Chapter 6
How Music and Social Engagement Provides Healthy Aging and Prevents Behavioural and Psychological Symptoms of Dementia

Hanne Mette Ridder

Introduction

There is no direct link between aging and dementia, as dementia is a syndrome not caused by age itself; however, the risk of getting dementia increases with age. The way we age will, together with genetic factors, influence the development of pathological changes in the brain and also influence how the symptoms of these changes are expressed. This is explained by the theory of cognitive reserve and the understanding of how the internal brain stem regulation system empowers mental effort and social interactions in a way that challenges in a positive manner. With the release of norepinephrine, age-related brain deterioration is prevented and cognitive function maintained. Norepinephrine is a neurotransmitter released from the locus coeruleus and plays a role not only in social engagement and learning but also in the development of Alzheimer's disease. In the following chapter, I will present this theoretical perspective on sensory processing and brain stem functioning in order to understand why music plays such a remarkable role in healthy aging, in the prevention of dementia symptoms and in keeping the person with advanced dementia socially engaged.

Healthy Aging

Populations live longer around the world, regardless of living in high- or low-income countries. Longevity is a great opportunity for modern societies but only if the extra years are "worth" living for the person. Health problems in old age may be a consequence of chronic disease and lead to reduced well-being; however such

H. M. Ridder (✉)
Department of Communication and Psychology, Aalborg University, Aalborg, Denmark
e-mail: hanne@hum.aau.dk

L. O. Bonde, T. Theorell (eds.), *Music and Public Health*,
https://doi.org/10.1007/978-3-319-76240-1_6

problems may be prevented or delayed. We know that physical activity and the right diet brings health, but we still know too little about lifelong mental and cognitive health. According to the WHO (2015), healthy aging requires that the person remains active, autonomous and integrated. It also requires a "process of developing and maintaining the functional ability that enables well-being in older age" (p. 228). Functional ability is determined by environmental factors *and* the person's intrinsic capacity. Environmental factors include anything from policies, systems, services and technologies. Among these, social relationships and cultural and social values are mentioned. Intrinsic capacities are the "combination of all the individual's physical and mental capacities" (WHO 2016a, p. 4).

Putting healthy aging on the political agenda seems a burning issue, but at the same time, we must carefully consider and question how we achieve healthy aging in modern societies. On the one hand, age is often stigmatized, and we witness age-ism, anti-aging ideals and gerontophobia. On the other hand, what we understand as good health is highly subjective, and a top-down regulated system that forces restrictions to everyday living may not have the expected benefits or encompass what we understand as good living.

The key actions in developing healthy aging and age-friendly environments include fostering older persons' autonomy and enabling engagement according to the WHO 5-year global strategy and action plan (WHO 2016a, p. 7). The WHO highlights "integrated and person-centred approaches" and suggests that such approaches have better outcomes without being more expensive than traditional services (WHO 2015, p. 115). Continued personal growth is key when it comes to enabling older people to do what they value and to stay autonomous. Personal growth means continuing to learn and apply knowledge, engage in problem solving, be able to make choices and keep a sense of control (p. 174). In addition, social and emotional growth is imperative for how health is perceived. According to the WHO, social and emotional growth has the chance to increase with age *if* the population has opportunities to improve self-knowledge, self-regulation skills and social relationships over the years (p. 174).

Loneliness is linked with decreases in health status and quality of life; therefore reciprocal relationships are regarded as important for the person's sense of self-worth and as a motivator for continued social engagement (WHO 2015, 188). Consequently, it becomes increasingly important to maintain relationships. If we aim to meet the societal response to healthy aging, this requires "a transformation of health systems that moves away from disease-based curative models" and moves towards person-centred and integrated care (p. 223).

Growth and Cognitive Reserve

Introducing the concept of personal growth for the aged person is in line with the developmental psychologist Erik Erikson (Erikson and Erikson 1998) who described old age as a period to achieve integrity. Integrity contributes to wisdom and is opposed to stagnation and despair. In order to overcome and/or accept despair, the person must be able to interact with others without being absorbed in own needs but concerned and interested in matters beyond these. Erikson even coined the term gerotranscendence. Transcending "gero" (old age) involves soul and body and the surpassing of all human knowledge and experience; achieving this first of all demands honesty and humility (Erikson and Erikson 1998). In a Western society, *learning* has often been understood as processes relevant only in childhood and adolescence, with adults having "achieved" learning and therefore with difficulties in learning new skills. In fact, with age learning does take longer time, but at the same time, the old person may better store new learned knowledge as it will connect to consolidated learning from earlier experiences. This is what *wisdom* is about and described as a late-emerging mental strength (Goldberg 2005).

The general view on learning changed with the breakthrough research on adult neurogenesis in the end of the twentieth century. The belief that humans are born with a restrained quantity of neurons was rejected when it was discovered that neurons are reproduced throughout life in specific brain areas such as in the hippocampus (Eriksson et al. 1998; Kuhn et al. 1996). In the same time period, it was also discovered that the degree of brain pathology observed at autopsy did not explain the degree of clinical manifestation of Alzheimer's disease (AD). The term cognitive reserve was devised to explain why some persons with AD perform perfectly well in cognitive tests despite clear neuropathological markers of AD (Stern 2009). It is assumed that those who are able to perform in spite of severe damage have a better connected brain, with mechanisms able to reorganize around the AD pathology (Robertson 2013). Four of the most common elements to improve cognitive reserve are according to the neuropsychologist and stress researcher Ian Robertson (2013) education level, mental activity, social engagement and enriched/novel environments.

Norepinephrine, Locus Coeruleus and Arousal

The elements contributing to cognitive reserve (education, mental activity, social engagement and enriched environments) all have an upregulating effect on the norepinephrine (NE) system. NE, also called noradrenaline, is a neurotransmitter and neuromodulator produced in a small area in the brain stem called the locus coeruleus. Its pathways connect to multiple brain regions such as the cerebellum, the forebrain and the spinal cord and regulate mood, memory, hormones, cerebral blood flow and motor behaviour (Zillmer and Spiers 2001). As NE is depleted with age, upregulation of NE may not only increase attention and learning but also reduce the risk of AD. NE, therefore, "is a strong candidate for mediating the compensatory aspect of cognitive reserve" (Robertson 2013, p. 304).

Dysfunction in the locus coeruleus and NE system is described to cause abnormalities in arousal level, leading to psychiatric symptoms and psychosis (Yamamoto et al. 2014), attention-deficit/hyperactivity disorder and depression (Wilson et al. 2013), and accelerate physiological aging (Williamson et al. 2015). Negative stress may lead to dysfunction; however, positive stress has the opposite effect. When NE is released during arousing, mentally challenging or novel situations that are perceived as *positively exciting*, interesting and stimulating, neurons are protected from damage. This may explain how education and engaging careers prevent or delay cognitive decline in aging and suggests that "cognitive challenges and physical exercise may be effective interventions throughout life that harness the anti-inflammatory and cell-protective qualities of NE to help to forestall cognitive decline and dementia" (Mather and Harley 2016, p. 224).

When a person experiences features of safety, this leads to autonomic reactions that promote "open receptivity with others" (Williamson et al. 2015, p. 4). A person's reactions to what is perceived as either threatening or safe are part of an evolutionary adaptive response in humans and activated prior to conscious awareness (Lanius et al. 2017; Porges 2009; Porges and Lewis 2010). This happens through a network of interconnected brain regions including the locus coeruleus. Consequently, by engaging in mental effort and social interactions in a way that challenges in a positive and safe way, the NE release will prevent age-related damage, maintain cognitive function for a longer time and open a window for social interaction.

Mental effort is according to Daniel Kahneman correlated with arousal and pupil size (Kahneman and Peavler 1969). Kahneman and his team used pupillary changes to investigate a wide range of psychological phenomena. When the pupils, the black spot in our eyes, widens (dilates) this is not only related to the brightness of what we see but also related to the difficulty or complexity of a task we are imagining or facing. As NE is regulating arousal levels, a relationship between the NE system, pupil size changes and human memory encoding is suggested (Hoffing and Aaron 2015). We may use this information to understand responses to music and how music may facilitate social interaction.

Dementia

When an older person experiences problems with remembering, comprehending, judging, thinking and learning, it has previously been regarded as a normal part of the aging process and that becoming "senile" is what all old people may expect. However, dementia is now regarded as not being a part of normal aging but caused by a range of different diseases (e.g. Alzheimer's disease) that leads to pathological changes and cell death in brain tissue. Although we know much more about dementia diseases, modern health care still struggles to provide integrated and person-centred care that allows for autonomy, engagement and personal growth. According to the WHO (2016b), persons with dementia are often denied basic rights and freedom, e.g. with physical and chemical restraints used extensively in care facilities.

Sensory Decline

The pathological changes in the brain due to dementia do not only affect how the person performs intellectually or bodily but in all aspects of performing in daily life, therefore, also in how the person senses. Sense perception is the process of "knowing" and begins with arousal and orientation and then sensation and finally perception (Zillmer and Spiers 2001). With sense perception, we organize, identify and interpret the sensory information and with the aim to understand where we are situated and what goes on in others, in ourselves and in the environment. Disturbed sensory processing makes it very challenging to understand sensory input and to make sense of situations and interactions.

Problems with sensation and perception may increase in normal aging, but is assumed to have accelerated progress in dementia. As an example, impaired auditory processing is observed to a larger degree in persons with AD than in a nonclinical population and may therefore be an early marker of AD (Daulatzai 2016). Sensory decline makes activities of daily living more challenging and may as a consequence inhibit the person in outgoing social activities. The consequences are often stress reactions or social isolation which may speed up the progression of dementia, leading to further cognitive decline. This is underlined by the fact that nursing home residents with dual sensory impairment (i.e. of concurrent vision and hearing) show greater cognitive decline over time compared to those without sensory impairment (Daulatzai 2016).

As an example, we may seek eye contact to be sure we are correctly understood or to be reassured. With visual impairment, we will miss such communicative signals, and we may more easily feel ignored or even rejected.

Behavioural and Psychological Symptoms of Dementia

To feel acknowledged is a need all human beings experience. According to dementia researcher Tom Kitwood (1997), such rudimentary needs are grounded in our evolutionary past and mediated by basic nervous system functioning. He defined a cluster of psychosocial needs (comfort, attachment, inclusion, occupation and identity) with all five needs coming together in the need for love. If the psychosocial needs are not met, the person with dementia will communicate them in other ways. With missing abilities to communicate and express oneself, the attempts to communicate needs may sometimes be difficult to understand for others. They may be misinterpreted and described as inappropriate or disturbing behaviour. It is difficult to define when such behavioural and psychological symptoms of dementia (BPSD) are caused by brain pathology or by communication related to psychosocial needs. BPSD is negatively associated with both patient and carer ratings of quality of life (Hurt et al. 2008). For future research regarding BPSD, it is recommended to focus on research on movement-based therapies, hands-on (touch) therapies and interventions provided during personal care routines and with these interventions tailored to balance individual arousal patterns (Kverno et al. 2009).

Eye Contact and Trust

Previously eye contact was described as important for feeling acknowledged, but for a person in a state of high arousal, direct eye contact may be perceived as a threat, and instead of bringing trust and resulting in meeting the psychosocial needs of the person, eye contact may lead to fight or flight responses (Lanius et al. 2017). This reminds us how important caregiver competences are. Caregivers must not only be able to understand when the person with dementia communicates psychosocial needs but also understand and accordingly react to their level of arousal. In one situation mutuality and eye contact help the person with dementia, in another, regulation and respectful distance.

Alzheimer's Disease and the Locus Coeruleus

Alzheimer's disease is the most common form of dementia. Certain patterns of protein deposition (amyloid and tau) are formed in the brain of persons with AD and progressively destroy neurons and the communication between them. These impairments have been observed to spread out from brain areas around the hippocampus. Hippocampus is a structure in the medial temporal lobe and plays a critical role in context-rich and context-free memory (Didic et al. 2011). Recent research, however, has shown that the locus coeruleus is particularly exposed to impairment and may be the first site exhibiting AD pathology (Mather and Harley 2016).

In order to understand the AD-related pathologic changes, scientists from Germany re-examined autopsy samples of tau protein from 2332 brains of persons from 1 to 100 years of age (Braak et al. 2011). They found abnormal tau already in childhood but did not see the negative influences of amyloid until later in life. All samples from individuals older than 40 years showed a pretangle stage with the changes developing from the locus coeruleus but still not yet leading to cell death. It seems such pretangle stage may last for decades, even five or more decades, with some samples from persons older than 90 years showing only a first stage of pathological neurofibrillary tangles. From this the researchers conclude that old age does not automatically lead to AD but that the pathologic development of tangles is "an uncommonly slowly progressive one that frequently extends into old age" (Braak et al. 2011, p. 967). This finding suggests that our efforts to prevent AD should maybe start already "during the first decades of life, by protecting caeruleus projection cells and/or preventing them from developing the pretangle material" (p. 968).

The locus coeruleus is described to be related to major depression in AD (Zweig et al. 1988) and aggressive behaviour (Herrmann et al. 2004). Herrmann and colleagues describe how NE is leading to sympathetic flight or fight response, and they carried out a review to examine pharmacological treatment of BPSD in AD. They found the study of the neurobiology of BPSD in AD fraught with methodological difficulties and only identified little research into the use of NE treatments for BPSD (Herrmann et al. 2004). In a recent publication, however, “the sensory hypothesis” is applied to explain how sensory decline promotes cognitive decline, leading to AD (Daulatzai 2016). Sensory stimulation of many different modalities activates the locus coeruleus and enhances NE. With this understanding as a starting point, it is relevant to examine if music, which may integrate auditory and other sensory stimulation, plays a role in healthy aging and in preventing AD and BPSD.

Music

According to the WHO (2015), continued personal growth is not only stimulated by employment or voluntary work but also by engagement in cultural and social activities. When people listen to music, it is mainly for regulating arousal and mood and for achieving self-awareness (Schäfer et al. 2013), whereas active involvement in music or musicking is described to play an important role for emotion regulation, identity formation, and engaging in cultural and social activities (DeNora 2000; Juslin and Sloboda 2010; Small 1998; Wigram et al. 2002). Several studies also point at music as a proponent for developing cognitive reserve and for preventing behavioural and psychological symptoms of dementia, which I will address in the following.

Listening to and Practicing Music

As described above, disturbed sensory processing may lead to difficulties in carrying out activities of daily living and/or to stress reactions, both leading to social isolation. In order to be able to socially engage in cultural activities, the processing of auditory stimuli plays a role. In a place with several people and lots of noise, it is challenging to focus on what you want to listen to and to ignore irrelevant sounds. Such complex listening abilities are better preserved in musicians, and musical training may therefore provide cognitive reserve (Alain et al. 2014; Fauvel et al. 2013; Seinfeld et al. 2013; Zendel and Alain 2012). This is in line with a study of 237 cognitively intact participants from whom self-reported formal musical training in early- to midlife was associated with improved late-life episodic and semantic memory performance. Intensive music training in early childhood leads to structural changes in the brain (Hyde et al. 2009) and is therefore regarded as a path to cognitive reserve (Gooding et al. 2014). The explanation could be that practicing music leads to better executive control later in life (Moussard et al. 2016).

It is complex to play music. As an example, pianists integrate the reading of music scores and movements of the fingers into an aesthetic and temporal context. This is very difficult in the beginning and demands lots of rehearsal, but with time, neural networks are stimulated and skills become implicit and can be performed with much less attention and effort (Bugos et al. 2007). In this way music may boost sensorimotor and cognitive functioning which suggests "the potential for music making as an interactive treatment or intervention for neurological and developmental disorders, as well as those associated with normal aging" (Wan and Schlaug 2010).

Music and singing facilitate learning and preservation of learned material in persons with AD, making music effective as a mnemonic technique (Palisson et al. 2015; Simmons-Stern et al. 2010). The benefits may play a role not only in the present moment but across the lifespan. Music training is described as an activity that modifies a hierarchy of brain structures, offering "distinct perceptual and cognitive benefits not observed with other forms of intense training or experience" (Moreno and Bidelman 2014, p. 94).

Dancing

Practicing a musical instrument involves movements of parts of the body in a temporal context, as does dancing. In a study by Porat et al. (2016), a group of participants with and without mild cognitive impairment (MCI) with a mean age of 70 years (ranging from 51 to 90 years) identified themselves as dancers ($n = 44$); they had engaged in either amateur dancing or formal dance training, some in their childhood, some still actively dancing. Cognitive tests and fMRI scans were compared with a group ($n = 43$) who reported having no dance experience. Although there were no significant differences between the groups in age, sex, education, or score on cognitive functioning, there was a higher proportion of persons with MCI between the nondancers. Further, the dancers performed better in learning and memory tasks and showed significant thinner cortical grey matter (Porat et al. 2016). These findings suggest that dance may provide cognitive reserve and correspond with a cohort study showing that leisure activities (reading, playing board games, playing musical instruments and dancing) reduce the risk of developing dementia (Verghese et al. 2003).

Music and Memory

Music is described as having the power to unlock memories and other cognitive capacities in AD (Clark and Warren 2015; Innes et al. 2017) and seems to involve distinct and task-dependent memory systems (Jacobsen et al. 2015). The network engaged in encoding musical memory is partly independent of other memory systems, and by comparing these brain areas with those affected by AD, researchers found the regions normally involved in musical memory encoding strikingly well preserved in AD (Jacobsen et al. 2015). Twin studies may in particular answer questions about music's cognitive reserve capacity, and in this context a study from Sweden is interesting as it compared those twins where only one played a musical instrument. After controlling for various demographic factors, the study showed that playing an instrument significantly decreases the risk of developing cognitive impairment and dementia, with a difference that seems to be due to music training and not only genetic factors (Balbag et al. 2014).

Music and Pupil Response

Pupil dilation may be an indicator of activation of the NE system and further to engagement and emotional response. Gingras et al. (2015) used an infrared optical eye-tracking system to explore music listening in nonmusicians ($n = 30$). The participants rated their level of arousal, pleasantness, tension and familiarity with the music while listening to short 6-second music excerpts. The study showed that arousal and tension ratings were significantly correlated with mean pupillary response, and that larger dilations were an indicator of music playing a greater role in life for the participant. Thus, if the level of arousal and tension in music listeners correlates with pupil dilation, the role of music in everyday living may be predicted through eye tracking, taking into account that "responses to music depend on characteristics of the listener as well as on the music itself" (Gingras et al. 2015, p. 9).

The role of listener preferences is confirmed by Laeng et al. (2016) who compared music-induced aesthetic "chill" responses with eye tracker measured pupil diameter during music listening ($n = 52$, mean age 32; range 21–59). They found that self-selected songs resulted in more chills than in songs selected by others and that pupil diameter mirrors intense responses to music (p. 172). Based on the pupillary responses, the researchers suggest a neuromodulatory role of the central NE system. This leads to the assumption that engagement in music not only is about the aesthetics of the music in itself but about the listener's relation to the music as well as individual preferences. Through their research in music chills, Laeng and colleagues describe the pupil as a mirror to music's soul, with the specific characteristics of music affecting listeners differently.

In summing up from this first part of the chapter, we may claim that engagement via positively challenging mental effort prevent age-related cognitive decline. This may explain why preferred music through the release of NE mediates healthy aging. With the upregulation of NE, music has a compensatory effect and may play a role in building up cognitive reserve and preventing symptoms of dementia.

Music and Social Engagement for Preventing BPSD

Among many other functions, music is described to play an important role for social engagement in older people or in dementia (Creech et al. 2013; Hallam et al. 2014; McDermott et al. 2014; Ridder 2011; Spiro 2010). Further, apart from having a preventive effect on cognition and dementia, music may reduce behavioural and psychological symptoms of dementia (Guzmán-García et al. 2013; Ridder et al. 2013; Särkämö et al. 2012; Sakamoto et al. 2013). In a meta-review of 34 music therapy studies, a significant effect of music therapy on disruptive behaviour and anxiety was found, as well as a positive trend for cognitive function (Zhang et al. 2017). An effect of music-based therapeutic interventions on BPSD was not confirmed in a recent Cochrane review, but an effect was confirmed for depression (van der Steen et al. 2017). Further, it was explained that “music therapists are specially qualified to work with individuals or groups of people, using music to try to help meet their physical, psychological and social needs” (p. 2).

As mentioned above music affects listeners differently according to personal preferences, and I therefore want to underline that there is no direct cause and effect relationship between music and reduction of BPSD. What I suggest here is a theoretical understanding of how social engagement, facilitated through music experiences, will allow for connecting with the person which enables meeting the psychosocial needs of the person. When psychosocial needs are met, those behavioural and psychological symptoms – understood as ways of communicating these needs – will diminish, leading to a reduction in ratings of BPSD.

For a person with dementia, the progressive loss of cognitive functions and disturbances of sensory processing impair the ability to understand and make sense of a situation and the intentions of a caregiver or others. For some persons with dementia, it becomes difficult to self-regulate and to feel acknowledged as a person. At an overall level, it becomes extremely challenging to remain active, autonomous and integrated. This affects quality of life and how health is perceived. For many, music could be a key to engage socially. This may be music experiences in the form of singing, dancing or playing instruments or expression through sounds. Or it may be through music listening by sharing emotional expressions inspired or stimulated from the music.

In a review of literature on human communication, Kraus and Slater (2016) explain how our modern languages and musical systems reflect human development in a world of sound (p. 84). Communication is a product of human cognitive abilities to make sense of sound and movements in order to construct a representation of what happens around us. Neurons adjust their firing to not only language but also to musical systems, making human brains innately wired with complex pattern detection mechanisms (p. 87). These mechanisms are present in newborns and seem to be preserved in dementia, although differently. Some persons with severe Alzheimer’s disease show fully normal musical abilities, whereas others show only partial preservation of the ability to perform musical tasks. For some, these abilities are lost (Vanstone and Cuddy 2010). Still, musical memory is surprisingly well preserved in many persons with AD (Jacobsen et al. 2015). For those individuals where the ability to enjoy and respond to music is still present, “this preservation could serve as an important avenue to enhanced quality of life for a group of people who have lost so many other abilities” (Vanstone and Cuddy 2010, p. 125). What may remain is the ability to tap into the inherent rhythms of music which may facilitate interpersonal synchrony (p. 97). This allows the person with dementia to predict what is coming next and to build social bonds. Such interpersonal synchrony is what communication is all about: "Words may scratch the surface, but sound can move us beyond words" (Kraus and Slater 2016, p. 97).

Conclusion

If interpersonal synchrony and the communicative sharing it fosters are meaningful to the person with dementia, we may expect the person to be mentally challenged in a positive way. The ability to relate to music is often preserved in persons with dementia, and this ability hereby provides an opportunity for social engagement. We may further expect this to affect brain stem systems, more specifically the locus coeruleus, and lead to the release of NE. Even if the person is not able to communicate verbally about the music experience or seems to have forgotten it shortly after due to severe dementia, this may explain why the confident and safe social interaction has a stabilizing function and the potential to positively affect overall health and well-being of the person and potentially lead to a reduction of BPSD. This understanding may help as an argument for promoting psychosocial care interventions integrating music activities, musical communication methods and music therapy. In addition, it may push our understanding of learning, calling for actions to integrate music and other engaging activities in our lives from early childhood. The preventive mechanisms from the positive influence on social engagement, education, mental activity and enriched environments contribute to promote good living, also in old age.

References

Alain, C., Zendel, B. R., Hutka, S., & Bidelman, G. M. (2014). Turning down the noise: The benefit of musical training on the aging auditory brain. *Hearing Research, 308*, 162–173. https://doi.org/10.1016/j.heares.2013.06.008.

Balbag, M. A., Pedersen, N. L., & Gatz, M. (2014). Playing a musical instrument as a protective factor against dementia and cognitive impairment: A population-based twin study. *International Journal of Alzheimer's Disease, 2014*, 1–7. https://doi.org/10.1155/2014/836748.

Braak, H., Thal, D. R., Ghebremedhin, E., & Del Tredici, K. (2011). Stages of the pathologic process in Alzheimer disease: Age categories from 1 to 100 years. *Journal of Neuropathology & Experimental Neurology, 70*(11), 960–969. https://doi.org/10.1097/NEN.0b013e318232a379.

Bugos, J. A., Perlstein, W. M., McCrae, C. S., Brophy, T. S., & Bedenbaugh, P. H. (2007). Individualized piano instruction enhances executive functioning and working memory in older adults. *Aging & Mental Health, 11*(4), 464–471. https://doi.org/10.1080/13607860601086504.

Clark, C. N., & Warren, J. D. (2015). Music, memory and mechanisms in Alzheimer's disease. *Brain, 138*(8), 2122–2125.

Creech, A., Hallam, S., Varvarigou, M., McQueen, H., & Gaunt, H. (2013). Active music making: A route to enhanced subjective well-being among older people. *Perspectives in Public Health, 133*(1), 36–43. https://doi.org/10.1177/1757913912466950.

Daulatzai, M. A. (2016). Dysfunctional sensory modalities, locus coeruleus, and basal forebrain: Early determinants that promote neuropathogenesis of cognitive and memory decline and Alzheimer's disease. *Neurotoxicity Research, 30*(3), 295–337. https://doi.org/10.1007/s12640-016-9643-3.

DeNora, T. (2000). *Music in everyday life*. Oxford: Oxford University Press.

Didic, M., Barbeau, E. J., Felician, O., Tramoni, E., Guedj, E., Poncet, M., & Ceccaldi, M. (2011). Which memory system is impaired first in Alzheimer's disease? *Journal of Alzheimer's Disease, 27*(1), 11–22. https://doi.org/10.3233/JAD-2011-110557.

Erikson, E. H., & Erikson, J. M. (1998). *The life cycle completed (extended version)*. New York: WW Norton & Company.

Eriksson, P. S., Perfilieva, E., Bjork-Eriksson, T., Alborn, A. M., Nordborg, C., Peterson, D. A., et al. (1998). Neurogenesis in the adult human hippocampus. *Nature Medicine, 4*(11), 1313–1317. https://doi.org/10.1038/3305.

Fauvel, B., Groussard, M., Eustache, F., Desgranges, B., & Platel, H. (2013). Neural implementation of musical expertise and cognitive transfers: Could they be promising in the framework of normal cognitive aging? *Frontiers in Human Neuroscience, 7*, 693. https://doi.org/10.3389/fnhum.2013.00693.

Gingras, B., Marin, M. M., Puig-Waldmüller, E., & Fitch, W. T. (2015). The eye is listening: Music-induced arousal and individual differences predict pupillary responses. *Frontiers in Human Neuroscience, 9*, 619. https://doi.org/10.3389/fnhum.2015.00619.

Goldberg, E. (2005). *The wisdom paradox: How your mind can grow stronger as your brain grows older. Library journal*. London: The Free Press.

Gooding, L. F., Abner, E. L., Jicha, G. A., Kryscio, R. J., & Schmitt, F. A. (2014). Musical training and late-life cognition. *American Journal of Alzheimer's Disease and Other Dementias, 29*(4), 333–343. https://doi.org/10.1177/1533317513517048.

Guzmán-García, A., Hughes, J. C., James, I. A., & Rochester, L. (2013). Dancing as a psychosocial intervention in care homes: A systematic review of the literature. *International Journal of Geriatric Psychiatry, 28*(9), 914–924. https://doi.org/10.1002/gps.3913.

Hallam, S., Creech, A., Varvarigou, M., McQueen, H., & Gaunt, H. (2014). Does active engagement in community music support the well-being of older people? *Arts & Health, 6*(2), 101–116. https://doi.org/10.1080/17533015.2013.809369.

Herrmann, N., Lanctôt, K. L., & Khan, L. R. (2004). The role of norepinephrine in the behavioral and psychological symptoms of dementia. *The Journal of Neuropsychiatry and Clinical Neurosciences, 16*(3), 261–276. https://doi.org/10.1176/appi.neuropsych.16.3.261.

Hoffing, R. C., & Aaron, R. S. (2015). Pupillometry as a glimpse into the neurochemical basis of human memory encoding Russell. *Journal of Cognitive Neuroscience*. 2*, 27*(4), 765–774.

Hurt, C., Bhattacharyya, S., Burns, A., Camus, V., Liperoti, R., Marriott, A., et al. (2008). Patient and caregiver perspectives of quality of life in dementia: An investigation of the relationship to behavioural and psychological symptoms in dementia. *Dementia and Geriatric Cognitive Disorders, 26*(2), 138–146. https://doi.org/10.1159/000149584.

Hyde, K. L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A. C., et al. (2009). Musical training shapes structural brain development. *The Journal of Neurosicence, 29*(10), 3019–3025. https://doi.org/10.1523/JNEUROSCI.5118-08.2009.

Innes, K. E., Selfe, T. K., Khalsa, D. S., & Kandati, S. (2017). Meditation and music improve memory and cognitive function in adults with subjective cognitive decline: A pilot randomized controlled trial. *Journal of Alzheimer's Disease, 56*, 899–916. https://doi.org/10.3233/JAD-160867.

Jacobsen, J. H., Stelzer, J., Fritz, T. H., Chételat, G., La Joie, R., & Turner, R. (2015). Why musical memory can be preserved in advanced Alzheimer's disease. *Brain, 138*(8), 2438–2450. https://doi.org/10.1093/brain/awv135.

Juslin, P. N., & Sloboda, J. A. (Eds.). (2010). *Handbook of music and emotion: Theory, research, applications*. Oxford: Oxford University Press.

Kahneman, D., & Peavler, W. S. (1969). Incentive effects and pupillary changes in association learning. *Journal of Experimental Psychology, 79*(2), 312–318. https://doi.org/10.1037/h0026912.

Kitwood, T. (1997). *Dementia reconsidered. The person comes first*. Buckingham: Open University Press.

Kraus, N., & Slater, J. (2016). Beyond words: How humans communicate through sound. *Annual Review of Psychology, 67*(1), 83–103. https://doi.org/10.1146/annurev-psych-122414-033318.

Kuhn, H. G., Dickinson-Anson, H., & Gage, F. H. (1996). Neurogenesis in the dentate gyrus of the adult rat: Age-related decrease of neuronal progenitor proliferation. *Journal of Neuroscience, 16*(6), 2027–2033.

Kverno, K. S., Black, B. S., Nolan, M. T., & Rabins, P. V. (2009). Research on treating neuropsychiatric symptoms of advanced dementia with non-pharmacological strategies, 1998–2008: A systematic literature review. *International Psychogeriatrics/IPA, 21*(5), 825–843. https://doi.org/10.1017/S1041610209990196.

Laeng, B., Eidet, L. M., Sulutvedt, U., & Panksepp, J. (2016). Music chills: The eye pupil as a mirror to music's soul. *Consciousness and Cognition, 44*, 161–178. https://doi.org/10.1016/j.concog.2016.07.009.

Lanius, R. A., Rabellino, D., Boyd, J. E., Harricharan, S., Frewen, P. A., & McKinnon, M. C. (2017). The innate alarm system in PTSD: Conscious and subconscious processing of threat. *Current Opinion in Psychology, 14*, 109–115. https://doi.org/10.1016/j.copsyc.2016.11.006.

Mather, M., & Harley, C. W. (2016). The locus coeruleus: Essential for maintaining cognitive function and the aging brain. *Trends in Cognitive Sciences, 20*(3), 214–226. https://doi.org/10.1016/j.tics.2016.01.001.

McDermott, O., Orrell, M., & Ridder, H. M. (2014). The importance of music for people with dementia: The perspectives of people with dementia, family carers, staff and music therapists. *Aging & Mental Health, 18*(6), 706–716. https://doi.org/10.1080/13607863.2013.875124.

Moreno, S., & Bidelman, G. M. (2014). Examining neural plasticity and cognitive benefit through the unique lens of musical training. *Hearing Research, 308*, 84–97. https://doi.org/10.1016/j.heares.2013.09.012.

Moussard, A., Bermudez, P., Alain, C., Tays, W., & Moreno, S. (2016). Life-long music practice and executive control in older adults: An event-related potential study. *Brain Research, 1642*, 146–153. https://doi.org/10.1016/j.brainres.2016.03.028.

Palisson, J., Roussel-Baclet, C., Maillet, D., Belin, C., Ankri, J., & Narme, P. (2015). Music enhances verbal episodic memory in Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 3395*, 1–15. https://doi.org/10.1080/13803395.2015.1026802.

Porat, S., Goukasian, N., Hwang, K. S., Zanto, T., Do, T., Pierce, J., et al. (2016). Dance experience and associations with cortical gray matter thickness in the aging population. *Dementia and Geriatric Cognitive Disorders Extra, 94704*, 508–517. https://doi.org/10.1159/000449130.

Porges, S. W. (2009). The polyvagal theory: New insights into adaptive reactions of the autonomic nervous system. *Cleveland Clinic Journal of Medicine, 76*(Suppl2), S86–S90. https://doi.org/10.3949/ccjm.76.s2.17.

Porges, S. W., & Lewis, G. F. (2010). The polyvagal hypothesis: Common mechanisms mediating autonomic regulation, vocalizations and listening. *Handbook of Mammalian Vocalization: An Integrative Neuroscience Approach, 19*, 255–264. https://doi.org/10.1016/B978-0-12-374593-4.00025-5.

Ridder, H. M. (2011). How can singing in music therapy influence social engagement for people with dementia. Insights from the polyvagal theory. In F. A. Baker & S. Uhlig (Eds.), *Voicework in music therapy. Research and practice* (pp. 130–146). London: Jessica Kingsley Publishers.

Ridder, H. M., Stige, B., Qvale, L. G., & Gold, C. (2013). Individual music therapy for agitation in dementia: An exploratory randomized controlled trial. *Aging & Mental Health, 17*(6), 667–678. https://doi.org/10.1080/13607863.2013.790926.

Robertson, I. H. (2013). A noradrenergic theory of cognitive reserve: Implications for Alzheimer's disease. *Neurobiology of Aging, 34*(1), 298–308. https://doi.org/10.1016/j.neurobiolaging.2012.05.019.

Sakamoto, M., Ando, H., & Tsutou, A. (2013). Comparing the effects of different individualized music interventions for elderly individuals with severe dementia. *International Psychogeriatrics/IPA, 25*(5), 775–784. https://doi.org/10.1017/S1041610212002256.

Särkämö, T., Laitinen, S., Tervaniemi, M., Numminen, A., Kurki, M., & Rantanen, P. (2012). Music, emotion, and dementia: Insight from neuroscientific and clinical research. *Music and Medicine, 4*(3), 153–162. https://doi.org/10.1177/1943862112445323.

Schäfer, T., Sedlmeier, P., Städtler, C., & Huron, D. (2013). The psychological functions of music listening. *Frontiers in Psychology, 4*, 511, 1–33. https://doi.org/10.3389/fpsyg.2013.00511.

Seinfeld, S., Figueroa, H., Ortiz-Gil, J., & Sanchez-Vives, M. V. (2013). Effects of music learning and piano practice on cognitive function, mood and quality of life in older adults. *Frontiers in Psychology, 4*, 810, 1–13. https://doi.org/10.3389/fpsyg.2013.00810.

Simmons-Stern, N. R., Budson, A. E., & Ally, B. A. (2010). Music as a memory enhancer in patients with Alzheimer's disease. *Neuropsychologia, 48*(10), 3164–3167. https://doi.org/10.1016/j.neuropsychologia.2010.04.033.Music.

Small, C. (1998). *Musicking: The meanings of performing and listening*. Middletown: Wesleyan University Press.

Spiro, N. (2010). Music and dementia: Observing effects and searching for underlying theories. *Aging & Mental Health, 14*(8), 891–899. https://doi.org/10.1080/13607863.2010.519328.

Stern, Y. (2009). Cognitive reserve. *Neuropsychologia, 47*(10), 2015–2028. https://doi.org/10.1016/j.neuropsychologia.2009.03.004.

van der Steen, J. T., van Soest-Poortvliet, M. C., van der Wouden, J. C., Bruinsma, M. S., Scholten, R. J. P. M., Vink, A. C. (2017). Music-based therapeutic interventions for people with dementia. *Cochrane Database of Systematic Reviews, 5*. No.: CD003477. https://doi.org/10.1002/14651858.CD003477.pub3.

Vanstone, A. D., & Cuddy, L. L. (2010). Musical memory in Alzheimer disease. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition, 17*(1), 108–128. https://doi.org/10.1080/13825580903042676.

Verghese, J., Lipton, R. B., Katz, M. J., Hall, C. B., Derby, C. A., Kuslansky, G., et al. (2003). Leisure activities and the risk of dementia in the elderly. *The New England Journal of Medicine, 348*, 2508–2516.

Wan, C. Y., & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist: A Review Journal Bringing Neurobiology, Neurology and Psychiatry, 16*(5), 566–577. https://doi.org/10.1177/1073858410377805.

WHO. (2015). *World Health Organization. World report on ageing and health*. Geneva: World Health Organization. Retrieved from http://apps.who.int/iris/bitstream/10665/186463/1/9789240694811_eng.pdf?ua=1.

WHO. (2016a). Global strategy and action plan on ageing and health (2016–2020). A framework for coordinated global action by the World Health Organization. Geneva: World Health Organization. Retrieved from http://www.who.int/ageing/GSAP-Summary-EN.pdf?ua=1.

WHO. (2016b). *World Health Organization. Fact Sheet*. Geneva: World Health Organization. Retrieved from http://www.who.int/mediacentre/factsheets/fs362/en/.

Wigram, T., Pedersen, I. N., & Bonde, L. O. (2002). *Comprehensive guide to music therapy*. London: Jessica Kingsley Publishers Ltd..

Williamson, J. B., Porges, E. C., Lamb, D. G., Porges, S. W. (2015). Maladaptive autonomic regulation in PTSD accelerates physiological aging. *Frontiers in Psychology*, *6*, 1571, 1–12. doi:https://doi.org/10.3389/fpsyg.2015.00571.

Wilson, R. S., Nag, S., Boyle, P. A., Hizel, L. P., Yu, L., Buchman, A. S., et al. (2013). Neural reserve, neuronal density in the locus ceruleus, and cognitive decline. *Neurology, 80*(13), 1202–1208. https://doi.org/10.1212/WNL.0b013e3182897103.

Yamamoto, K. I., Shinba, T., & Yoshii, M. (2014). Psychiatric symptoms of noradrenergic dysfunction: A pathophysiological view. *Psychiatry and Clinical Neurosciences, 68*(1), 1–20. https://doi.org/10.1111/pcn.12126.

Zendel, B. R., & Alain, C. (2012). Musicians experience less age-related decline in central auditory processing. *Psychology and Aging, 27*(2), 410–417. https://doi.org/10.1037/a0024816.

Zhang, Y., Cai, J., An, L., Hui, F., Ren, T., Ma, H., et al. (2017). Does music therapy enhance behavioral and cognitive function in elderly dementia patients? A systematic review and meta-analysis. *Ageing Research Reviews, 35*, 1–11. https://doi.org/10.1016/j.arr.2016.12.003.

Zillmer, E. A., & Spiers, M. V. (2001). *Principles of neuropsychology*. Belmont: Wadsworth. Thomson Learning.

Zweig, R. M., Ross, Y. I. T. C. A., Hedreen, S. J. C., Steele, C., Cardillo, M. J. E., Whitehouse, P. J., et al. (1988). The neuropathology of aminergic nuclei in Alzheimer's disease. *Annals of Neurology, 24*(2), 233–242.