health utility. The singing intervention had a long-term positive effect on health-related QOL as well as a short-term positive effect on mental health-related QOL, anxiety, and depression (Coulton et al., 2015). Overall, singing was reported to be more cost-effective than usual activities (Coulton et al., 2015). Also qualitative analysis of the subjective experiences of the participants in the trial provided converging results that the singing groups led to better physical, psychological, social, and community well-being (Skingley et al., 2016)

### *Cognitive and motor impact of musical activities*

By inducing positive affect and heightened arousal, exposure to music (often with fast tempo and in major mode) can temporarily enhance cognitive performance, also in elderly persons. Studies comparing the short-term effects of background music versus no music in older adults have reported an enhancement of performance on tasks of psychomotor speed (Bottiroli, Rosi, Russo, Vecchi, & Cavallini, 2014), verbal fluency (Thompson, Moulin, Hayre, & Jones, 2005), and episodic memory (Bottiroli et al., 2014; Ferreri et al., 2014) induced by the music. In contrast, one study reported that background music had a distractive effect on cognitive performance in a visual associative memory task in older adults (Reaves, Graham, Grahn, Rabannifard, & Duarte, 2016). Also the cognitive effects of regular musical activities have recently been the focus of active study. Elderly persons who have had long-term musical training earlier in life have been shown to have faster performance and neural timing in language tasks (Bidelman & Alain, 2015) as well as enhanced auditory attention (Zendel & Alain, 2014) and executive function, including working memory and cognitive control (Amer, Kalender, Hasher, Trehub, & Wong, 2013; Hanna-Pladdy & MacKay, 2011).

Similarly, instrumental musical training that takes place in old age has been observed to improve cognitive performance in various tasks in healthy seniors (age  $\geq$  60 years). Bugos et al. (Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007) randomized 31 older adults who had no previous musical training to a music intervention group receiving 6 months of individualized piano training or to a control group. Compared to the control group, the music group showed marked improvements on neurocognitive tests of attention, executive function, and processing speed (Trail Making Test, Digit Symbol test), both immediately after the training period and in a 3-month longitudinal follow-

up (Bugos et al., 2007). Similar results were also obtained by Seinfeld et al. (Seinfeld, Figueroa, Ortiz-Gil, & Sanchez-Vives, 2013) in a non-randomized study of 29 older adults: 4 months of piano lessons and daily training enhanced performance on an executive functions test measuring inhibitory control and divided attention (Stroop test) as well as reduced fatigue and improved QOL compared to a control group. In a recent within-subjects study of more intensive (30 hours, 3 hours per day) piano training in older adults, Bugos et al. found that older adults reported enhanced musical self-efficacy after the training, but no significant transfer was observed to general self-efficacy or to physiological measures of stress (cortisol) (Bugos, Kochar, & Maxfield, 2016).

In addition to piano training, also the impact of other music-based interventions focusing on music and movement have been explored in healthy seniors. In the two-arm RCT study of Hars et al. (Hars, Herrmann, Gold, Rizzoli, & Trombetti, 2014), 134 community-dwelling older adults who were at increased risk for falling received either a group-based music intervention involving different multitask exercises executed to the rhythm of music or no treatment for 6 months. The intervention group showed an improvement in tests of general cognition (MMSE) and in inhibitory control (one of the subtests of the Frontal Assessment Battery) as well as reduced self-reported anxiety (Hars et al., 2014). Kattenstroth et al. (Kattenstroth, Kalisch, Holt, Tegenthoff, & Dinse, 2013) investigated the multidomain efficacy of a 6-month weekly dance training program (Agilando™) developed for the elderly in 35 healthy older adults in a two-arm RCT study (dancing vs. no treatment control). The dance training improved performance on a broad range of test motor / cognitive measures, including posture, hand motor control, tactile processing, attention, memory, and processing speed, as well as increased subjective well-being. Importantly, the subjects who benefited most from the intervention were the ones with who lowest performance at baseline, suggesting that dancing could be applicable also to those elderly persons who are starting to show age-related cognitive or motor impairment.

Finally, the association between musical activity and cognitive wellbeing was found also in large prospective cohort study (N = 469) of persons ≥ 75 years by Verghese et al. (2003) that assessed the relationship between different leisure activities and risk of dementia. Along with reading and playing board games, playing musical instruments and dancing were reported to be the leisure activities that were specifically linked to a reduced dementia risk (Verghese et al., 2003). This pivotal finding was very recently followed up in a three-arm single-blind RCT study of 201 Japanese older (mean age 76 years) adults with mild cognitive impairment (MCI) which compared the cognitive effects of a dancing intervention (40 weeks, 1 hour per week) and a music intervention (playing musical instrument; 40 weeks, 1 hour per week) to a control group receiving only health education (N = 67 in each group). The results of this pioneering study showed that both dancing and music playing improved general cognition (MMSE) and that dancing had an additional positive effect on memory (Doi et al., 2017). No effects of tests of attention / executive function (Trail Making Test) were observed (Doi et al., 2017). Taken together, these findings suggest that musical leisure activities are clearly beneficial for seniors and can serve as an effective means to combat age-related cognitive decline.

## **Musical activities in ageing-related neurological diseases**

### *Musical activities in stroke*

Aesthetic and cultural leisure activities, such as listening to music or dancing, are important for stroke survivors, but unfortunately the patients are often not able to participate in these due to health issues

or inaccessibility of services (O'Connell, Cassidy, O'Neill, & Moss, 2013). Even in rehabilitation centres, stroke patients typically spend 50-70% of their daily time not engaged in therapeutic activities or social interaction (Bernhardt, Dewey, Thrift, & Donnan, 2004; De Wit et al., 2005), and many patients experience that their true rehabilitation needs are not properly met by the health care system (McKevitt et al., 2011). During the last 10 years, there has been growing interest in the application of musical activities to support cognitive, motor, and emotional recovery from stroke and to enhance brain plasticity during the recovery period.

Of different everyday musical activities, self-implemented music listening is perhaps most easily applicable in the rehabilitation setting. Särkämö and colleagues (Forsblom, Särkämö, Laitinen, & Tervaniemi, 2010; Särkämö et al., 2008, 2010, 2014a) performed a parallel-group RCT comparing the long-term effects of a 2-month daily music listening (min 1 hour per day) intervention to an audio book listening intervention and standard care (control group) in acute stroke patients (N = 60). Both the audio book and music material was self-selected and the listening was self-implemented with portable players, with the help of music therapists, family members, and nursing staff. The music material comprised mostly of songs with lyrics that were familiar to and preferred by the patients. Outcome was assessed using neuropsychological tests and mood questionnaires as well as auditory magnetoencephalography (MEG) measurements and structural magnetic resonance imaging (sMRI) performed at acute, 3-month, and 6-month post-stroke stages. In a 6-month follow-up, music listening was found to be superior to audio book listening and standard care in improving the recovery of verbal memory (story recall and auditory word-list learning) and focused attention (Stroop and mental subtraction) and reducing depression and confusion (Särkämö et al., 2008) as well as in increasing positive mood, relaxation, and motor activity (Forsblom et al., 2010). Using MEG, these behavioural gains induced by music listening were also linked functionally to enhanced neural efficiency of auditory encoding, as indexed by stronger mismatch negativity (MMN) responses (Särkämö et al., 2010). The MMN is a memory-related electrophysiological measure generated by a temporofrontal network of auditory change detection (Näätänen et al., 2011). Using voxel-based morphometry (VBM) analyses of sMRI data, music listening was also found to enhance structural neuroplasticity as indicated by increased grey matter volume in spared prefrontal (superior frontal gyrus) and limbic anterior cingulate, ventral striatum) regions (Särkämö et al., 2014a).

In addition to the generic effects of daily music listening, there are recent studies exploring also the use of music-based interventions specifically targeted towards the rehabilitation of different cognitive, language, and motor deficits caused by stroke. In two within-subjects studies (N = 3 and N = 19), listening to pleasant music during performance in standard visuospatial attention tasks (e.g., cancellation, line bisection) was reported to temporarily alleviate the leftward attentional bias associated with the **spatial neglect** syndrome compared to unpleasant music and no music conditions (Chen, Tsai, Huang, & Lin, 2013; Soto et al., 2009), most likely owing to the mood- and arousal-enhancing effect of enjoyable music. Similarly, also training with playing musical tone sequences (e.g. scales) on a keyboard or on small percussions pads in the horizontal (left-right) plane has been shown to reduce neglect in three within-subject case / group studies (Bernardi et al., 2017; Bodak, Malhotra, Bernardi, Cocchini, & Stewart, 2014; Guilbert, Clément, & Moroni, 2016). Notably, in the case study of Guilbert et al. (2016), which contained a longitudinal follow-up, the training-induced gains were maintained 4 months after the training had ended.

Another music playing-based intervention is the *Music-Supported Training* (MST), in which stroke patients train both gross and fine movement of the hemiparetic upper extremity by playing keyboard

(MIDI piano) and electronic drum pads. In a two-arm RCT, Schneider et al. (Schneider, Münte, Rodríguez-Fornells, Sailer, & Altenmüller, 2010; Van Vugt, Ritter, Rollnik, & Altenmüller, 2014) studied 62 subacute stroke patients who received a 3-week intensive (5 sessions per week, 30 min per session) MST intervention and conventional physical therapy or only conventional physical therapy (control group). The MST group showed significant improvement in the speed, precision, and smoothness of fine and gross movements of the hemiparetic upper extremity in standard motor tests, compared to the conventional therapy control group as well as to a separate control group (N = 15) who received the same amount of constraint-induced movement therapy (CIT). Similar results on motor outcome were obtained also in Germany and Spain in three subsequent randomized or case-control studies of subacute stroke patients (N = 9-28; Van Vugt, Ritter, Rollnik, & Altenmüller, 2014; Grau-Sánchez et al., 2014) and chronic stroke patients (N = 20; Ripollés et al., 2016; Rodríguez-Fornells et al., 2012), together also with the enhancement of attention, processing speed, and memory as well as positive effects on mood. In the brain, the behavioural motor gains were coupled with increased motor cortical excitability measured with transcranial magnetic stimulation (TMS) (Amengual et al., 2013; Grau-Sánchez et al., 2014) as well as improved connectivity and functioning of motor cortical areas as indexed by changes in event-related desynchronization / synchronization in electroencephalography (EEG) (Altenmüller, Marco-Pallares, Münte, & Schneider, 2009) and activity changes in functional MRI (fMRI) on motor and music listening tasks (Ripollés et al., 2016).

For **aphasic** stroke patients, *Melodic Intonation Therapy* (MIT) where the patient trains speech production through singing intonation and rhythmic tapping has been found to improve verbal expression in tests measuring continuous speech, repetition, and naming in case studies (2-3 patients; Schlaug, Marchina, & Norton, 2008; Zumbansen, Peretz, & Hébert, 2014) and in one small-scale (N = 27) two-arm cross-over RCT (van der Meulen, van de Sandt-Koenderman, Heijenbrok-Kal, Visch-Brink, & Ribbers, 2014). At the neural level, these gains have also been linked to enhanced activation of right hemisphere frontal speech-motor regions using fMRI (Schlaug et al., 2008) and to increased right frontotemporal structural connectivity, indexed by changes in the fractional anisotropy (FA) of the right arcuate fasciculus using diffusion tensor imaging (DTI; Wan, Zheng, Marchina, Norton, & Schlaug, 2014). In addition to aphasia, singing-based interventions have been used in **dysarthria**, a relatively common motor speech disorder after stroke, with two small within-subjects studies reporting benefits in speech motor coordination (e.g., respiration and articulation) and prosody (Kim & Jo, 2013) and in speech intelligibility and naturalness (Tamplin, 2008).

There has been increasing interest also in more group-based music interventions, which have the added value of being more widely applicable and involving a social interaction element compared to individual-based methods. The MST protocol has been reported to be equally effective motorically and emotionally when applied in individual and pair settings (Van Vugt et al., 2014). Also the effects of **choir singing** have recently been explored in three small pilot studies. Qualitatively, participating in a community choir is perceived by stroke and Parkinson's disease patients as helpful in the self-management of the social and emotional consequences caused by the illness, such as social isolation, low mood, and communication deficits (Fogg-Rogers et al., 2016). In a within-subjects questionnaire and interview study by Tamplin and colleagues (Tamplin, Baker, Jones, Way, & Lee, 2013), aphasic stroke patients (N = 13) reported reduced psychological distress and enhanced confidence, mood, motivation, and communication after participating weekly in a community choir for 20 weeks. Recently, in a pilot three-arm RCT of chronic aphasic patients (N = 23), Zumbansen et al. (2016) compared the effects of weekly choir and drama group interventions to standard care. While no significant outcome effects were observed for the interventions, the level of attendance to the social



activities was linked to improved functional communication, and the protocol was found to be feasible.

### *Musical activities in dementia*

Given the dramatically increasing prevalence of Alzheimer's disease (AD) and other dementia illnesses (Prince et al., 2013), there is a pressing need for effective ways to support cognitive, emotional, and social functioning in this population, both in persons with dementia (PWDs) and their family members and caregivers. Importantly, music-induced emotions and memories are often preserved even in more advanced stages of dementia (Cuddy, Sikka, & Vanstone, 2015), possibly owing to relative preservation of medial frontal and limbic areas in AD (Jacobsen et al., 2015), which enables the therapeutic use of music across the dementia spectrum, from mild cognitive impairment (MCI) to severe dementia.

Regarding the immediate effects of music in PWDs, pleasant and stimulating background music has been observed to temporarily reduce anxiety (Irish et al., 2006) as well as enhance awareness (Arroyo-Anlló, Díaz, & Gil, 2013) and cognitive performance in tasks of episodic (autobiographical) memory (El Haj, Fasotti, & Allain, 2012; Irish et al., 2006) and verbal fluency (Thompson et al., 2005). AD patients have also been shown to better recall verbal material presented in a musical (as song lyrics) vs. spoken context (Simmons-Stern, Budson, & Ally, 2010). In addition, there are a number of non-randomized and randomized intervention studies in PWDs (N = 8-68) with moderate-severe dementia residing in a long-term care facility that have assessed the emotional and social impact of caregiver-implemented musical leisure activities, primarily utilizing the listening of individualized (preferred) music, over a time period ranging from short (15-30 min) single sessions to multiple weeks. Using observational ratings, these studies have reported short-term beneficial effects of music on anxiety (Gerdner, 2005; Sung, Chang, & Lee, 2010), agitation (Garland, Beer, Eppingstall, & O'Connor, 2007; Remington, 2002; Ziv, Granot, Hai, Dassa, & Haimov, 2007), and positive social behaviors and interaction (Clair, 2002; Ziv et al., 2007). Notably, in one study, the playing of Baroque music on the background in a long-term dementia care unit was found to increase the number of observed behavioural disturbance episodes (e.g. agitation, aggressiveness) compared to a control period (Nair et al., 2011). There are also a few RCT studies reporting no significant benefits of musical activities on neuropsychiatric symptoms when compared to another control intervention (cooking; Narme et al., 2014) or to standard care (Raglio et al., 2015) in moderate-severe dementia. In summary, the evidence seems to suggest that exposure to music may have short-term (momentary) positive emotional and cognitive effects and that songs may function as a mnemonic aid in dementia, but overall the efficacy of musical activities on alleviating behavioural disturbances or neuropsychiatric symptoms in moderate-severe dementia remains inconclusive. Similar results were recently reported also on a meta-analysis of music therapy in dementia (van der Steen et al., 2017).

In addition to music intervention studies in more advanced dementia, there has recently been interest also in the efficacy of music in earlier stages of dementia. Särkämö and colleagues (Särkämö et al., 2014b, 2016a, 2016b) performed a parallel-group RCT in PWDs with mild-moderate dementia (N = 89) and their caregivers (family members and nurses) comparing the short- and long-term efficacy of two 10-week music interventions, which focused on coaching the caregivers of PWDs to use either regular singing or listening of familiar songs together with the PWD at home or care unit, to standard care. The music coaching intervention entailed identifying which songs were emotionally and autobiographically most important to the PWD and instructing the caregivers on how to utilize

music with the PWD in everyday life for different purposes (e.g., relaxation, reminiscence, and vitalization). Also regular musical “homework” were included in order to root the activity to the everyday home setting. Outcome was assessed using neuropsychological tests and mood and QOL questionnaires performed at baseline, after the intervention, and 6 months later. Both singing and music listening were found to help maintain general cognition (MMSE) and executive function and alleviate depression (Särkämö et al., 2014b). Singing, however, was more effective than music listening or standard care in enhancing working memory and episodic (autobiographical) memory, especially in PWDs who had mild dementia, as well as in reducing the psychological stress and burden experienced by the caregivers (Särkämö et al., 2014b, 2016a). The positive effects of music on depression were also more prominent in PWDs with mild AD-type dementia (Särkämö et al., 2016a), and there was a partly different pattern of emotional benefits in the two music interventions: music listening was more calming and relaxing (reducing agitation) whereas singing was more energizing and refreshing (reducing fatigue) compared to standard care (Särkämö et al., 2016b).

Regarding the cognitive effects of singing, converging results have recently been obtained in two non-RCT group studies. Maguire and others reported that 4 months of regular group singing, but not music listening, improved performance on tests of general cognition and visuospatial processing in PWDs (N = 45; Maguire, Wanschura, Battaglia, Howell, & Flinn, 2015). Similarly, Satoh et al. (2015) found that psychomotor speed and mood were improved in PWDs (N = 10) after a 6-month karaoke-based singing training program. Interestingly, these effects were coupled with decreased parietal activation in an fMRI karaoke task, suggestive of improved neural efficiency of cognitive processing (Satoh et al., 2015). Regarding the social perspective singing, a recent dyadic study of PWDs and their family carers (N = 10) participating in group singing together showed no significant effects of singing on standardized measures of cognition, mood, and QOL whereas engagement levels were very high and qualitative data showed strong positive effects on wellbeing (Camic, Williams, & Meeten, 2013). Another similar qualitative study (Unadkat, Camic, & Vella-Burrows, 2017) of PWD-caregiver couples (N = 17) also found that while PWDs and caregivers benefit from the singing activity independently (e.g., supporting identity and confidence in PWDs and providing enjoyment and liberation in caregivers), it also has a positive relational impact for them as a couple (e.g., enhancing togetherness).

## Concluding remarks

Based on the studies reviewed above, there is now emerging evidence that musical leisure activities or music-based interventions performed outside a formal music therapy context can have many potential benefits for cognitive, motor, emotional, and social functioning both in normal ageing and for elderly persons with debilitating neurological illnesses, including stroke and dementia. In summary, music listening has an enhancing effect on mood and arousal, which can temporarily improve cognitive performance in attention or memory tasks in healthy older adults as well as in stroke patients with neglect and in PWDs. Evidence from recent RCT studies also indicates that when music listening is done regularly and frequently, it can facilitate cognitive, emotional, and neural recovery after stroke and support cognitive functioning, mood, and QOL in mild-moderate dementia. Active musical hobbies, such as playing an instrument, singing, or dancing, have been shown enhance executive functions, mood, or QOL in healthy aged adults. As such, regular musical activities hold a lot of promise as a way to maintain better mood and QOL and offset the gradual cognitive and neural decline associated with normal ageing, potentially having a neuroprotective effect for

neurodegenerative diseases, but long-term evidence (with many years follow-up) for this is still lacking and more research is needed.

In stroke rehabilitation, active playing- or singing-based interventions have shown very promising effects for improving upper-extremity motor recovery, speech production, and mood, and have potential applications also in the rehabilitation of the neglect syndrome. In PWDs, the specific impact of musical activities seem to depend on the severity of dementia symptoms: while positive effects on neuropsychiatric symptoms, such as agitation, and social interaction are seen in more advanced (severe) dementia, the cognitive benefits of music, for example on working memory, are limited to singing-based group interventions in mild-moderate dementia. This suggests that the combination of cognitive, motor, and social stimulation provided by active music interventions could be important for slowing the progression of cognitive symptoms in the early stages of dementia, but, again, this claim needs to be put to test in large-scale longitudinal trials with a follow-up spanning many years. The recent RCT results of Doi et al., (2017) on the positive effects of dancing and instrument playing on cognitive functioning over 10 months in elderly persons with MCI provide an important first step in this direction.

Overall, although positive findings from individual small studies are converging to support the use of music in neurological care and rehabilitation, large and high-quality RCTs are still needed to build a more solid clinical evidence base and to establish the use of music more widely in the rehabilitation and care units. In addition to RCTs, which are often difficult to implement in practice due to their high cost, also methodologically rigorous non-RCT studies, such as long-term panel or cohort studies, on musical activities are needed. On a practical note, when designing a music intervention outcome study, especially in PWDs, it is important to carefully consider (i) what kind of music is actually used in the intervention (i.e., how well it matches the individual musical preferences of the participants), (ii) how the intervention is implemented (i.e., in which situations, how often and frequently, and by whom), (iii) using outcome measures that are standard, with established reliability and validity, and implemented by adequately trained persons who are blinded to group allocation, and (iv) including a sufficiently large sample size and long post-intervention follow-up to be able to establish robust and long-term effects of the intervention. In future studies, it would be valuable to report also the effect sizes or the Minimal Detectable Change (MDC) / Minimal Clinically Important Difference (MCID) values of the outcome measures in order to establish the practical clinical significance of the results. Moreover, there is also a call for clinical music intervention studies combining behavioural outcome measures with neurophysiological and –endocrinological markers as well as structural and functional neuroimaging methods that can better elucidate the neural mechanisms underlying the efficacy music and, eventually, help target the interventions at the individual level for different neurological disorders. In future, it would also be interesting to compare whether a specific music intervention that has a well-established protocol and that has shown efficacy in one neurological disorder, would be the applicable and effective also in other neurological disorders. For example, MST has successfully been used in motor stroke rehabilitation, but it could potentially have benefits also for the physical health and the emotional and cognitive wellbeing of PWDs. On the other hand, common musical activities that have multiple motor, cognitive, emotional, and social elements, such as group singing and dancing, are widely suitable across different neurological disorders.

## Conflicts of Interest

The author declares no Conflicts of Interest.

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