Finding Memories Through Music and Movement in Cognitive Impairment

by

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Abstract

It is important to understand how rhythm and music affect movements of individuals with mild-to-moderate cognitive impairment (MCI) as music choice may provide an opportunity to enhance interactions through movement performance and behaviour. Current research has explored the potential therapeutic effects of personalized music on anxiety, emotion, and memory in this target population. However, it is not clear how moving to pre-recorded music may yield benefits in movement performance and behaviour to improve the lives of persons with mild-to-moderate cognitive impairment. Therefore, the present case series study investigated if and how movement performance and anxiety changed when individuals with mild-to-moderate cognitive impairment (*N*=3) moved to self-chosen versus researcher chosen music when performing a movement-based task on a tablet computer compared to age and sex matched control participants (*N*=13). There were two sessions, one week apart, including a familiarization and an experimental session. The pre-recorded music was selected from Apple Music with self-chosen music being selected by the participant/caregiver and researcher chosen music selected by the principal investigator. The researcher chose music was within 5 beats per minute of the self-chosen music song and within a genre they enjoy. Participants performed the same movement task in each music condition, in a counter-balanced order. The results of the study indicated that music choice may have not been a factor when it came to response time, variable error, and anxiety for both the MCI and control participants. Based on the Likert enjoyment levels and the lack of any difference between self and researcher chosen music conditions, music enjoyment appears to play a larger role than autonomy to improve performance. This finding contributes to our understanding of how music enjoyment may enhance interactions through improvements in movement and anxiety in persons with cognitive impairment. Future research should seek to understand the role music choice and enjoyment play in single and whole-body movements and how rhythm and entrainment may factor into movement performance.

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Introduction

There are 661,500 Canadians living with dementia and by 2050 this number is expected to rise to over 1,700,000, an almost triple increase (Alzheimer's Society of Canada, 2022). Alzheimer's disease (AD) is the most common form of dementia and may contribute to 60-70% of all dementia cases worldwide, with the number set to rise to 139 million by 2050 (World Health Organization, 2020). Music is a way to provide a unique and personally meaningful opportunity to connect with someone living with AD as well as have a profound effect on their behaviour and quality of life. Given the prevalence of dementia in society, the reported benefits of physical activity for cognition, and research showing how rhythm can help improve movement performance, the present study will try to understand how, when, and why music might benefit dementia patients (with a focus towards AD).

El Haj and colleagues (2015) reported poor production of self-defining memories, defined as events that are specific, vivid, affectively intense and include enduring concerns about oneself, in individuals with AD. The authors proposed improvement in memories might be achieved through exposure to self-chosen music. They found that persons with AD produced more self-defining memories during exposure to their own-chosen music than to researcher-chosen music or during silence (El Haj et al., 2015). In a related study, Gómez Gallego & Gómez García, (2017) had 42 patients with mild to moderate AD participate in music therapy for six weeks. Significant improvements were observed in memory, orientation, depression, and anxiety in both mild and moderate cases and in delirium, hallucinations, agitation, irritability, and language disorders in the group with moderate AD. In addition, the effects on cognitive measures were appreciable after only four music therapy sessions. Therefore, music combined with movement may help persons

with AD improve memory and overall health and well-being to flourish and thrive in their environment.

Preferred music is used in reminiscence therapy for individuals living with dementia. Reminiscence therapy is a nonpharmacological approach to try and increase active group participation, provide a safe place for persons with dementia to interact socially, to share their memories with other residents, and to improve their self-image (Ashida, 2000). It is thought that due to emotional ties, selecting preferred music one enjoys may better preserve memory in persons with dementia, even with declining cognitive function. Cheung and colleagues (2018), had 58 participants diagnosed with moderate dementia in a music-to-movement group (MM) listen to their own preferred music and move their limbs and trunk, twice a week for six weeks. Music-to-movement sessions were composed of 5 minutes of singing a greeting song, 20 minutes of MM activities including batting balloons, waving ribbons, foot tapping, playing musical instruments (i.e. hand bells, drums, triangles, etc.), and mimicking movements demonstrated by the interventionist and 5 minutes of singing a closing song (Cheung et al., 2018). This group was compared with a music listening group (ML) and a social activity (SA) group. Results demonstrated improvements in cognitive functions such as short-term memory (total storage and delayed memory variables) in the MM group and improvements of delayed memory and global cognitive function in the ML group from baseline to post-intervention follow-up. Overall, music with movement and listening to music without movement helped improve various cognitive components in moderate persons with dementia. These results may provide new opportunities for adults with dementia to interact in their environment to help improve cognition.

Besides the benefits of combining music with basic physical activities, forms of exercise such as walking have demonstrated improvements in working memory. Dance specifically has

shown developments in visuospatial learning, visuospatial delayed recall and executive function response inhibition (Merom et al., 2016). Dance is a challenging and stimulating activity that may prove to be important for persons with AD to enhance brain function. Research has shown that when healthy individuals (between the ages of 63-80 years of age) learn new and complex dance moves and choreographies, grey matter volume changes occur in the left precentral gyrus at 6 and 18 months and in the right parahippocampal gyrus at 18 months, which is key for cognitive memory function (Müller et al., 2017). Overall, dance creates challenge by engaging older adults in a constant state of learning that may keep controlled processing active (Rehfeld et al., 2018). The increased complexity may create higher demands on attention and memory processes, thus helping to promote improvements in brain structure (Müller et al., 2017; Rehfeld et al., 2018). While movement is often combined with music during both musical and many physical activities such as dance, the role of memory for specific music and how recall interacts with movement performance has not been studied.

Autonomy and enjoyment are two important areas to consider when looking at exercising choice in music selection and how music enjoyment may affect performance. Music has demonstrated improved enjoyment of sprint interval training (SIT) while enhancing acute exercise performance compared to no music (Stork et al., 2015). Specifically, perceived enjoyment has shown to be consistently higher and significantly increase overtime with the addition of music and may have the potential to improve adherence to exercise in the long term (Bartlett et al., 2011; Stork et al., 2015). Therefore, music enjoyment may have the capacity to improve movement performance. Although, music was selected by the individual to create a personalized music playlist during SIT training, which may have played a role in improved perceived enjoyment results overtime (Stork et al., 2015). Thus, exercising choice is an area of research that has been

reported in improving movement performance (Wulf & Lewthwaite, 2016; Ziv & Lidor, 2021). One additional point is not all participants had high motivational ratings of the music they selected compared to the no music condition (Stork et al., 2015). For future, it may be interesting to see if autonomy and enjoyment may differ during self-chosen versus researcher-chosen music conditions and how it affects movement performance.

Optimizing Performance Through Intrinsic Motivation and Attention for Learning (OPTIMAL) theory holds central roles for motivation and attention to direct learning and performance outcomes (McKay & Ste-Marie, 2022; Wulf & Lewthwaite, 2016). The theory proposes three primary factors that affect learning and performance including autonomy (provide learners with choices), expectancies (positive or negative consequences anticipated by the learner as a function of performing a skill), and attentional focus (directing one's attention externally on the intended effect of a movement compared to internally focusing on the body parts involved in the movement) (McKay & Ste-Marie, 2022; Wulf & Lewthwaite, 2016). Research has supported OPTIMAL theory when it comes to autonomy and its ability to improve movement performance (Wulf & Lewthwaite, 2016; Ziv & Lidor, 2021). Although research has also reported inconsistencies that can come with OPTIMAL theory suggesting that autonomy does not always improve movement performance (Bacelar et al., 2022; Carter & Ste-Marie, 2017; Leiker et al., 2019; McKay & Ste-Marie, 2020, 2022; St. Germain et al., 2022; Yantha, McKay, & Ste-Marie, 2022). Overall, researchers have reported both beneficial and no effects of autonomy in different motor learning settings. However, studying autonomy with mild-to-moderate cognitive impairment (MCI) patients to investigate how music choice and enjoyment may factor into a movement-based task has not been studied.

Music and rhythm have the potential to improve the accuracy and consistency of both reaching movements and whole-body movements. Whereas, motor sequence learning in older adults has shown that age-related decreases in working memory contribute to the age-related deficits in the initial acquisition of motor sequences (King et al., 2013). Given conscious recall and processing are impaired, including music specific to their interests may help individuals access non-conscious neural pathways for movement performance and ultimately enhance interactions with those around them. Given the potential benefits of music and autonomy, and the gap in the research literature related to autonomy and music selection, I investigated if adults with and without mild-to-moderate dementia show improvements in movement performance and anxiety when moving to self-chosen music compared to researcher-chosen music.

Literature Review

Dementia and Types

Dementia is an umbrella term for several diseases affecting behaviour (i.e. depression, agitation and anxiety), memory and other cognitive abilities to a degree that the decline interferes significantly with a person's ability to maintain their activities of daily living (Garrido et al., 2017; World Health Organization, 2020; Garrido et al., 2020). Currently, dementia is the seventh leading cause of death in the world and around 55 million people have dementia worldwide, with 10 million new cases developing each year and one new case occurring every three seconds (World Health Organization, 2020; Alzheimer Society of Manitoba, n.d.). By 2030, this number is set to rise to 78 million and by 2050, 139 million people are expected to be diagnosed with dementia (World Health Organization, 2020). It is one of the major causes of disability and dependency among older adults worldwide causing physical, psychological, social, and economic impact, not

only for people with dementia, but also on their caregivers, families, and society at large (World Health Organization, 2020).

Dementia is known to be progressive where symptoms gradually get worse as brain cells become damaged and eventually die. Different forms of dementia resemble Alzheimer's disease (AD) in that they also involve a progressive degeneration of brain cells that is currently irreversible including vascular dementia, frontotemporal dementia, Creutzfeldt-Jakob disease, Lewy body dementia, Huntington's disease, and Parkinson's disease.

There are three common progressions of dementia including early middle and late stages. For the purpose of my project, I focused on the early to middle stages of the disease. Early-stage dementia is often overlooked because the onset is gradual. The symptoms can include forgetfulness, losing track of the time, and becoming lost in familiar places (World Health Organization, 2020). In middle stage dementia the signs and symptoms become much clearer and more restricting, including becoming forgetful of recent events and people's names, becoming lost at home, having increasing difficulty with communication, needing help with personal care, and experiencing behaviour changes, including wandering and repeated questioning (World Health Organization, 2020). It is important to realize that dementia is not a specific disease, but a variety of diseases and injuries that primarily or secondarily affect the brain that can cause dementia (See Appendix A).

There are many underlying causes of dementia, and the most common form is AD, contributing to 60-80% of cases (Alzheimer Society of Canada, n.d.). AD causes symptoms that are irreversible such as memory loss, difficulty performing daily activities, and changes in judgement, reasoning, behaviour, and emotions (Alzheimer Society of Canada, n.d.). AD was first identified by Dr. Alois Alzheimer in 1906 (Hippius & Neundörfer, 2003) . It is known as a

progressive, degenerative brain disease where several changes occur. First the brain cells shrink, or disappear, and are replaced by dense, irregularly shaped plaques and existing brain cells get clogged with thread-like tangles, another indicator of the disease (Alzheimer's Society of Manitoba, n.d.). Dr. Alois Alzheimer defined plaques and tangles as the two hallmarks of the disease that differentiate AD from other forms of dementia (Hippius & Neundörfer, 2003). Overtime, these tangles will block healthy brain cells and shrinkage will take place thus affecting how the brain functions. Specifically, plaques are deposits of a protein called "beta amyloid" or A-beta and when they clump together in the brain, they form plaques, which prevent signals from being transferred between nerve cells in the brain, ultimately causing the cells to die, leading to cognitive decline (Alzheimer Society of Canada, n.d.). Whereas, tangles are fiber clumps of a protein called Tau, which can be seen as parallel railroad tracks within the brain where nutrients and other important materials travel along to keep brain cells alive (Alzheimer Society of Canada, n.d.). In healthy brain areas, tau proteins make sure the nutrients can reach their destination but in unhealthy brain areas, the tau protein collapses and twists, forming tangles that prevent nutrients from reaching brain cells, resulting in cell death (Alzheimer Society of Canada, n.d.).

Appendix A shows a diagram of an umbrella representing dementia and each fold of the umbrella represents a disorder that affects the brain causing the various dementia symptoms. Additionally, the handle of the umbrella is being held by the person diagnosed with a certain disorder affecting the brain, which in this case is AD that is bolded as an example. It has a double pointed arrow in either direction because an individual will already have the specific disease (i.e., AD) but will start by experiencing symptoms of dementia first and eventually will get diagnosed with a certain disorder that affects the brain from various tests/scans (i.e., AD). This double pointed arrow applies to the other common forms of dementia under the umbrella in Appendix A.

Other common forms of dementia include Lewy body dementia, frontotemporal dementia, young onset dementia, vascular dementia, mixed dementia, Creutzfeldt-Jakob disease, and mild cognitive impairment. Vascular dementia is a type of dementia caused by damage to the brain from a lack of blood flow or from bleeding in the brain. It can be a consequence of a stroke or cerebral small vessel disease (i.e., narrow or cause long-term damage to the blood vessels in the brain) (Alzheimer Society of Canada, n.d.). It is the second most common form of dementia behind AD. Mixed dementia is another common form and is considered a combination of vascular dementia and AD. On the other hand, mild cognitive impairment is a clinical condition where someone has problems with memory, language, thinking or judgement that are greater than what we would expect with normal aging (Alzheimer Society of Canada, n.d.). It is often, but not always, thought to be a transitional phase from cognitive changes of normal aging to those typically found in dementia (Petersen et al., 2014). There are two subtypes including amnestic mild cognitive impairment, where memory loss (specifically episodic memory) is the main symptom and it has a stronger association with AD as it has similar less severe brain changes (Petersen et al., 2014). The second subtype is non-amnestic mild cognitive impairment where memory is not the main problem. Instead, other thinking abilities such as organizing and planning, reasoning, learning or judgement may be affected as well as executive functions, language and visuospatial abilities (Petersen et al., 2014). Another common form of dementia is Lewy body dementia, which is characterized by abnormal deposits of a protein called alpha-synuclein that form inside the brain's nerve cells (Raz et al., 2016). These deposits are known as "Lewy bodies" and the formation of them is unknown. Also, this type of dementia can occur by itself, or together with AD or Parkinson's disease.

Another form of dementia is Frontotemporal dementia (FTD), which affects the frontal and temporal lobes in the brain. These brain areas are generally associated with personality, behaviour, emotions, language, speech, abstract thinking, and movement (Alzheimer Society of Canada, n.d.). There are different types of FTD including behavioural variant Frontotemporal Dementia (bvFTD), the most common form of FTD and is associated with early behavioural and executive deficits; non-fluent variant primary progressive aphasia, with progressive deficits in speech, grammar and word output; and semantic-variant primary progressive aphasia, which is a progressive disorder of semantic knowledge and naming (Bang et al., 2015).

Another type of dementia is Creutzfeldt-Jakob disease (CJD), which is a rare, fatal brain disease caused by an abnormal form of a substance called prion protein (Alzheimer Society of Canada, n.d.). In its normal form, prion protein is made by most body cells and does not cause disease but in its abnormal form it is toxic to brain cells and causes disease (Alzheimer Society of Canada, n.d.). It is worth mentioning that prion diseases are unique transmissible neurodegenerative diseases that have diverse phenotypes (Gambetti et al., 2003; Iwasaki, 2017). CJD can be sporadic, familial (i.e. genetic mutation), or acquired by infection (Gambetti et al., 2003; Iwasaki, 2017). The disease progresses rapidly and most people with CJD die within 6 months from when the illness began, and some can live up to a year but rarely longer.

Lastly, young onset dementia is another form of dementia where symptoms start before the age of 65 and accounts for 2-8% of all dementia cases (Alzheimer Society of Canada, n.d.). While it is rare, 28,000 Canadians under the age of 65 are living with it (Alzheimer Society of Canada, n.d.). The diagnosis is difficult, and it comes with its own unique challenges especially when people are diagnosed in their 40s or 50s. For the purpose of this study, young onset dementia, and CJD patients were excluded. These specific dementia subtypes were excluded because young onset

dementia does not fall within the requested age range (i.e., 60-85 years old) upon diagnosis, and CJD is quite complex, and dementia is not the only primary symptom.

Finally, dementia can also result as a secondary symptom from a variety of diseases or developmental disorders, including corticobasal degeneration, Huntington's disease, Multiple Sclerosis, Down Syndrome, Niemann-Pick disease type C, normal pressure hydrocephalus, Parkinson's disease, posterior cortical atrophy, progressive supranuclear palsy, traumatic brain injury, and Wernicke-Korsakoff syndrome. For the purpose of this study, dementia that is considered to be a secondary result of a disorder was also excluded. To summarize, the focus of the study was on individuals who have dementia as a primary symptom, such as those diagnosed with AD.

Dementia Pathophysiology

Alzheimer's disease (AD) is characterized by pathological cerebral changes that manifest in the fifth decade of life (additional detail can be found below). These pathological changes occur long before the first cognitive changes become apparent or structural atrophy can be objectified by MRI techniques (Jack et al., 2013, 2010; Toepper, 2017). The main pathological characteristics of AD within the cortex are the formation of extracellular plaques and intracellular neurofibrillary tangles, consisting of amyloid-ß peptides and hyperphosphorylated tau protein (Toepper, 2017). Specifically, there are three distinct abnormalities of the brain that take place.

First, the brain will become atrophied with narrowed gyri, widened sulci, reduced brain weight, and enlarged ventricles (Kandel et al., 2013). Additionally, both grey and white matter tissue types will atrophy in patients diagnosed with AD. Grey matter is unmyelinated neural tissue where information is processed and is also where the extracellular amyloid plaques and neurofibrillary tangles develop, the two hallmarks of AD (Nasrabady et al., 2018). White matter

is myelinated neural tissue (axons) that enable communication with other brain areas via neural tracts. The myelin sheath that encases the axon is crucial for increasing the speed of neural transmission. Studies with AD patients have reported that neuronal loss with the addition of white matter degeneration and demyelination may be important pathophysiological features in the risk and progression of the disease (Nasrabady et al., 2018). Specifically, white matter hyperintensities (WMH), which are commonly seen on brain MRI scans and are a consequence of cerebral small vessel disease (a contributor to vascular dementia), can cause cognitive decline by decreasing information processing speed. These changes may lead to executive dysfunction and ultimately, dementia (Prins & Scheltens, 2015). Additionally, radiological markers of white matter damage can occur as early as 22 years before the estimated age of symptom onset in humans who carry AD mutations (Lee et al., 2016; Nasrabady et al., 2018). These white matter changes are believed to reflect demyelination and axon damage (Nasrabady et al., 2018; Prins & Scheltens, 2015).

Together, the various changes occurring throughout the brain impact the central nervous system's capacity for neuroplasticity. Neuroplasticity is defined as the ability of the human brain to adapt to various changing demands by altering its functional and structural properties to improve learning and memory (Hötting & Röder, 2013). In other words, neuroplasticity is the capacity of the nervous system to modify its structure and function in response to many events including normal development and maturation of the organism, the acquisition of new skills ("learning") in immature and mature organisms, after damage to the nervous system and as a result of sensory deprivation (Bavelier & Neville, 2002; Hötting & Röder, 2013). In a way, neuroplasticity is a "double-edged sword" as based on one's environmental demands the associated neural changes can lead to improvements in function, but also diminished performance.

Neuroplasticity is a complex concept and is associated with various physiological processes including synaptic plasticity (i.e., effectively modifying chemical synapses for short or long periods of time (short term or long-term potentiation and depression)). Such functional modification can be affected by intrinsic or extrinsic signals including rapid firing (intrinsic) or direct synaptic input from other neurons and more diffuse actions of neuromodulators (extrinsic) (Kandel et al., 2013). Short term potentiation partly happens from the release of a transmitter in the motor nerve terminal, which opens acetylcholine (Ach) receptor-channels in the muscle membrane causing it to rapidly depolarize resulting in an EPSP (Kandel et al., 2013). In contrast, neurons can produce an inhibitory postsynaptic potential (IPSP) to counteract the EPSP such as in the common flexor/extensor muscle analogy.

Synaptic strength is important to consider as it can be modified presynaptically, by altering the release of neurotransmitter, or postsynaptically, by modulating the response to transmitter, or both (Kandel et al., 2013). Some of these biochemical reactions lead to long-lasting changes in synaptic strength, a set of processes called long-term synaptic plasticity that are thought to be important during synapse development and for regulating neural circuits in the adult brain (Kandel et al., 2013). In particular, an NMDA receptor-dependent long-term potentiation (LTP) of excitatory synaptic transmission has been implicated in certain forms of memory storage (Kandel et al., 2013). Applying this knowledge to my study, long-term changes in synaptic strength may implicate memory storage, which can affect development and learning. Specifically, whether movement may improve in dementia patients by using an external auditory stimulus such as music.

Transmitter release is another process that can be modulated quickly, and this change can be maintained for seconds, to hours, or even days. The two different mechanisms that can mediate this change include changes in Ca^{2+} influx or changes in the amount of transmitter released in

response to a given Ca^{2+} concentration (Kandel et al., 2013). Synaptic strength is commonly enhanced by intense activity and in many neurons a high-frequency train of action potentials is followed by a period where a single action potential produces successively larger postsynaptic potentials (Kandel et al., 2013). The opposite effect, a decrease in the size of postsynaptic potentials, occurs in response to more prolonged periods of high-frequency stimulation, which is known as synaptic depression (Kandel et al., 2013). These terms and processes all refer to short term potentiation and depression but post tetanic potentiation at certain synapses can be followed by LTP (also initiated by Ca^{2+} influx) which can last for many hours, days, or even weeks. During prolonged tetanic stimulation, synaptic vesicles become depleted at the active zone, and this would result in synaptic depression (Kandel et al., 2013). Therefore, short-term, and long-term potentiation and depression play a role in one's ability to initiate movement, develop, and learn new tasks and enhance one's memory, thus contributing to an individual's neuroplasticity.

Neurotrophins, such as brain-derived neurotrophic factor (BDNF) and insulin-like growth factor-1 (IGF-1), play important roles in supporting neuroplasticity. Physical exercise increases the availability of neurotrophins, which is thought to have beneficial effects on cognition by enhancing neuroplasticity (Hötting & Röder, 2013). Thus, physical exercise helps enhance the effects of learning and may prevent diseases associated with cognitive decline including dementia. Although, there are benefits with cognitive training as well. Research looking at 40-55-year old's who engaged in cardiovascular training and spatial cognitive training over six months saw that physical training alone might not be sufficient to induce significant functional changes in brain networks of spatial learning (Holzschneider et al., 2012; Hötting & Röder, 2013). Rather physical and cognitive stimulation might provide corresponding contributions for improving a variety of brain functions.

Overall, if someone is diagnosed with AD, their ability to adapt to their environment and make changes in their behaviour will be weakened. Their ability to learn and form memories will become difficult from the changes occurring to their functional and structural capabilities due to diminished neuroplasticity. Although, it remains to be seen if music might play a role in helping maintain/increase brain plasticity in dementia patients, which in turn may provide benefits to cognition and movement.

The second distinct abnormality of the brain is the reported findings of extracellular plaques. Post-mortem studies of the brain from AD patients reveal extracellular plaques of dense material called amyloid, large aggregates of fibrillar peptides arranged as sheets (Kandel et al., 2013). These neuronal changes are associated with processes of astrocytes and microglia (inflammatory cells). These are two important types of neuroglia, which are fundamental for homeostasis, maintenance, defence, and regeneration of the central nervous system (CNS) (Rodríguez-Arellano et al., 2016).

Astrocytes are known as the most diverse type of neuroglia responsible for every conceivable homeostatic task in the CNS. These cells also play a crucial role in the regulation of neuroinflammation (Colombo & Farina, 2016; Fakhoury, 2018; Parpura et al., 2012; Parpura & Verkhratsky, 2012; Rodríguez-Arellano et al., 2016). Additionally, astrocytes help with the maintenance and permeability of the blood-brain barrier (BBB), a multi-cellular unit involved in the exchange of molecules in and out of the brain (Abbott, 2002; Abbott et al., 2006; Fakhoury, 2018). Astrocytes express growth factors and cytokines to tightly regulate and maintain the permeability of the BBB during inflammatory conditions and in doing so help control the passage of immune cells into the CNS (Argaw et al., 2006; Fakhoury, 2018). When the BBB is compromised in an AD patient, a significant amount of beta-amyloid is not tainted despite the

various catabolic processes in place (Niedowicz et al., 2011). The BBB isolates nervous tissue in the CNS from the general circulation providing a mechanism to maintain a constant environment within (Martini et al., 2018). This is necessary to continue maintaining control and proper functioning within the CNS. Additionally, astrocytes act as secretory cells of the CNS releasing neurotransmitters (e.g. ATP, glutamate or GABA), neuromodulators (such as kynurenic acid) and trophic factors, also known as tissue hormones (such as growth factors), which all affect various aspects of plasticity and information processing in the CNS (Malarkey & Parpura, 2008; Parpura et al., 2011; Rodríguez-Arellano et al., 2016). Loss of astroglial function and reactivity contributes to the onset of neurodegenerative diseases (i.e., AD) and to the aging brain.

The other common type of neuroglia is known as microglia, which are resident macrophages that account for a small portion of cells (i.e. 10%) in the CNS (Solito & Sastre, 2012). They are one of the first immune cells that become active during an inflammatory reaction and constitute the first line of cellular defence against invading pathogens and other types of brain injury (Solito & Sastre, 2012). Additionally, microglia are highly engaged in the formation of beta-amyloid plaques in the brains of AD patients. They exert dual functions in AD either with a moderate activation or overactivation. With a moderate activation their protective effects come in by facilitating clearance of beta-amyloid in the brain while overactivation of these cells by beta-amyloid or beta-amyloid precursor protein (APP) (the result of the development of beta-amyloid), could trigger an exaggerated inflammatory response that may worsen the neurodegenerative processes in AD (Fakhoury, 2018). Therefore, it has been said that glial-mediated inflammation including astrocytes and microglia, is a ‘double-edged sword’, performing both detrimental and beneficial functions in AD (Fakhoury, 2018; Hanisch & Kettenmann, 2007; Sierra et al., 2013).

The last common abnormality of the brain occurs when neurons are affected but are still alive. In this situation the neurons will have cytoskeletal abnormalities, the most common being the accumulation of neurofibrillary tangles, which are filamentous inclusions in the cell bodies and proximal dendrites that contain paired helical filaments and straight filaments (Kandel et al., 2013). Molecular analysis revealed that these abnormal inclusions in cell bodies and proximal dendrites contain aggregates of tau, a hyperphosphorylated microtubule-associated protein (Fakhoury, 2018; Niedowicz et al., 2011). Tau plays a key role in intracellular transport, specifically in axons by binding to and stabilizing microtubules. Impairments in axonal transport compromise synaptic stability, trophic support, and other interactions, eventually causing nerve cells to die and the neurofibrillary tangles to remain in the extracellular space as 'tombstones' of the cells destroyed by the disease (Kandel et al., 2013). Although tangles are an important defining feature of AD, it still remains unclear what their role is as well as the hyperphosphorylated tau, play in the pathogenesis of the disease. It has been found that no mutations of the tau gene are found in familial AD, which leads some to view tangles as a consequence, but not a cause, of AD symptoms (Kandel et al., 2013). Even if tangles are not sufficient to "cause" AD, they most likely contribute to disease progression and the various symptoms that follow.

Overall, these neuronal alterations do not occur throughout the brain but rather affect specific regions including the entorhinal cortex (i.e., located in the medial temporal lobe), the hippocampus (i.e., embedded deep within the temporal lobe), the neocortex (i.e., part of the cerebral cortex), and the nucleus basalis (i.e., lies within the basal forebrain and innervates throughout the cortex and medial temporal lobe structures), which are especially vulnerable (Kandel et al., 2013). The alterations that occur in the entorhinal cortex and the hippocampus are most likely the structural underpinnings of problems with declarative memory (i.e. episodic and

semantic memory), which is one of the first symptoms in AD, and involves learning new information (Dubois et al., 2010; Dubois et al., 2007; Toepper, 2017; Kandel et al., 2013). As a consequence, AD patients typically show poor retrieval and recognition performances at learning tasks (Buckner, 2004; Budson, Michalska, et al., 2002; Budson, Sullivan, et al., 2002; Chapman et al., 2011; Schacter & Slotnick, 2004; Toepper, 2017; Wolk et al., 2008). The main reason for these deficits is an encoding dysfunction that blocks the consolidation of new information into long-term memory and with that the formation of cerebral representations (Toepper, 2017). Therefore, consequently, subjects are not able to recall learned content. Overall, impaired retrieval of learned content and item recognition are the first signs of an AD-related episodic memory dysfunction and thus can be regarded as the cardinal symptoms of AD-related cognitive decline (Toepper, 2017).

Besides episodic memory, semantic memory is also affected in early AD stages. Often the symptom demonstrated is word-finding difficulties (Henderson et al., 1990; Toepper, 2017; Verma & Howard, 2012). Due to the degeneration of semantic networks, AD patients have restricted access to semantic memory content (Di Giacomo et al., 2012; Martin & Fedio, 1983; Passafiume et al., 2012; Toepper, 2017). As a consequence, they commonly show poor performances on naming tasks that require the identification of objects. On the other hand, tangles are usually first evident in neurons of the entorhinal cortex, the likely site of early memory disturbance, before plaques even start to appear in this area (Kandel et al., 2013).

There are various parts of the brain affected in AD including the frontal, parietal, occipital and temporal lobes. Specifically, as AD spreads beyond the medial temporal lobe (MTL) structures to adjacent temporal, parietal, and frontal association cortices, several higher order cognitive abilities become affected such as language abilities (i.e. aphasia), confrontation naming (word

retrieval), verbal fluency, semantic categorization and a reduced ability to recall over-learned facts (i.e. the number of days in a year) (Bondi et al., 2017; Hodges & Patterson, 1995). Plaques first start by manifesting in the temporal lobe (i.e. MTL) and the orbitofrontal cortex to expand to different cortical association cortices as well as to the hippocampus, amygdala, diencephalon (above the brainstem and between the cerebral hemispheres), and basal ganglia (Goedert, 2015; Toepper, 2017). Overtime, as the disease moves into the later stages, the mesencephalon (part of the midbrain located in the most frontal part of the brainstem), brain stem, and cerebellum become affected. Whereas, neurofibrillary tangles manifest in the locus coeruleus (located in the pons of the brainstem) as well as in the entorhinal and transentorhinal cortices before affecting the hippocampus and frontal brain regions (Goedert, 2015; Toepper, 2017). Afterwards, neurofibrillary changes involve other cortical areas in the later stages of the disease. These changes include different biochemical processes contributing to the formation of plaques and tangles, which eventually leads to cerebral tissue damage, synaptic failure and overall cell death (Choi et al., 2014; Querfurth & LaFerla, 2010; Toepper, 2017). It is noteworthy to mention that AD can be regarded as a synaptic dysfunction rather than a neural dysfunction since the loss of synapses seems to exceed the loss of neurons and represents the strongest association to dementia (Querfurth & LaFerla, 2010; Teipel et al., 2011; Toepper, 2017).

Additionally, the limbic system is affected early in an AD patient, which is involved with memory and emotion and links the lobes of the brain, enabling them to connect behaviour with memories (Alzheimer Society of Canada, n.d.). When damage occurs to this system, individuals may have trouble finding objects and remembering where they were placed, suspiciousness, irritability, depression, or anxiety (Alzheimer Society of Canada, n.d.). Specifically, the signs expressed depend on the area of the brain that is damaged.

The hippocampus and temporal lobes are two common areas affected. The hippocampus is where verbal and visual memory are processed. Verbal memory relates to words such as remembering what you read or say or hear whereas visual memory lets you recognize objects, faces and places to guide you around your environment (Alzheimer Society of Canada, n.d.). On the other hand, the temporal lobes control new learning (i.e., episodic memory) and short-term memory. When diagnosed with AD the changes that may develop in these areas can cause the person to have an inability to retain memory of the recent past, to live in the present moment and to recognize familiar faces, objects, or places, and develop a loss of vocabulary (Alzheimer Society of Canada, n.d.). As well, the parietal lobes can be affected. They are responsible for putting activities in a sequence such as how you put your clothes on in the right order, which require a logical sequence (Alzheimer Society of Canada, n.d.). Additionally, the parietal lobes contribute to your understanding of spatial information such as where other objects are around you or where you are in a specific environment. The changes that can arise in these lobes for someone with AD will depend on whether the left or right side of the brain is affected but can include using words incorrectly, difficulty understanding what others are saying, getting lost easily, balance and gait difficulties and more (Alzheimer Society of Canada, n.d.).

Another area that can be affected is the frontal lobe. It is responsible for initiating activity, lets you plan and organize your actions and it regulates your social judgement and behaviour such as knowing what behaviour is appropriate to a situation, interpreting the feelings of other people and monitoring your own actions (Alzheimer Society of Canada, n.d.). Lastly, the occipital lobe can be affected. It controls vision, and the ability to see and combine colours, shapes, angles, and movement into meaningful patterns. This lobe is not usually directly involved in AD but the surrounding visual areas that allow them to put the elements of vision together can be affected

leading to unusual perceptual difficulties such as loss of depth vision or the inability to see movement (Alzheimer Society of Canada, n.d.).

As the disease progresses, the brain will continue to shrink causing different areas to alter resulting in various personality and behaviour changes as cognitive decline persists. The individual affected will continue to lose a part of themselves to the point where they may not remember their loved ones and sometimes their own name. Their behaviour will be altered, their personality ever-changing and their memories disappearing. Music has shown great promise in helping improve many functions lost including their behaviour and mood, and overall quality of life (Davison et al., 2016; Garrido et al., 2017; Gómez Gallego & Gómez García, 2017; Pongan et al., 2017). Specifically, music has demonstrated the ability to improve various types of memory for AD patients (Deason, et al., 2018; El Haj et al., 2015; El Haj, Fasotti, & Allain, 2012; Gómez Gallego & Gómez García, 2017; Palisson et al., 2015; Simmons-Stern et al., 2010; Simmons-Stern et al., 2012). Music may be an important non-pharmaceutical therapy to contribute to the ongoing and complicated puzzle that is dementia.

AD is the only form of dementia discussed above because it is the most common form. It should be noted that each type of dementia has similarities and differences physiologically, behavioural, and psychologically, with each having their own complexities that are quite complicated and in depth.

Risk Factors and Diagnosis

The major risk factor for developing AD is age, which leads to exponentially increased incidence and prevalence rates across the lifespan (Toepper, 2017; Kandel et al., 2013). Additionally, family history and education level can contribute to risk for both males and females. Although, the most significant genetic risk factor discovered in sporadic late-onset AD is an allele

of the gene APOE (apolipoprotein E) (Kandel et al., 2013). The APOE protein is a major carrier of cholesterol and other lipids in the blood and the gene is expressed as three alleles, APOE-e2, APOE-e3, and APOE-e4 and they all differ from each other from only a few amino acids (Kandel et al., 2013). The APOE-e4 allele is located on chromosome 19 apart of the gene for apolipoprotein E, a low density lipoprotein cholesterol carrier and those that have this allele are at risk for AD (Bondi et al., 2017; Strittmatter et al., 1993). It is only present in a few percent of the population, but it has been found in 40-50% of those with AD (Kandel et al., 2013). In addition to age as a major risk factor, sex and gender are strong predictors. Sex and gender can interact with age across the lifespan and throughout development to alter the risk for dementia. Sex is defined as the classification of human beings according to their sex chromosomal compliment, with females having two X chromosomes and males having one X and one Y chromosome, hormonal differences (e.g., effects of estrogen or testosterone), or reproductive differences (e.g., pregnancy or menopause) (Podcasy & Epperson, 2016; Rocca et al., 2014; Woods & Tsui, 2013). On the other hand, gender refers to a person's psychosocial and cultural self-identification as being a man, a woman or gender queer (Podcasy & Epperson, 2016). The main discussion related to gender involves education level and intellectual enrichment. Education is gender-related and has a similar effect on the risk of dementia or AD in men and women, however, lower education is historically more common in women than men in many countries (Rocca et al., 2014). Although, women who obtain a higher level of education early in life and carry the APOE-e4 allele may reduce the harmful effects they experience (Rocca et al., 2014; Wang et al., 2012). Additionally, it has been hypothesized that lifetime intellectual enrichment (including education, primary occupation early in life and cognitively stimulating leisure activities) in midlife or later life may provide an important brain reserve mechanism to delay the onset of cognitive decline and dementia in

combination with receiving a higher education level early in life (Rocca et al., 2014; Vemuri et al., 2012, 2014). Education and intellectual enrichment are key factors to consider when helping prevent and/or delay the development of dementia.

Sex differences in brain development serve as a well-known area where medical conditions and other risk factors associated with dementia act to increase or reveal vulnerability to pathological cognitive aging (Podcasy & Epperson, 2016). It has been mentioned that smoking, coronary artery disease and brain injury with loss of consciousness increase the risk for dementia in males whereas longer lifespan, female sex hormones, diabetes and obesity increase the risk for dementia in females. Risk factors for both male and females include age, family history, APOE genotype (E4 allele), and education level (gender-related). Based on the dementia one is diagnosed with, sex plays a critical role. Specifically, for AD, there is almost a twofold increased risk in women versus men (Podcasy & Epperson, 2016; Seshadri et al., 1997). Neurodegeneration and clinical symptoms typically occur much more rapidly in females once a diagnosis is suspected and they are often diagnosed earlier in the course of the illness than men (Podcasy & Epperson, 2016). Although, it is known that men will have a shorter life span after diagnosis is confirmed (Farrer et al., 1997; Podcasy & Epperson, 2016). Another risk factor for AD that varies by sex is inflammation. Inflammatory dysregulation tends to be stronger in females because they have more microglia than males, especially during adolescence, a time where female-biased disorders such as depression and anxiety are on the rise (Podcasy & Epperson, 2016). Therefore, this disruption in microglia can set the stage for development of neurodegenerative disease in older adulthood (Hanamsagar et al., 2015; Podcasy & Epperson, 2016). Moving forward, sex and gender may influence treatments and the effectiveness in targeting modifiable risk factors such as type 2 diabetes, thyroid disease, or concussion with loss of consciousness. If we can target the risk factors

by looking at the influence sex and gender play, we may be able to prevent or delay the development of dementia.

There are different biomarkers associated when diagnosing someone with dementia. These biomarkers may be used to distinguish different aspects of the underlying pathology, detect presymptomatic pathological changes, predict decline or conversion between clinical disease states and/or monitor disease progression and response to treatment (Ahmed, Paterson, et al., 2014). The specific biomarkers of dementia currently in clinical use include imaging biomarkers such as structural brain imaging (computed tomography (CT) or magnetic resonance imaging (MRI)) as well as functional imaging (Positron Emission Tomography (PET) or Functional MRI (fMRI)) as well as fluid biomarkers including cerebrospinal fluid (CSF) (i.e., ß-Amyloid, t-tau and tau phosphorylated at 181 (p-tau)). Also, a new imaging technique has emerged known as diffusor tensor imaging (DTI). CT and MRI are recommended for all those being investigated for dementia. Although, MRI in particular can assess vascular damage, white matter signal changes with a wide range of causes as well as providing superior grey/white contrast without radiation exposure (with rates of atrophy considered surrogate markers of neurodegeneration) (Ahmed, Murphy, et al., 2014; Ahmed, Paterson, et al., 2014). In AD, typical imaging appearance is of global brain atrophy with early disproportionate symmetrical involvement of the medial temporal lobe structures including the hippocampus (Ahmed, Paterson, et al., 2014; Harper et al., 2014). Therefore, medial temporal lobe atrophy can help predict individuals who will go on to develop clinical AD from mild cognitive impairment with a sensitivity and specificity of 73% and 81% respectively (Ahmed, Paterson, et al., 2014; Duara et al., 2008; Frisoni et al., 2010). PET allows for visualization and quantification of patterns of brain hypometabolism and hypoperfusion, which show characteristic patterns that differ in different dementia syndromes (Ahmed, Paterson, et al., 2014; Kipps et al.,

2009). The typical AD pattern imaging is bilateral hypometabolism and hypoperfusion in the temporal and parietal cortices. Specifically, Amyloid PET is imaging of brain amyloid in vivo and has been shown to correlate closely with autopsy measures of fibrillar amyloid load and has the potential to rule in/out AD pathology as the cause of cognitive decline in a patient with cognitive impairment (Ahmed, Paterson, et al., 2014; Clark et al., 2011). On the other hand, fMRI measures alterations in regional cerebral blood flow using a linked blood-oxygen-level-dependent (BOLD) signal change in the magnetic properties of cerebral venous blood (Ahmed, Paterson, et al., 2014).

A key fluid biomarker to consider is cerebrospinal fluid (CSF) analysis. It uses a variety of immunochemical techniques to allow for a range of neuronal-specific or neuronal-enriched proteins to be measured so an accurate diagnosis of dementia can be determined. Specifically, CSF levels of ß-Amyloid, t-tau and tau phosphorylated at 181 (p-tau) are of significance.

Lastly, diffusor tensor imaging (DTI) is a new technique that enables white matter tract integrity to be assessed and measures of its integrity have been linked to episodic memory function (Lockhart et al., 2012). Injury to white matter tracts that connect frontal and temporal cortex, and frontal cortex and striatum, might (to some extent) explain the differences in memory performance between older individuals (Prins & Scheltens, 2015). Therefore, impaired white matter integrity, measured by DTI, is associated with an increased future risk of WMH (white matter hyperintensity) development, leading to decreased cognitive performance and ultimately dementia. Overall, it is important to know the background behind key risk factors of dementia and the ways to diagnosis the disease because it will help to understand dementia on a deeper level and to apply this knowledge to the field of music therapy and movement performance.

Memory and Dementia

Memory is a vast term that encompasses many different topics and is vital for one's ability to learn and remember. Most of all, memory provides individuals with a sense of personal identity and is a process by which knowledge that we learn is encoded, stored, and later retrieved (Kandel et al., 2013). Whereas learning refers to a change in behavior that results from acquiring knowledge about the world, which then is stored in memory (Kandel et al., 2013). Thus, learning and memory are interconnected on such a deep level by creating a solid foundation that makes up who we are and enhances our individuality in the process. There are two distinct types of memory including short-term memory (also known as working memory) and long-term memory. Short-term memory is our ability to store information and maintain current, transient, representations of goal-relevant knowledge (Kandel et al., 2013). Two subsystems branch off working memory. One is for verbal information, and another is for visuospatial information. The functioning of these two subsystems is directed by a third system known as the executive control processes. This third system is thought to allocate attentional resources to the verbal and visuospatial subsystems, and to monitor, manipulate, and update stored representations (Kandel et al., 2013) (See Appendix B for a Diagram of Short-Term Memory).

Whereas long-term memory encompasses two types of memory including implicit (unconscious retrieval) memory and explicit (conscious retrieval) memory. Implicit memory is an unconscious form of memory that is evident in the performance of a task and is typically manifested in an automatic manner (also known as nondeclarative memory) (Kandel et al., 2013). Different types of implicit memory include priming (i.e., perception of a word or object is improved by prior exposure), skill learning (i.e., procedural memory), nonassociative learning (i.e., habituation and sensitization) and associative learning (i.e., classical and operant conditioning).

Priming is a type of implicit memory that does not depend on the medial temporal lobe structures and has two types. First, conceptual priming, which provides easier access to task relevant semantic knowledge because it has been used before and is correlated with decreased activity in the left prefrontal regions that subserve initial retrieval of semantic knowledge (Kandel et al., 2013). Secondly, perceptual priming occurs within a specific sensory modality and depends on cortical modules that operate on sensory information about the form and structure of words and objects (Kandel et al., 2013). Most tasks will include both conceptual and perceptual priming to provide unconscious retrieval of information. Additionally, the medial temporal structure is responsible more so for explicit memory whereas implicit memory tends to be independent of this structure. Nonassociative learning (another form of implicit memory when a subject is exposed once or repeatedly to a single type of stimulus) takes on two types as well including habituation (where a decreased response occurs when a benign stimulus is presented repeatedly) and sensitization (an enhanced response to a wide variety of stimuli occurs after the presentation of an intense or noxious stimulus) (Kandel et al., 2013).

On the other hand, associative learning involves two types as well including classical conditioning (learning a relationship between two stimuli) and operant conditioning (learning a relationship between the organism's behavior and the consequences of that behavior) (Kandel et al., 2013). Operant conditioning is also known as trial-and-error learning. Overall, implicit memory involves a wide variety of brain regions, most often cortical areas that support the specific perceptual, conceptual, or motor systems recruited to process a stimulus or perform a task (Kandel et al., 2013). Implicit memory is a crucial form of long-term memory that allows us to retrieve information and perform tasks without conscious effort and involves a variety of structures. Long-term storage of implicit memory involves the neocortex for priming, the striatum for skills and

habits, the amygdala for learned fear (i.e., emotional responses), the cerebellum for learned motor skills (i.e., skeletal musculature), and certain reflex pathways for nonassociative learning such as habituation and sensitization (See Appendix C: Long-Term Memory) (Kandel et al., 2013).

Many aspects of personality, much of what we do in our daily life is guided by implicit memory and a great deal of what we experience cannot be directly accessed by conscious thought. This is significant to consider for future research studies about implicit memory storage and the subsequent concerns of individuality. For instance, Deason and colleagues (2018) examined implicit and explicit memory performance during three different conditions (instrumental, song and spoken auditory stimuli) in healthy older adults and mild AD patients over three weeks (Deason et al., 2018). The musical conditions (instrumental and song) included complex music (i.e., songs on the radio), with a variety of components compared to something simpler. They observed the mere exposure effect (related to implicit memory and is expressed as a preference for familiar stimuli over unfamiliar stimuli even in the absence of conscious memory) in instrumental and song conditions but not in the spoken condition for both groups. Whereas, in the explicit recognition memory task, performance was better in both groups for the spoken condition than in the musical conditions (Deason et al., 2018). An important takeaway from these results is during the exposure effect, they did not observe a group difference offering evidence that this implicit memory function remains intact in patients with mild AD (Deason et al., 2018). Specifically, persons with AD demonstrated very little recollection overall and more familiarity towards all conditions suggesting that a simple exposure to a stimulus might tap into memory networks in persons with AD who may still demonstrate a preference for information familiar to them such as through music (Deason et al., 2018). This shows how complex musical stimuli may help contribute

to memory performance in patients with AD in the short term and how implicit memory might be an area for future research to target memory in dementia.

Explicit memory (also known as declarative memory) is highly flexible and involves conscious retrieval of previous experiences as well as conscious recall of factual knowledge about people, places, and things (Kandel et al., 2013). Different types of explicit memory include episodic memory (the memory of personal experiences or autobiographical memory) and semantic memory (memory for facts). The medial temporal lobe plays a critical role in both semantic and episodic memory and is evident in patients who have difficulties forming and retaining new conscious memories of their personal experiences or the meanings of new concepts (Kandel et al., 2013). Something worth mentioning about explicit memory is the brain does not have a single long-term store for its memories but instead storage of any item of knowledge is widely distributed among many brain regions and can be accessed independently (by visual, verbal, or other sensory clues) (Kandel et al., 2013). Additionally, explicit memory is mediated by four processes including encoding, storage, consolidation, and retrieval. Encoding includes processing new information by linking it to existing information in memory and is important for determining how well the learned material will be remembered whereas storage involves neural mechanisms and sites where memory is retained overtime (Kandel et al., 2013).

Long-term memory has an unlimited capacity whereas short-term memory is limited to holding only a few pieces of information in any given moment. Two areas of the brain critical for encoding and storing explicit memory are the prefrontal cortex (mediates working memory to hold information for short periods of time and depends on persistent neural activity) and the hippocampus (more stable form of storing declarative information for long periods of time and involves long-lasting changes in strength of synaptic connections) (Kandel et al., 2013). Although,

the ultimate storage site for all declarative memories is within the cerebral cortex. Another process of explicit memory is consolidation, which is the process that makes temporarily stored and still liable information more stable, and retrieval is the process where stored information is recalled by bringing back to mind different kinds of information that are stored in different parts of the brain (Kandel et al., 2013). It has been noted that activity in the medial temporal lobe is greater when people engage in deep encoding as well as the left pre-frontal cortex is enhanced, which suggests the frontal lobe and medial temporal lobe processing contributes to encoding episodic memory (Kandel et al., 2013). Specifically, episodic memory depends on the interaction between cognitive control processes in the prefrontal cortex and associative binding mechanisms in the medial temporal lobe (Kandel et al., 2013). Therefore, the interaction between the medial temporal lobe and distributed cortical regions is also central to memory consolidation. The hippocampus is another critical brain region involved with explicit memory and is found within the medial temporal lobe. Increased activity within the hippocampus helps retrieve contextual or event details associated with episodic memory. Specifically, the hippocampus receives multimodal sensory and spatial information from the nearby entorhinal cortex, which is important for explicit memory.

The other form of long-term memory is known as semantic memory and deals with general knowledge about the world, encompassing facts, concepts, and information about objects as well as words and their meanings (Kandel et al., 2013). The information from semantic memory is commonly stored in a distributed manner in the neocortex, including the lateral and ventral temporal lobes. Semantic knowledge is quite remarkable in its organization and flexibility among many brain regions. Overall, explicit memory is essential for our ability to remember personal experiences and knowledge about the world and creating a sense of personal identity and involves long-term memory storage of specific areas beginning in the hippocampus and the medial temporal

lobe of the neocortex. Overtime these long-term explicit memories are transferred to different regions of the neocortex and even some cognitive, motor, and perceptual skills that are initially stored in explicit memory ultimately become so ingrained with practice that they become stored in implicit memory (Kandel et al., 2013). Therefore, explicit, and implicit memory are highly important for an individual to develop, learn and grow and each have different parts of the brain that aide in their performance. Using two memory systems together is the rule rather than the exception. They both overlap and are commonly used together in many learning experiences and with constant repetition, often explicit memory can turn into implicit memory.

Additionally, explicit, and implicit memory can use music to elicit past experiences (explicit) and thus demonstrate an emotional response (implicit) from individuals such as older adults as well as those diagnosed with dementia. For instance, explicit memory (i.e., verbal episodic memory) has demonstrated that musical association (i.e., sung lyrics) during the encoding stage facilitates learning and retention in AD patients (Palisson et al., 2015). Specifically, sung texts are better remembered than spoken texts (presented alone with a silent movie sequence) (Palisson et al., 2015). Therefore, texts encoded in a musical condition provide a better learning performance with more lines learned as well as a better immediate recall during the encoding phase and better retention after a 5-min delay (delayed recall) (Palisson et al., 2015). Additionally, a form of episodic memory known as autobiographical memory (i.e., the memory of personal experiences) has demonstrated significance when it comes to memory and recall. Autobiographical recall has shown to be significantly related to life era for better performance in mild-to-moderate dementia patients compared to moderate dementia patients. Results demonstrated life era being better from remote past (0-20 years old) than for medium-remote past (20-50 years old), which in turn was better than for the recent past and present (Foster & Valentine, 2001). Specifically, superiority of

recall was demonstrated in music (i.e., familiar and novel) compared to cafeteria noise for remote past and medium-remote past but not for recent memories suggesting a possible contribution from associative facilitation and the importance of structured sound (Foster & Valentine, 2001). Thus, long-term memories seem to be more well-preserved in persons with mild-to-moderate dementia and are recalled better with the use of familiar and novel music. On the other hand, implicit memory plays an added role in how one reacts to music such as their sensorimotor response (i.e., dependent on the basal ganglia, cerebellum and neocortex) (Kandel et al., 2013).

Long-term and short-term memory play an important role in an individual's life. Imagine if it started to faulter and disappear. Dementia patients gradually experience this over the course of their diagnosis and music may be a way to utilize alternative neural pathways to generate past memories, and thus improve their sensorimotor response (i.e., movement performance), mood, and quality of life and bring them the power to experience human connection on a whole new level.

Music and Dementia

Music has been used as a form of connection for many years and throughout the course of history, it has transcended into a form of therapy to help those diagnosed with various syndromes and diseases including dementia to improve their mood and quality of life. Music therapy is a type of intervention that is inexpensive and enjoyable with no adverse effects and it has emerged as a promising alternative for patients with dementia (Gómez Gallego & Gómez García, 2017). Recently, it has been demonstrated that personalized music for persons with dementia in nursing homes can provide a vast array of applications from enjoyment and satisfaction to social engagement with family visitors and staff members to reduced feelings of anxiety, depression and agitation (Davison et al., 2016). Group music therapy sessions designed and led by music therapists have shown a positive impact in persons with mild and moderate dementia in different musical

activity sessions over a six-week period. Results showed improvements in cognitive function, orientation and memory regardless of dementia severity and large improvements were seen in anxiety and depression in both mild and moderate groups (Gómez Gallego & Gómez García, 2017). Although, only in the moderate dementia group did delusions, hallucinations, irritability, language, and agitation improve. In summary, music therapy helps to stimulate cognitive function, improves mood and reduces behaviour problems triggered by stressful conditions (Gómez Gallego & Gómez García, 2017). Also, by providing tailored musical preferences, this may have improved each participants experience and benefited the results drawn.

Additionally, individualized music sessions have been proposed in a long-term setting to see if quality of life can be improved for persons diagnosed with dementia (Weise et al., 2018). These potential results (if proved to be effective and widely applicable), may be implemented on a larger scale in institutional care as an easy-to-administer intervention (Weise et al., 2018). Therefore, research has started to look and see if preferred music has the potential to improve the lives of persons with dementia not only in a short-term setting but also long-term. Developing a strong feeling of familiarity towards musical stimuli has shown to be superior to verbal ones (i.e., short stories or poems) in the short (two weeks) and long-term (two-month delay) in moderate to severe patients with AD (Samson et al., 2009). Specifically, old compared to new stimuli had an enhanced familiarity for musical and verbal excerpts after two weeks but after a two-month delay, old stimuli remained statistically significant for musical excerpts but not for verbal ones. This suggests that musical information is better retained than verbal information in a delayed memory task and maintains implicit learning even in the case of a neurodegenerative disease (Samson et al., 2009). Memory for music can be relatively preserved even despite severe verbal memory deficits in patients diagnosed with AD. Given the powerful and long-lasting memory-enhancing

effect of musical stimuli, the potential benefits of using music in rehabilitation are infinite (Samson et al., 2009).

A case study demonstrated how sparing of musical memory may be detected in dementia and may be reliably and quantitatively assessed through behavioural observation (Cuddy & Duffin, 2005). Musical memory is an example of a complex skill- a skill integrating pitch, rhythm, timbre, dynamic, linguistic, visual, kinesthetic, and emotional components (Cuddy & Duffin, 2005). In the case of dementia, weakened components may be supported and reinforced through co-activation processes thus sparing of musical memory may be the most available and accessible form of the sparing of a complex skill in dementia (Cuddy & Duffin, 2005). As a result, music may be a vital non-pharmaceutical therapy to aid in the performance of memory in persons with dementia. Some key emotional dimensions to consider regarding better memory retrieval and formation is arousal and valence. Arousal refers to the excitation level elicited by music (ranging from very relaxing to very exciting) whereas valence is the emotional value on a continuum from negative to positive (or unpleasant to pleasant) elicited by a musical stimulus (Eschrich et al., 2008). Ratings of valence have proven to be positively associated with better recall and seems to be an important modulator of episodic long-term memory for music although, stimuli which induce high arousal are not necessarily better remembered in undergraduate and graduate students (i.e., 19 to 44 years old) (Eschrich et al., 2008). Emotion induced by music is processed automatically and greatly influences recognition in musical memory within this population. With very positive valence ratings and strong emotions, music can improve one's memory performance (i.e., formation and retrieval) in a recognition task (Eschrich et al., 2008). Therefore, arousal, valence and emotional intensity may be key dimensions to consider when evaluating musical memory in persons with dementia.

Additionally, music can be used as a memory enhancer (musical mnemonic) for associated verbal information in AD patients and healthy older adults. AD patients seem to demonstrate better performance on a task of recognition memory for the lyrics of children songs (simple, unrepeated lyrics, repetitive melodies and a perfect tail rhyme scheme for four lines used) when those lyrics were accompanied at encoding by a sung recording compared to a spoken recording (Simmons-Stern et al., 2010). Looking further into the topic of musical mnemonics, research determined the extent this mnemonic benefit of musical encoding extends to explicit memory for information contained in lyric content related to instrumental activities of daily living (Simmons-Stern et al., 2012). Simmons-Stern et al. (2012), discovered that general content information studied in sung lyrics may be better remembered than that studied in spoken lyrics from musical encoding for AD patients but not for specific content information. General content questions included responding with a yes or no answer, which directed the participant to one of two specific content questions where they were given a choice of two actions. The two questions they answer are about 80 object items, forty of which were studied and the other forty were unstudied. Therefore, music may be best suited to enhance one's familiarity and metamemorial confidence to benefit general memory related functioning, quality of life, depression, agitation, cognitive function and various other factors (Simmons-Stern et al., 2012). Even though recollection of specific details related to song material could not be recalled from persons with AD, familiarity and metamemorial confidence improvements were shown and this can go a long way in helping persons with AD and healthy older adults with their activities of daily living. Music has the power to enhance memory through the adaptation of tailoring lyrics to the task at hand, which is something to be valued and applied to persons with dementia.

Musical mnemonics may have the ability to induce brain plasticity and oscillatory synchrony (i.e., repetitive patterns of neural activity) in neural networks that underly memory performance in healthy adults and multiple sclerosis patients. Temporal synchrony (i.e., the simultaneous appearance of sensory inputs that may not necessarily be simultaneous) is a prerequisite for efficient network formation in memory and a musical template such as a song for verbal learning induces cortical plasticity characterized by higher synchrony in learning related networks (Thaut et al., 2005). Higher synchrony in learning related networks may produce more stable neural traces for long-term memory whereby increased oscillatory synchrony in learning networks may be the neurophysiological basis for persistent memory for music despite severe memory loss (Thaut et al., 2005). As well, there would be improved access to verbal knowledge through music in neurological conditions such as dementia (Thaut et al., 2005). Therefore, external rhythm as a temporal structure in music may drive internal rhythm formation in recurrent cortical networks for motor control and cognition (Thaut et al., 2005). The deeper meaning and understanding behind the extent to which music can impact one's memory performance and motor control and learning is remarkable within the highlighted groups. Thus, it may be important to understand the effects in the greater dementia population.

Music has certain beneficial qualities compared to other non-pharmaceutical therapies such as cooking in moderate to severe dementia patients. Research has demonstrated positive changes in cooking and music groups including improved emotional state (i.e., emotional facial expression and mood), reduced severity of behavioural disorders and reduced professional caregiver distress (Narme et al., 2014). Although, music sessions elicited stronger effects on the behavioural disturbances and the related caregivers' distress, the improvement of agitation and mood were stronger following cooking sessions and there were no significant changes in cognition for either

group (Narme et al., 2014). These results may have been due to a few factors such as a lack of a control group to compare the results with, the music sessions did not have music tailored to individual preferences, and how variety and creativity was provided more so in the cooking sessions rather than the music sessions. Therefore, these factors may have contributed to the lack of cognitive significance and how music and cooking seem to produce equal benefit eliciting positive emotions in moderate to severe dementia patients. Although, results may be different in patients with mild-to-moderate dementia compared to healthy age and sex matched controlled participants in a music intervention (i.e., tailored to individual musical preferences).

Research has shown that select cognitive and physical based activities may provide a reduced risk of developing dementia in a prospective 21-year study in older adults between 75-85 years of age (Verghese et al., 2003). Participation in cognitive-based activities have demonstrated a reduced risk of AD, vascular dementia and mixed dementia and the frequency of participation in these activities are also related to the reduced risk regardless of education level (Verghese et al., 2003). The specific activities included reading, playing board games, playing musical instruments, and dancing, which were all associated with a lower risk of dementia. Three out of the four beneficial leisure activities were cognitive-based, and dancing was the only form of physical activity that showed benefits after the prospective 21-year study established by a point system that resulted in a cognitive-activity and physical-activity score. Based on participants frequency in each activity, high activity frequency correlated with a higher percent reduced risk of dementia. Specifically, increasing the frequency can predict a delay in the onset of accelerated memory decline (leading to dementia) and create a protective effect when playing a musical instrument or dancing (Verghese et al., 2003; Wan & Schlaug, 2010). Thus, to minimize the detrimental effects

of the aging brain, older adults should engage in challenging, multisensory, cognitive, and motor activities on a regular and intensive basis.

Music consists of organized patterns of sounds and learning to play a new song requires considerable practice, which brings to light the importance frequency of an activity plays (Cowles et al., 2003). In a case study of an 80-year-old moderate-to-severe AD patient (SL) with musical experience, he learned to play a new song and showed some memory for the song despite his near absence of episodic memory function (Cowles et al., 2003). Additionally, SL had relative sparing of the right hemisphere that did not seem to be crucial for playing songs learned before disease onset, but it may be necessary to learn and remember a new song (Cowles et al., 2003). This case study sheds light on important factors of the brain in a more severe case of dementia and an area to take note of when trying to help a person with dementia learn new information through music. It would be interesting to apply this study to a larger sample size and with persons diagnosed with mild-to-moderate dementia to see if the results are similar. Also, utilizing a familiar song personal to the participant but changing the lyrics to mirror specific parts about the individual's life might be an interesting route to take for future studies to see about improving activities of daily living. By including specific details, the individual can no longer remember but adding it to a song they like (i.e., utilizing the melody) may be a remarkable tool to utilize and enhance cognition and movement.

Additionally, music has the power to evoke autobiographical memories (i.e., past personal events) involuntarily in patients with mild AD compared to silence (El Haj et al., 2012). When given several executive tasks to perform followed by 2 mins of listening to their favourite music, participants had 5 minutes to describe their memories in detail and then they were asked to rate their current mood and emotional content of their memories on a five-point scale (El Haj et al.,

2012). Overall, music-evoked autobiographical memories were found to be more specific, to be accompanied by more emotional content and impact on mood, to be retrieved faster, and to induce less executive control than memories evoked in silence, which are all characteristics of involuntary memories (El Haj et al., 2012). Autobiographical memory encompasses different components such as personal-semantics (general knowledge about an individual) and autobiographical-episodes (specific personal events related to an individual). Furthermore, a component of autobiographical episodes is self-defining memories, which is associated with personal identity and an individual's life story with key aspects such as self-discovery and self-understanding. As the disease progresses, persons with dementia tend to lose their sense of identity, so to try and preserve this as long as possible is crucial. Researchers demonstrated, in patients with mild AD, that they can produce more self-defining memories when exposed to their own music than when exposed to researcher chosen music or in silence (El Haj et al., 2015). Specifically, when AD participants listened to their own chosen music, they had 3 minutes to describe their memories and in that short amount of time, they produced more self-defining memories than autobiographical-episodes or personal-semantics compared to the other conditions (El Haj et al., 2015). Therefore, music has this incredible capacity to help persons with dementia enhance their memory specifically with their own favourite music. This is a great start, but further research is needed to see if self-chosen music has the capacity to not just improve memory but also movement performance and behaviour.

Movement and Dementia

Dance may be defined as the act of one or more bodies moving in a rhythmic manner cued by music but even in its simplest form, dance requires a complex and simultaneous engagement of various physical and cognitive abilities (Dhami et al., 2015). The specific elements of dancing can vary greatly, but common features include learning new sequences of movements and

rehearsing them, music accompaniment, and typically being held in a group, fostering social interaction (Dhami et al., 2015). Dance is, without question, a complex task, made of numerous components that come together in sequence but a particular feature that may emphasize its therapeutic value is its incorporation of music, providing a source of cognitive stimulation and physical exercise (Dhami et al., 2015). Plato once said, "music and rhythm find their way into the secret places of the soul," and throughout history, this has been proven time and time again especially within older adults and those diagnosed with dementia (Van de Winckel et al., 2004). Dancing is an activity that emerged from a need for social interaction and non-verbal communication, and it is a universal form of expression consistent across generations, cultures, and social classes throughout the world (Kattenstroth et al., 2013). Compared to other kinds of physical activities or playing an instrument, dance comprises rhythmic motor coordination, balance and memory, emotions, affection, social interaction, acoustic stimulation, and musical experience apart from its requirements for physical activity (Kattenstroth et al., 2013). Thus, dance may be a powerful intervention tool to utilize in healthy and vulnerable populations and an applied future direction to take from this study.

In healthy older adults, a six-month dance intervention enhanced postural, sensorimotor, and cognitive performance especially in those with the lowest performance levels prior to the intervention (Kattenstroth et al., 2013). Even at a later stage in life, perceptual and cognitive abilities were maintained by dancing. Specifically, healthy older adults in the intervention group showed improvements in cognition, reaction times (i.e., high levels of attention and fast well-coordinated motor responses), tactile and motor performance, posture and lifestyle (i.e., subjective well-being) whereas controls showed no improvements and instead demonstrated degradation of performance in many tasks (Kattenstroth et al., 2013). Also, the intervention group was able to

perform larger forward centre of pressure (COP) displacements in the anterior direction, while backward COP displacements were increased in the lateral direction indicating enhanced postural stability since participants were able to shift their COPs further without taking a step forward or falling (Kattenstroth et al., 2013). Therefore, dancing seems to be a beneficial option to help improve age-related degeneration by enforcing and maintaining plasticity processes thus contributing to successful aging in healthy older adults (Kattenstroth et al., 2013).

Music has even demonstrated the power to improve cognition in moderate to severe persons with dementia through a daily music-based exercise (dance) program for three months (Van de Winckel et al., 2004). Dance is a common form of exercise that is challenging yet creative and enjoyable for persons with dementia and can help improve behaviour and motor function as well as aid in prevention (Verghese et al., 2003). There are promising results that have recently been found suggesting music may help to learn motor sequences in AD aiding in motor learning (Moussard et al., 2014; Palisson et al., 2015). In a study comparing AD patients and healthy older adult controls (all non-musicians), participants had to learn four different sets of 10 gestures (i.e., music with synchronized production during learning, music without synchrony, metronome with synchrony, and metronome without synchrony) (Moussard et al., 2014). Results were gathered based on the number of gestures remembered and their order sequence in immediate and 10-minute delayed recalls.

Overall, persons with AD showed a modest advantage for the music condition, with a greater percentage of gestures recalled in immediate recall and a minimal effect for the order of gesture sequence in delayed recall as well as better performance for the sequences that were learned without synchrony in delayed recall (Moussard et al., 2014). Whereas control participants showed better scores in delayed recall when gestures were learned in synchrony, demonstrating

that synchrony was helpful to controls but detrimental to persons with AD (Moussard et al., 2014). This study shows how music provides greater benefit to those with more pronounced cognitive impairment and this should be further investigated to see if similar results appear for a mild-to-moderate dementia group. Also, results may have differed and showed a greater benefit of music if variety was considered, and participants had a say in which music they heard. Providing choice may impact how one connects with music, produces movement, and impacts cognition. To conclude, music may be utilized as a mnemonic for gesture-sequence learning in persons with AD, although, synchronization of gesture production during encoding does not help performance (Moussard et al., 2014). Therefore, synchronizing music with movement performed by an experimenter, may provide negative results to persons with AD but if music were linked to a sequence-learning task on a tablet computer in a mild-to-moderate dementia group where they have more control over their movements, different conclusions may be drawn. To maximize the effect of music and to assess motor learning, it would be interesting to link the two and apply them to activities of daily living for each person with dementia.

Recent evidence has come to light that dance for Parkinson's disease (PD) compared to an exercise intervention of matched intensity, yields different outcomes based on the artistic elements of the movement experience using the same patients as their own control subjects in the two different interventions (Fontanesi & DeSouza, 2021). Specifically, looking at how the artistic elements of a Dance for PD session (i.e., presence of music, the use of narrative and metaphorical language, and a social reality of art-partaking, established and reinforced by dance teachers, live musicians and a group of peers with PD addressed as "dancers") shapes participants physiological, affective, self-efficacy, and motor changes (i.e., gait performance) (Fontanesi & DeSouza, 2021). By comparing a single dance session to a single exercise session of matched intensity, PD patients

improved in a variety of important areas to improve their overall quality of life. Recreating this study with a dementia population would be interesting to see if similar results may be drawn.

Overall, dance may be a form of physical exercise and a source of cognitive stimulation to induce neuroplasticity and enhance cognition to help persons with dementia through the power of music combined with movement. Dance should be further investigated for its potential as a vital tool to not only help with aging, but to help those fight back against neurological disorders including dementia (Dhami et al., 2015).

Objectives/Hypotheses

Music and rhythm may have the potential to improve the accuracy and consistency of both reaching movements and whole-body movements. Given conscious recall and processing are impaired in patients with mild-to-moderate cognitive impairment (MCI), including music specific to a participant's interests may help individuals access non-conscious neural pathways for movement performance and ultimately enhance interactions with those around them.

I predicted that exposure to music personal to participants with MCI will lead to improvements in movement performance as measured by improvements in temporal and spatial movement performance measures (i.e., response time (reaction time/touch time and movement time), and variable error) compared to researcher-chosen music. I predicted that pre-recorded participant/caregiver chosen music will have a greater impact on movement performance and anxiety compared to pre-recorded researcher chosen music to complete an upper limb movement sequence task utilizing a virtual xylophone format on a tablet computer. Based on recent research in our lab, I predicted a control group of older adults will benefit from the addition of music to the task, but with intact conscious processing compared to the MCI group, will show no differences between self-chosen and researcher chosen music. With respect to movement performance, I

predicted that movements prepared based on defined memories will be more efficient (decreases in temporal parameters), consistent (decreased trial-trial variability), and accurate (improved mean endpoints) in the MCI group. I also predicted that the positive influence of music on anxiety and enjoyment level will be greater for self-chosen music in the MCI group.

Method

Design

Given the sample size of the MCI and control groups, a case series study design was utilized. Specifically, individual participants (cases) from the group of interest were described in comparison to the control group's performance overall. A case series study design was used to control for individual variability and to understand if there were immediate effects of self-chosen and/or researcher-chosen music on movement performance and anxiety across two sessions. Due to difficulties with recruitment, a case series study design was utilized with 3 participants with mild-to-moderate cognitive impairment (MCI). Participants were allocated to self-chosen or research-chosen music first using pre-made sealed envelopes. The self-chosen and research-chosen music conditions were randomized and counterbalanced so the order of conditions was balanced across participants and groups. The study was conducted either in person at the University of Manitoba in the Perceptual Motor Integration (PMI) lab or remotely by dropping off a data collection tablet computer and then working with participants using an online platform (i.e., Zoom) through a different computer/laptop or mobile device. A baseline/familiarization session was also completed one week before the experimental session to gather detailed information about music preferences and other demographic details (see Appendix D).

Participants

A power analysis was conducted using G*power software to determine the sample size required to achieve a power of .9 to detect an effect size between 0.25 and 0.37 with the primary outcome being response time. It was estimated using an alpha (α) level of 0.05 for two groups and two measurements. The required sample size for the estimated effect sizes was between 22-46 participants (i.e., 11-23 participants per group). This aligns with sample sizes used in previous studies with a similar research design (Ptomey et al., 2018). This was a conservative estimate for the movement performance variables due to their continuous nature (time and distance). Subjects were recruited through community resources such as the Minds in Motion Program with the Alzheimer's Society of Manitoba, Deer Lodge Centre, and Riverview Health Centre (to name a few). Data was collected from 13 age and sex matched control participants (8 females, 5 males) with an average age of 67.77 years (*SD* = 5.99) and 3 participants with mild-to-moderate cognitive impairment (MCI) (2 females, 1 male) with an average age of 72.33 years (*SD* = 11.24).

Inclusion criteria for the MCI group included that each participant needs to be within the age range of 60-85 years old, speak English, live in Winnipeg, Manitoba, Canada, have access to or own a laptop/computer or mobile device with Zoom installed and have a working camera, and have a MoCA score between 10-23. Exclusion criteria for this group was any older adults <60 years of age and >85 years of age, cannot speak English, lives outside Winnipeg, Manitoba, Canada, if they are experiencing aphasia (affecting the participants ability to communicate verbally, in written form and/or to understand language), any eye or hearing disabilities and other sensory deficits (numbness, pain, or tingling in the upper and/or lower extremities), if they have severe cognitive impairment or any other form of dementia in the severe stages, if they do not have access to or own a laptop/computer or mobile device with Zoom installed and have a working

camera (if they chose to complete the task in this format), if their MoCA score is < 10 or ≥ 23, and if they have additional comorbidities on top of their MCI that impacts their ability to perform the upper limb task (e.g., any current musculoskeletal injuries in the upper extremities).

Inclusion criteria for the healthy age and sex-matched control group include being between the ages of 60-85 years old, without a known diagnosis affecting the central nervous system, cognition, or their ability to complete the upper limb task, lives in Winnipeg, Manitoba, Canada, has a MoCA score ≥ 24, has access to or owns a laptop/computer or mobile device with Zoom installed and have a working camera (if they chose to complete the task in this format), and they can speak English. The MoCA criteria was adjusted to include control participants who fell just short of the original criteria (≥ 26/30), with the additional criteria that they did not have a diagnosis of cognitive impairment. Exclusion criteria for this group was any healthy older adult <60 years of age and >85 years of age, participants diagnosed with any comorbidities affecting their central nervous system, cognition or ability to perform the upper limb task (such as severe arthritis, stroke, etc.), those with any sensory deficits including eye or hearing disabilities or numbness, pain or tingling in the upper extremities, if they do not have access to or own a laptop/computer or mobile device with Zoom installed and has a working camera (for the online format), live outside Winnipeg, Manitoba, Canada, have a MoCA score < 24, if they cannot speak English, and if a participant has any musculoskeletal injuries that will interfere with task performance.

Recruitment of participants started by reaching out to specific facilities such as Deer Lodge Centre, Riverview Health Centre, and the Alzheimer's Society of Manitoba through email. If organizations were interested, they were forwarded the recruitment poster to advertise for the study and to distribute how they saw fit such as through email. Also, if participants were interested and wanted to know more information, the principal investigator emailed them a lay summary that

provides additional details about the study. If they did not hear back from organizations in a week after the email was sent, the principal investigator or a research staff member would follow up by telephone or email. If participants wanted to participate, a convenient date and time would be discussed to book the familiarization session first and if the participant passed that session, they would discuss a date and time for the experimental session. All participants were provided written informed consent in accordance with the polices from the University of Manitoba's Research Ethics Board. Please see Appendix E for a sample informed consent document for control participants and guardian/substitute decision makers for the MCI participants who were administered the same document with the appropriate title.

Music Selection

Music was based on the results from each participant's music selection questionnaire for both music conditions and was performed by the principal investigator. For the researcher-chosen music condition, the music selected was based on genre (trying to find a song within the same genre as the self-chosen music song or within a genre the participant provided on their music selection questionnaire that they enjoy), beats per minute (bpm) (songs were selected within 5 bpms from the self-chosen music song), and year (within same decade as the self-chosen music song). A decision to select the researcher-chosen music from a genre participants had selected on the music selection questionnaire was made in an effort to reduce any potential for anxiety that may increase expressive behaviours from persons with MCI. The music was played through the participants own laptop speakers from the Zoom session rather than headphones to increase comfort as participants perform the tablet computer task. For each music condition, one song was selected, and each song started at a certain point (just before the chorus) and was manually rewound to the same point during each experimental trial. Each music clip was around 30 seconds

in length (dependent on the participant) and played through Apple Music. Lastly, I did not ask participants to choose music based on a particular purpose to reduce the complexity of music selection, therefore, a variety of bpms were played from participant to participant.

Music counterbalancing included randomizing the music condition order by pulling an envelope out of a box. Inside each envelope contained a slip of paper with the music condition written on it. Beforehand, a research staff member created 20 envelopes with researcher chosen music written on the slips of paper and 20 envelopes with self-chosen music written on different slips of paper. The envelopes were placed in a small box and mixed up in a random order. The principal investigator or a research staff member randomly selected one of the envelopes and this would show which music condition was played first. The music condition not selected was played second. Once that envelope was selected, it was discarded into a separate box. Twenty envelopes were created for each group due to the original power analysis and the target goal of 20 participants for each group.

Measurement Tools

The measures that were assessed include anxiety and movement performance as well as cognition to confirm eligibility for the study. We assessed cognition through the Montreal Cognitive Assessment (MoCA). The MoCA was administered to assess cognition level in the mild-to-moderate cognitive impairment (MCI) and control group. The MoCA was performed by the principal investigator if participants did not already have a score out of 30 or if their score was over three months old. The assessment took about 10 minutes to complete. The MoCA test is a cognitive screening test designed for milder forms of major neurocognitive disorder, which assesses different cognitive domains such as short-term and working memory, language, executive functions, visuospatial skills, attention, concentration, abstraction, calculation, and orientation to

time and place using a paper and pencil test (Swinnen et al., 2021). For mild Alzheimer's disease (AD) their score could be between 11-21 (average is 16) and for mild cognitive impairment (MCI) their score could be between 19-25 (average is 22). The cut-off score is 18 separating mild AD from MCI but there is overlap between the two since AD is determined by the presence of cognitive impairment in addition to loss of autonomy. Therefore, severity can be graded where MCI falls within a score of 18-25 and moderate cognitive impairment will fall within a score of 10-17 and anything less than 10 is considered severe cognitive impairment (and anyone in the severe stages will be excluded from the study). The specificity of the MoCA to exclude older adults without cognitive impairment is good at 87%, but more importantly, the MoCA's sensitivity in detecting mild cognitive impairment is excellent at 90%, and it is considerably more sensitive than the Mini Mental State Examination (MMSE) (Nasreddine et al., 2005). Also, the MoCA detected mild AD with high sensitivity at 100% and excellent specificity at 87% (Nasreddine et al., 2005). The MoCA has a good construct validity (r values range from 0.46 to 0.75) (Freitas et al., 2012), inter-rater reliability (r = 0.97), test-retest reliability (r = 0.88), and internal consistency (Cronbach's alpha = 0.89) (De Roeck et al., 2019; Swinnen et al., 2021). The total score ranging from 0 to 30 was used and higher scores will indicate better cognitive functioning.

For the current study, the MoCA criteria was changed for control participants from $\geq$ 26/30 to $\geq$ 24/30 due to some participants not meeting the criteria but had no known diagnosis of cognitive impairment (CI). Therefore, the altered MoCA criteria was utilized for the control participants. One CI participant fell above the cut off ($\geq$ 24/30) but was included in the CI group because the participants also had a known diagnosis of cognitive impairment.

To assess anxiety we used the Rating Anxiety on Dementia (RAID) scale for MCI participants (Shankar et al., 1999). The RAID scale consists of short interviews conducted by a

qualified researcher in individual meetings with the guardian/caregiver first followed by the person with dementia in the other. This is to help the researcher be informed during the questioning of certain symptoms in the participant interview. Each interview took about 10 minutes to complete (20 minutes total). This scale has 18 items divided into four categories: worry, apprehension and vigilance, motor tension, and automatic hypersensitivity (Shankar et al., 1999). Each item is rated on a 4-point scale and a score of 11 or more suggests significant clinical anxiety (Shankar et al., 1999). The rating should be based on signs and symptoms occurring during two weeks prior to the interview. Research has shown the RAID scale to have a test-retest reliability ranging from 0.53 to 1, indicating moderate to good reliability and an interrater reliability ranging from 0.51 to 1 (Shankar et al., 1999). Also, the RAID has been found to correlate significantly with other anxiety scales and covers a good range of anxiety symptoms/signs and has good construct validity for assessing anxiety (Shankar et al., 1999). The overall agreement on individual items ranges from 82-100% (inter-rater) and 84-100% (test-retest) (Shankar et al., 1999). Cronbach's alpha was 0.83, suggesting that RAID has a high level of internal consistency. Alpha was calculated for each sub-group of the scale to consider whether the items within a sub-group were equally affected by the patient's anxiety status. The alpha values for the sub-scales ranged from moderate to high: Worry (alpha = 0.65); Apprehension and vigilance (alpha = 0.67); Motor tension (alpha = 0.51); Autonomic hyperactivity (alpha = 0.74) (Shankar et al., 1999). This scale was administered to the mild-to-moderate CI group during the familiarization session as a baseline measure. We wanted to see if the score on the RAID scale co-varied with performance in the different music conditions.

Additionally, the State Trait Anxiety Inventory (STAI) is a self-report scale that was used to measure the participants general anxiety level and their anxiety in the moment. Both the Trait Anxiety scale and the State Anxiety scale was used from the STAI. Each scale includes 20

statements and took about 10 minutes to complete. The Trait Anxiety scale evaluates participants general anxiety levels (i.e., relatively stable aspects of anxiety proneness including general states of calmness, confidence, and security), which was evaluated only during the familiarization session for both groups (the mild-to-moderate CI group and the healthy older adult control group) (Julian, 2011). On the other hand, the State Anxiety scale evaluates the current state of anxiety, asking how respondents feel "right now, at this moment" using items that measure subjective feelings of apprehension, tension, nervousness and worry and activation/arousal of the autonomic nervous system (Julian, 2011). For each scale, each item was rated on a 4-point scale. For the State Anxiety scale, it assessed intensity of current feelings (at this moment": 1- not al all, 2- somewhat, 3- moderately so, and 4- very much so (Julian, 2011). For the Trait Anxiety scale, it assessed frequency of feelings "in general": 1- almost never, 2- sometimes, 3- often, and 4- almost always (Julian, 2011). This scale was administered during the experimental session at baseline and after each music condition. The State Anxiety scale was repeated after each music condition and took roughly five minutes to complete due to repeated administration. It is worth mentioning that the Trait Anxiety scale has 11 items that indicate high levels of anxiety, and the State Anxiety scale has 10 items. While the remaining 9 items on the Trait Anxiety scale and 10 items on the State Anxiety scale, a high rating indicates the absence of anxiety (19 out of the total 40). Therefore, the scoring rates would be reversed (4, 3, 2, 1). To obtain scores, we added the weighted scores (considering the fact that the scores are reversed for the absent anxiety items), scores varied from a minimum of 20 to a maximum of 80, the higher score indicating greater anxiety. A scoring rubric was used to evaluate each scale for every participant.

The State Trait Anxiety Inventory (STAI) test-retest reliability coefficients on initial development (Julian, 2011, Spielberger et al., 1983) ranged from 0.31 to 0.86, with intervals

ranging from 1 hour to 104 days (Julian, 2011). Since the State Anxiety Scale tends to detect transitory states, test-retest coefficients were lower for the State Anxiety scale as compared to the Trait Anxiety scale (Julian, 2011). Internal consistency alpha coefficients were quite high ranging from 0.86 for high school students to 0.95 for military recruits (Julian, 2011; Spielberger et al., 1983). The State Anxiety Scale is more responsive to change as compared to the Trait Anxiety Scale. For the Trait Anxiety scale the coefficients ranged from 0.65 to 0.86, whereas the range for the State Anxiety Scale was 0.16 to 0.62 (Spielberger et al., 1983). This low level of stability for the State Anxiety scale was expected due to responses to the items on the scale are thought to reflect the influence of whatever transient situational factors exist at the time of testing (Spielberger et al., 1983). Therefore, the State Anxiety scale was used to assess changes in anxiety with the different music conditions. Participants completed the State Anxiety scale in hardcopy form at baseline, after the first music condition and after the second music condition.

Movement performance was assessed through dependent measures including response time (touch time/reaction time and movement time) and movement consistency (i.e., variable error). For the upper-limb music and movement task, we used a motor sequence task where participants pressed a series of targets on a tablet computer (similar to a virtual xylophone) using the E-Prime 3 software. Each target was bordered with a designated colour (i.e., red, blue, yellow, green, or purple) with the middle of the target white (See Appendix G). First participants engaged in two practice trials without music to familiarize themselves with the task. A no music condition was not included as participants were already engaging with the task a lot and I wanted to minimize fatigue from setting in. Then participants engaged in 5 experimental trials with their first music condition, either self or researcher-chosen music. The task had participants start with their index finger on the black square at the bottom of the screen (i.e., home position). Next, one of the five targets

randomly filled in with its designated border colour once the participant touched the home position. There were 20 target presses per trial and each trial included a unique 20 target sequence in random order. Participants were asked to tap each target as quickly and as accurately as possible. Once tapped, the target returned to its original state and participants returned their index finger to the home position before another target was identified. This continued until the sequence ended, then the music stopped indicating the end of one trial (See Appendix G).

We measured each dependent variable through the timing of touching the screen. Movement time was the time it took the participants finger to travel from the home position to the target (measured in milliseconds). Touch time/reaction time was the time it took the participants finger to begin moving from the home position once a target filled in (measured in milliseconds). Lastly, variable error was the average standard deviation (SD) for each target location of end-point variability in pixels divided by the number of targets (measured in pixels but was converted to centimeters). The variable error showed how consistent participants taps were. We wanted to see if participants were moving faster, were moving with equal consistency, or were trading speed for consistency or vice versa.

A Dell Latitude 7410 windows laptop was used to record the time and location of key/screen presses for the dependent measures. The targets were 2.2 cm in width x 2.2 cm (137 x 137 pixels) in length while the home position was 2 cm in width x 2 cm in length (124 x 124 pixels). Targets were spaced 2.3 cm (130 pixels) apart from each other (See Appendix H). The amplitudes (distance from the centre of the home position to the centre of each target) were as follows, yellow- 13.5 cm, blue and green- 14.4 cm, and red and purple 16.1 cm. Therefore, the index of difficulty for each amplitude was 3.62 (yellow- 13.5 cm), 3.71 (blue and green- 14.4 cm), and 3.87 (red and purple- 16.1 cm). A diagram showing the dimensions of the task in pixels can

be found in Appendix H and a task diagram showing the target margin of error can be found in Appendix I. The display panel dimensions of the Dell Latitude 7410 windows laptop were 30.937 cm in height x 17.399 cm in width (1920 x 1080 pixels). We measured response time (total of touch time, reaction time, and movement time), and variable error via the touch interface on the tablet computer.

Lastly, we presented a Likert Enjoyment scale with photos of different emotional expressions (See Appendix J) to measure participants enjoyment level on a scale from 1 to 5 (no enjoyment to high enjoyment) at baseline and after each music condition. The Likert Enjoyment scale was provided at baseline and after each music condition in hardcopy form and at the end of the task in the E-Prime software on the data collection laptop. Participants reported which facial expression best described how they felt by pointing to or verbally saying which face best represented how they felt.

Procedure

The study protocol was portable and remote or in-person at the University of Manitoba (234 Investors Group Athletic Centre) in the Perceptual Motor Integration (PMI) lab. For remote testing, participants found a convenient location in any quiet room with a table and chairs. Guardian/caregiver/substitute decision makers helped mild-to-moderate cognitive impairment (MCI) participants choose a preferred time of day and listening environment for the familiarization and experimental sessions. The participant was asked to sit in a comfortable position. The familiarization and experimental sessions each took between 45 minutes to one hour to complete on separate days one week apart. Eligibility was partially screened when scheduling the familiarization visit to identify if the participant fell within the age range of 60-85 years old, spoke English, lived in Winnipeg, Manitoba, Canada and had access to or owns a laptop/computer with

Zoom installed or available transportation to the University of Manitoba. If the participant was interested and fell within the inclusion criteria, consent, COVID-19 consent, and study summary documents were shared (via email or a package was dropped off to the participants place of residence) to allow participants additional time to review the documents. As well, we asked the participant (and guardian/caregiver/substitute decision maker if the participant had MCI) to think about their favorite music including genre, song choice, artists, and instruments. This allowed them additional time to prepare before going into the familiarization session. Participants were allowed to fill out the documents before the familiarization session and bring their questions up during the session. Additionally, we confirmed beforehand if they wanted to conduct the familiarization session remotely through Zoom or in-person at the University of Manitoba.

Familiarization Session

At the familiarization session, if the participant decided on a remote format, the participant received Zoom meeting information through email to either click on the link or use the ID login and password in their Zoom account through a separate computer/laptop or mobile device. Once participants were admitted into the Zoom meeting with the principal investigator, they were greeted. Next, informed consent was sought from the participant and, if needed, their guardian/caregiver/substitute decision maker. If the participant became ineligible for the study or chose not to move forward with the study and the participant or guardian/caregiver/substitute had already signed the consent form, the document was kept in a locked fireproof safe in the PMI lab (234 Investors Group Athletic Centre) at the University of Manitoba in a file for ineligible participants. Since cognition was affected, the MCI participants were unable to provide informed consent, therefore, a two-step process was implemented where a guardian/caregiver/substitute decision maker gave informed consent and the participant diagnosed with MCI provided assent.

Participants were informed during the informed consent process of their right to withdraw during the consent process or at any later time. If participants wished to withdraw at any point during the study, they absolutely could without any penalty. If they did want to withdraw, it was noted when and why the participant withdrew. MCI participants were asked to provide assent at the start of each session (familiarization and experimental sessions) and before each music condition.

Once informed consent and assent were complete, the COVID-19 consent form was provided for each participant to review and sign. Afterwards, the demographics questionnaire was reviewed. The demographics questionnaire asked questions to determine each participant's eligibility for the study. This included birth date, gender, cultural heritage, the city and province they reside in, if they spoke English, if they wear glasses or contact lenses or hearing aids, do they have any situations where they have difficulty hearing, if they have any eye or hearing sensitivities (i.e., light or sound), if they are experiencing any symptoms of aphasia (difficulty communicating), if they have a dementia diagnosis (if they do, what stage they are in, what type do they have, and if they are taking any dementia-specific medications), and if they have a Montreal Cognitive Assessment (MoCA) score (if yes, is it less than 3 months old and to indicate the score if it is within 3 months).

If persons with MCI indicated they had completed a MoCA assessment and it was less than 3 months old and fell within the inclusion criteria ($< 24/30$ and $\geq 10/30$), they were able to move forward reviewing the rest of the documents in the familiarization session. If they provided a score that was less than 3 months old but fell outside the inclusion criteria ($\leq 10/30$), the participant was unable to move forward with the study. Although, if participants scored $\geq 24/30$ but $< 26/30$ (the original cutoff for normal cognition in the original MoCA criteria) and they had a known diagnosis of CI, the participant was able to move forward with the study in the CI group. If they indicated a

score that was greater than 3 months old or if they did not have a MoCA score, the principal investigator (trained to administer the MoCA assessment) administered the MoCA assessment with the consent of the participant and guardian/caregiver/substitute decision maker. The assessment took around 10 minutes to complete depending on the participant. The participant score then confirmed if they had a score < 26/30 with a known diagnosis of CI but ≥ 10/30 the participant was eligible for the MCI group. If the participants score was ≥ 24/30 with no known diagnosis of MCI, they were able to take part in the control group. If the participant fell within the inclusion criteria for either the MCI or control group, they moved forward with the familiarization session. If they fell outside the inclusion criteria, the participant was thanked for their time and were unable to move forward with the remainder of the study. Although, if they did not meet the criteria or if they chose not to move forward with the second session even if they were eligible, the participant was provided with half the honorarium ($10) for their time.

Next, the music selection questionnaire was reviewed. The questionnaire asked a variety of questions related to the participants musical interests such as their favourite songs, artists, and/or instruments. If needed, participants could ask for assistance from the principal investigator or their guardian/caregiver/substitute decision maker. The principal investigator would focus on the participants top three song choices for their self-chosen music condition.

Following the music selection questionnaire, the State Trait Anxiety Inventory (STAI)- Trait Anxiety scale was administered to both groups. This measure was only completed during the familiarization session to gain a baseline anxiety score from each participant. The Trait Anxiety scale is a self-report questionnaire and only took about 10 minutes to complete. Participants were asked to complete the 20 questions and were able to ask for assistance from the principal investigator or their guardian/caregiver/substitute decision maker if necessary.

Finally, the RAID scale was administered only to the MCI group. The RAID scale is a short interview conducted by the principal investigator in individual meetings with the guardian/caregiver/substitute decision maker in one meeting and the participant in another. As per the instructions, the principal investigator interviewed the guardian/caregiver/substitute decision maker first to help inform the questioning about certain symptoms in the participant interview. Each session was around 10 minutes in length and each of their responses were based on their feelings two weeks prior to the session. At the end of the familiarization session, the principal investigator scheduled the participants date and time for their experimental session (roughly within one week) if the participant wanted to continue.

If the participant and/or guardian/caregiver/substitute decision maker decided they wanted to complete the familiarization session in person at the University of Manitoba in the PMI lab, the same process was administered as the remote setting and their parking fee was covered. Since all the familiarization session forms were provided to participants before their session, they had the option to fill out all the forms beforehand. Therefore, if all forms were completed before the session, the principal investigator only reviewed specific points in all the forms and asked the participant if they had any questions. Therefore, the first session took less than one hour to complete. If the participant did not fill out the forms in advance, time was given after reviewing each document for the participant to fill out. Thus, the sessions time lasted close to one hour. Around one week after the familiarization session was complete (see Appendix D) and if the participant met all the inclusion criteria, they scheduled their experimental session.

Experimental Session

On the day of the experimental session, participants screened themselves for COVID-19 symptoms using the Manitoba COVID-19 Shared Health Screening Tool. The research staff

involved did the same. One of the research staff members or the principal investigator called each participant the morning of their scheduled experimental session confirming they were feeling good to continue. If they said they were not feeling well, the session was rescheduled. If they indicated they had no COVID-19 symptoms and were feeling good, the session moved forward as scheduled. If the participant said they wanted to complete the experimental session remotely over Zoom, a research staff member delivered the research equipment (a bag containing the Dell Latitude 7410 windows data collection laptop utilizing custom software designed using E-Prime 3 with the program preloaded (and no other data), its charging block, and the experimental session forms in a large envelope including a hardcopy Likert Enjoyment scale and three copies of the STAI State Anxiety Scale questionnaire) with a contactless approach to the participants preferred place of testing.

The research staff member dropped off the research equipment in a reusable bag, and they sanitized all equipment prior to delivery. Equipment delivery was to the participants doorstep at a mutually agreed upon time (15 minutes before the scheduled Zoom experimental session) and the research staff member either called the participant or knocked on their place of residence once they arrived. If the participant requested their familiarization session forms in hardcopy format, they left their familiarization form package on their doorstep for the research staff member to collect. The research staff member returned to their motor vehicle and stayed in the area in case any issues arose.

To start, the participant used the same Zoom meeting information or link from the familiarization session sent to them through email. They would click on the link or use the ID login and password in their Zoom account through a separate computer/laptop or mobile device. Once participants were admitted into the Zoom meeting with the principal investigator, they were

greeted, and verbal assent was sought. Once verbal assent was confirmed and if the participant still indicated they would like to move forward with the study, baseline measures were taken before the first music condition. Participant's enjoyment level was measured using the hardcopy Likert Enjoyment scale (see Appendix J) and anxiety was measured using the STAI State Anxiety Scale, to look at the participant's current anxiety level in the moment. The scale took no more than 10 minutes to complete. Three copies were provided in the experimental session hardcopy package upon equipment drop-off with different titles (baseline, 1st music condition and 2nd music condition) in the top right-hand corner. Participants were asked to complete the 20 questions and would ask for assistance from the principal investigator, or their guardian/caregiver/substitute decision maker if necessary. This measure was repeated after each music condition.

After assessing for enjoyment level and anxiety, the principal investigator shared their screen to play the acquisition trial video demonstrating the task participants would perform. The video included the principal investigator performing two trials of the task, one without music and one with music. Once the video was done, we asked participants if they had any questions before moving forward. Next, we helped participants set up the data collection laptop that was dropped off to them. Participants would angle their own laptop/computer screen or mobile device so we could clearly see the data collection laptop when they interacted with it. Once the data collection laptop was open, the principal investigator provided the details needed for the participant to get onto the desktop screen of the laptop. On the desktop screen, the principal investigator asked each participant to angle the data collection laptop screen until it was in a position, they felt like they were reaching to touch the screen. Then, each participant was able to adjust themselves into a comfortable position in order to perform the task. Afterwards, the principal investigator instructed participants to double click on the folder labeled, "TASK" in the middle of the data collection

laptop desktop screen. Once inside the folder, the principal investigator asked participants to double click on the E-Prime green running man icon labeled "Movement Task OPEN ME." Next, they were instructed to put in the appropriate participant number and session number provided by the principal investigator before they followed the task instructions on the screen. After confirming they understood the instructions, the participant completed two practice trials without music for a 20-count sequence. Participants used their index finger to press 5 stationary targets on a touch screen (similar to a virtual xylophone). Each of the 5 targets have a different colored border (i.e., red, blue, yellow, green, or purple) and they were at the top of the computer screen, while the home position (black square) (where the participant placed their index finger to start the task) was at the bottom of the laptop screen closest to the participant. During the two practice trials, participants familiarized themselves with the task and after each practice trial the principal investigator confirmed if the participant felt they were reaching to tap the targets. If they verbally confirmed yes, the angle was next considered by the principal investigator before moving into the experimental trials. But if the participant verbally confirmed no or if the principal investigator felt based on visually seeing their movements through the angle their camera was positioned, the principal investigator asked if the participant could push the laptop screen back away from them to angle the screen further in order for a reaching movement to occur.

Once the practice trials were complete, each participant moved forward with the 5 experimental trials (each trial including a 20-count sequence) for the first music condition (See Appendix F). Participants used their index finger to press the same 5 stationary targets from the practice trials except this time while listening to music (self-chosen music or researcher chosen music, which were counterbalanced). The same movement sequence task was repeated for both music conditions.

The individual trial began with a blank screen with a small "+" displayed in the centre. The image lasted 1.5-2secs (known as the foreperiod) and was randomized across trials in each music condition. This allowed a slight pause to occur before the trial began and let each participant know to get ready. Once the foreperiod was over, the first music clip played (based on the condition selected). Participants placed their index finger on the home position after which the first target illuminated with its designated filled in colour. Once the participant saw the target filled in, they were instructed to quickly and as accurately as possible to tap the target. Once the target was tapped, it would return to its original bordered state. The participant then moved back to touch the home position before another target would fill in. Each participant repeated the task of moving to the identified target and returning to the home position until the 20-count sequence ended then the music stopped, indicating the end of a trial. After each trial, the participant was instructed to wait for the principal investigators cue to move forward with the next trial. During this time, the principal investigator needed to rewind the clip in Apple Music to its designated start time selected beforehand. Once the principal investigator was ready, they indicated the participant could move forward with the next trial.

Movement performance was measured during the 5 experimental trials while participants performed the movement-sequence task on the data collection laptop including touch time/reaction time, movement time, and variable error. Once participants completed their first music condition, they had a 10-minute break before they engaged in the second music condition (either self-chosen or researcher chosen music) (See Appendix D & F). Following each music condition, enjoyment level was measured through the Likert Enjoyment scale with photos of different emotional expressions (See Appendix J), which was included in the task on the data collection laptop after the 5 experimental trials were complete. This scale provided an indication if participants

enjoyment level changed in either the self-chosen music condition and/or the researcher-chosen music condition. Afterwards, anxiety was measured through the STAI State Anxiety scale following each music condition (using the appropriate sheet labeled in the top right corner based on condition) to gain insight into how they were feeling in the moment. Lastly, participants were debriefed after both music conditions were completed and reminded of the $20 honorarium the research staff member would be providing them upon equipment pick up. If a participant indicated they wanted a copy of their results on their consent form, they were reminded of this upon study completion.

After the session was completed, the principal investigator reminded the participant (and caregiver/guardian/substitute decision maker for a MCI participant) that the research staff member who dropped off the equipment was coming by to pick everything up as well as the three completed STAI state anxiety scale questionnaires within the same envelope. Participants (and/or caregiver/guardian/substitute decision maker for a MCI participant) left the bag of equipment including the data collection laptop, the charging block, and experimental session envelope on their doorstep. Then the research staff member performed a safe contactless pick up wearing a mask and appropriate PPE before returning to their motor vehicle. Afterwards, they continued to sanitize all equipment with alcohol spray and a paper towel before putting it back in the bag and dropping it off with the principal investigator to review.

For in-person testing at the University of Manitoba in the PMI lab, the principal investigator met the participant in the main lobby of 234 Investors Group Athletic Centre. Afterwards, the principal investigator brought the participant up to the second floor to complete the study within the PMI lab. The same procedure was utilized when administering the task except music was played through a Bose speaker and the data collection laptop screen was fully flat on the table. The

participant was able to adjust the laptop by bringing it to closer to them but not past the edge of the table. Throughout testing, the principal investigator set up the laptop and the task as well as provided all the forms needed (i.e., Likert Enjoyment Scale and three copies of the STAI State Anxiety Scale). As mentioned, parking was covered for participants, and they received a $20 honorarium after completing the experimental session.

Data Analysis

The dependent variables of interest were response time, variable error, and state anxiety scores. Response time was captured using E-Prime software and was defined as the duration of time in milliseconds from when the target became opaque (the signal to move) until the participant touched the target. Response time is a measure of the duration of time it took participants to plan, initiate and perform each movement to a target. Variable error was calculated as the standard deviation of the target touch locations on the computer screen measured in pixels. Variable error was calculated separately in the X and Y axes. Paired sample t-tests were used to detect statistically significant differences between music conditions for response time and variable error. Two separate one-way ANOVAs were used to detect changes in: 1) anxiety level at baseline, self-chosen and research-chosen music conditions. 2) anxiety level at baseline, in condition 1 and 2 (regardless of music condition). Prior to conducting parametric statistics, any target touches that were outside the target region were removed (see Target Misses for details on the trials removed). Each dependent variable was then assessed for normality using Shapiro-Wilks. The required level of significance for all tests was set at a $p < 0.05$. Follow-up Bonferroni corrected t-tests were conducted for any significant effects from the one-way ANOVA.

Due to limited sample size and large variation in MoCA scores, the results from the MCI participants are presented as a case series for comparison with the control group data.

Results

In the following section, the results will be presented in two sections: 1) the results of the control group; 2) the results of the mild-to-moderate cognitive impairment (MCI) group.

Control Group

Participant Characteristics

Data was collected for the first session from fourteen control participants (9 females, 5 males) who were recruited from the Winnipeg region to participate in the study. Two participants fell below the cut off of the original MoCA criteria ≤ 26/30 but did not report having received a diagnosis of MCI. However, one participant who fell below the original MoCA criteria chose not to move forward with the second session. Therefore, a total of 13 control participants completed both sessions of the study protocol (8 females, 5 males; average age 67.77 years (*SD* = 5.99), between the ages of 60-77). A summary of each control participant's MoCA score as well as the average and standard deviation (*SD*) can be found in *Table 1: Control group Montreal Cognitive Assessment (MoCA) Scores*. The average MoCA score was 26/30 (*SD* = 1.5), range- 24-29.

A summary of each control participants STAI Trait Anxiety Scale scores as well as the average and standard deviation (*SD*) can be found in *Table 2: Control Group State Trait Anxiety Inventory (STAI) Trait Anxiety Scale scores*. The questionnaire was administered during each participant's first session to gain a baseline general anxiety score out of 30. The average trait anxiety scale score was 33 (*SD* = 7), range- 22-46.

Table 3: Control Group Likert Enjoyment Scale (1-5) presents a summary of the Likert Enjoyment Scale for each control participant as well as the average and standard deviation (*SD*) at baseline and self and researcher-chosen music. The scale asks, "which facial expression best describes how you feel right now?" This scale was administered at baseline and after each music

condition. Participants completed each music condition in a counterbalanced order to gain an understanding of their enjoyment level after completing the movement base task. Enjoyment level was measured as 1 (no enjoyment), 2 (little enjoyment), 3 (mild enjoyment), 4 (moderate enjoyment), or 5 (high enjoyment). The average Likert enjoyment scale for the control participants at baseline was 4.2/5 (*SD* = 0.8), range- 2-5, for self-chosen music 4.9/5 (*SD* = 0.3), range- 4-5, and for researcher-chosen music 4.7/5 (*SD* = 0.6), range- 3-5.

Table 1. Control group Montreal Cognitive Assessment (MoCA) scores

Participant	Montreal Cognitive Assessment (MoCA) Score (/30)
C1	26
C2	26
C3	26
C4	29
C5	26
C6	27
C7	26
C9	24
C10	27
C11	26
C12	25
C13	29
C14	27
AVERAGE	**26**
SD	**1.5**
LEGEND: C- Control, SD- Standard Deviation	

Table 2. Control Group State Trait Anxiety Inventory (STAI) Trait Anxiety Scale scores

Participant	STAI Trait Anxiety Scale Score (20-80)
C1	39
C2	24
C3	35
C4	22
C5	29
C6	39
C7	33
C9	32
C10	28
C11	29
C12	30
C13	46
C14	43
AVERAGE	**33**
SD	**7**
LEGEND: C- Control, SD- Standard Deviation	

Table 3. Control Group Likert Enjoyment Scale (1-5)

Participant	Baseline	Self-Chosen Music Condition	Researcher-Chosen Music Condition
C1	5	5	5
C2	5	5	4
C3	5	5	5
C4	4	5	5
C5	4	5	5
C6	4	5	3
C7	4	5	5
C9	2	4	4
C10	4	5	5
C11	4	5	5
C12	4	5	5
C13	5	5	5
C14	5	5	5
AVERAGE	**4.2**	**4.9**	**4.7**
SD	**0.8**	**0.3**	**0.6**
LEGEND: C- Control, SD- Standard Deviation			

Response Time

As assessed by the Shapiro-Wilk's test (p = 0.148), the assumption of normality was not violated. One outlier was detected that was more than 1.5 box lengths from the edge of the box in a boxplot (the box shows the interquartile range, and an outlier is defined as 1.5 box lengths from the median). Inspection of their values did not reveal them to be extreme and they were kept in the analysis. A paired samples t-test was used to determine whether there was a statistically significant mean difference between the response times with self-chosen music compared to researcher-chosen music when participants engaged in a movement-based task. The data presents response time mean and standard deviation (*SD*) in milliseconds for each music condition. The paired sample t-test revealed there was no statistically significant difference between researcher and self-chosen music, t (12) = 0.45, p = 0.660, d = 0.125. Participants mean response times during the self-chosen music condition was 508 msecs (*SD* = 85) compared to the researcher chosen music condition 502 msecs (*SD* = 76). See *Figure 1. Control group (CG) average response time (msecs) based on music condition (n = 13)* for the control group means and standard deviation bars.

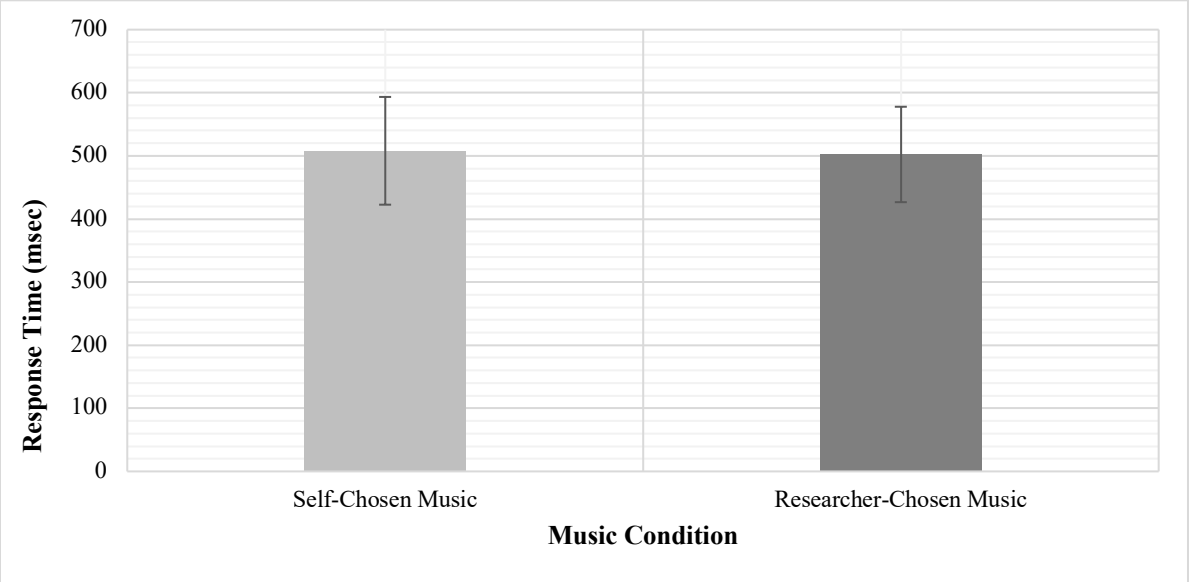

Figure 1. Control group (CG) average response time (msec) based on music condition (*n* = 13)

Variable Error

The assumption of normality for variable error in the X axis was violated, as assessed by the Shapiro-Wilk's test (p = 0.004). One outlier was detected for one participant's variable error in the X axis that was more than 3 box lengths from the edge of the box in a boxplot (the box shows the interquartile range, and an outlier is defined as 3 box lengths from the median). Due to an extreme outlier being present, visual inspection of the participants raw data in self and researcher-chosen music conditions was conducted and did not reveal any extreme outlier values (SPSS identified an extreme outlier to be 3 box lengths from the edge of the box and is identified with an Asterix (*)). However, it was determined that one participant deviated far from the mean and had a greater variability compared to other control participants. Therefore, that one participant was removed from the descriptive statistics analysis. Once the participants data was removed, the assumption of normality for variable error in the X axis was not violated, as assessed by the Shapiro-Wilk's test (p = 0.592).

A paired samples t-test was used to determine whether there was a statistically significant mean difference between the variable error in the X and Y axis with self-chosen music compared to researcher-chosen music when participants engaged in a movement-based task. The data presents variable error mean (standard deviation (SD)) for each music condition. The paired sample t-test revealed there was no statistically significant difference between self and researcher-chosen music, t (12) = -0.54, p = 0.60, d = -0.149. Participants variable error in the X axis during the self-chosen music condition was 16 pixels (SD = 4) compared to the researcher chosen music condition 17 pixels (SD = 5). *See Figure 2. CG average RX variable error (pixels) based on music condition (n = 13)* for the control group means and standard deviation bars. Note that if the outlier was included in the analysis, the results were consistent (i.e., no significant difference).

For variable error in the Y axis, the assumption of normality was not violated, as assessed by the Shapiro-Wilk's test ($p = 0.921$). There were no outliers in the data, as assessed by inspection of a boxplot. The paired sample t-test revealed there was no statistically significant difference between researcher and self-chosen music, $t\ (12) = -0.05$, $p = 0.96$, $d = -0.01$. Participants variable error in the Y axis during the self-chosen music condition, 15 pixels ($SD = 4$) compared to the researcher-chosen music condition, 15 pixels ($SD = 3$). *See Figure 3. CG average RY variable error (pixels) based on music condition (n = 13)* for control group means and standard deviation bars.

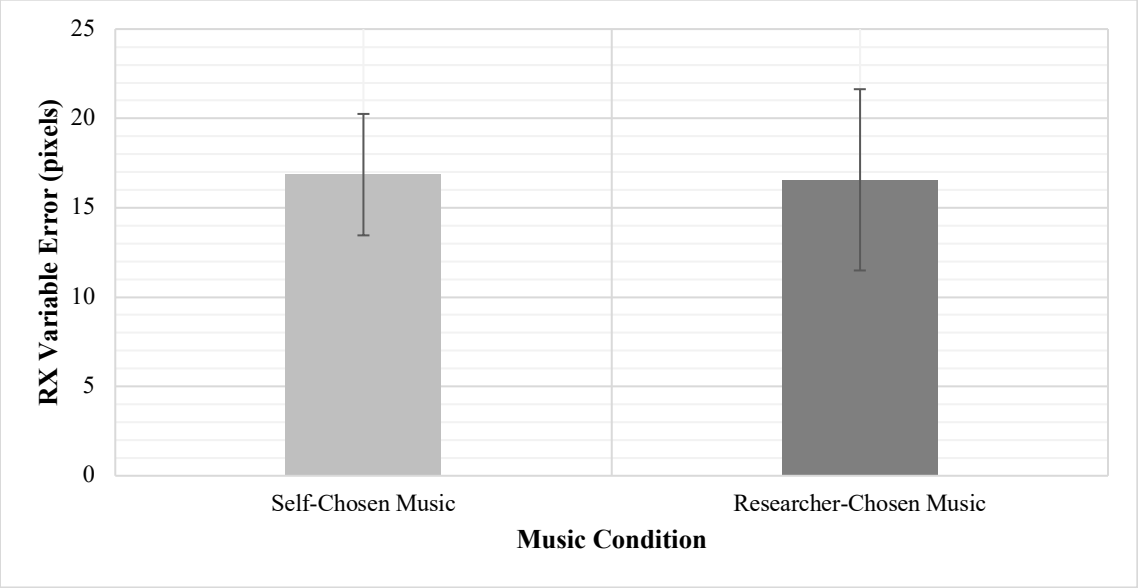

Figure 2. CG average RX variable error (pixels) based on music condition (*n* = 13)

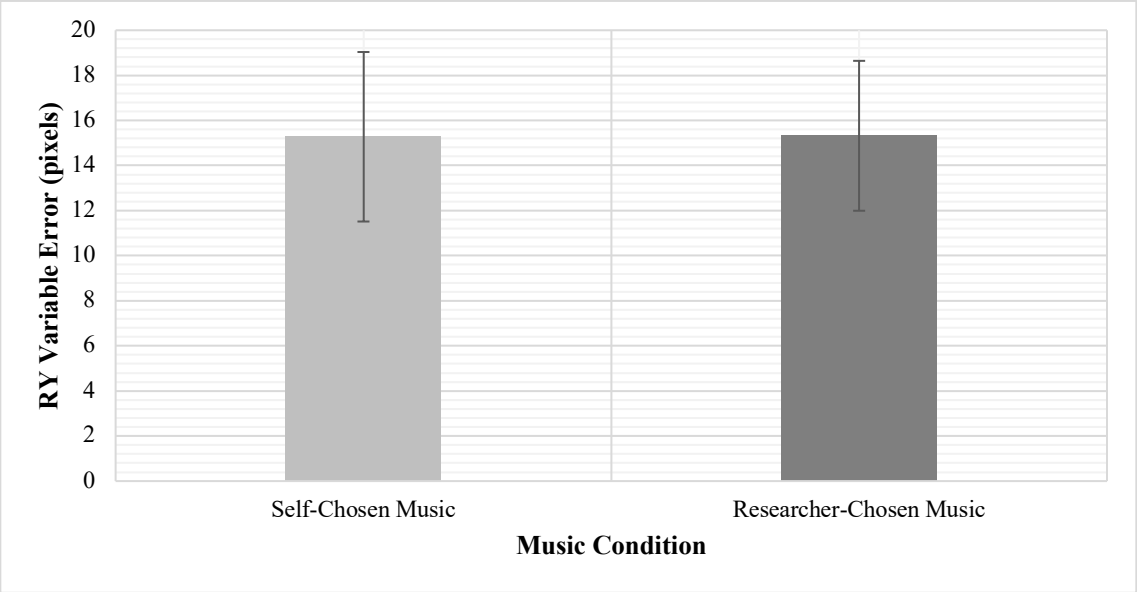

Figure 3. CG average RY variable error (pixels) based on music condition (*n* = 13)

Target Misses

Two summary tables can be found in Appendix K - Control group summary of target misses during self-chosen music condition and Appendix L - Control group summary of target misses during researcher-chosen music condition outlining the total number of target touch misses for the control participants out of the total number of target touches over 5 trials (100 total target touches) during the movement task in the self-chosen and researcher-chosen music condition. The outliers were visually removed before target analysis to present an accurate picture of the data because the participant did not hit within the target region on those trials. A target miss was measured in the X axis, Y axis, or both. On average, 1-3% of trials missed the target in the control group.

Anxiety Score

A one-way repeated measures ANOVA was conducted to determine if the State Trait Anxiety Inventory (STAI) scores decreased from baseline with self-chosen music and/or researcher-chosen music. Participants engaged in both music conditions in a counter-balanced

order. There were no outliers at baseline as assessed by boxplot; data at baseline was normally distributed as assessed by Shapiro-Wilk test ($p = 0.07$). There were outliers for the self-chosen and researcher-chosen music STAI scores as assessed by boxplot that was more than 1.5 box lengths from the edge of the box (the box shows the interquartile range, and an outlier is defined as 1.5 box lengths from the median); data during self ($p = 0.001$) and researcher-chosen music ($p = 0.01$) was not normally distributed as assessed by Shapiro-Wilk test. Visual inspection of the boxplot in self- and researcher-chosen music conditions did not reveal any extreme outlier values (SPSS identified an extreme outlier to be 3 box lengths from the edge of the box and is identified with an Asterix (*)) and they were kept in the analysis (the box shows the interquartile range, and an outlier is defined as 3 box lengths from the median). Data is presented as mean (standard deviation (*SD*)). STAI scores decreased from a baseline average score of 29 (*SD* = 7), to a researcher-chosen music average score of 24 (*SD* = 4), to a self-chosen music average score of 22 (*SD* = 4). However, Bonferroni pairwise comparisons showed that the scored differences were only statistically significant between baseline and self-chosen music ($p = 0.01$). See *Figure 4. CG average STAI State Anxiety Scale score based on music condition (n = 13)* for the control group means and *SD* bars.

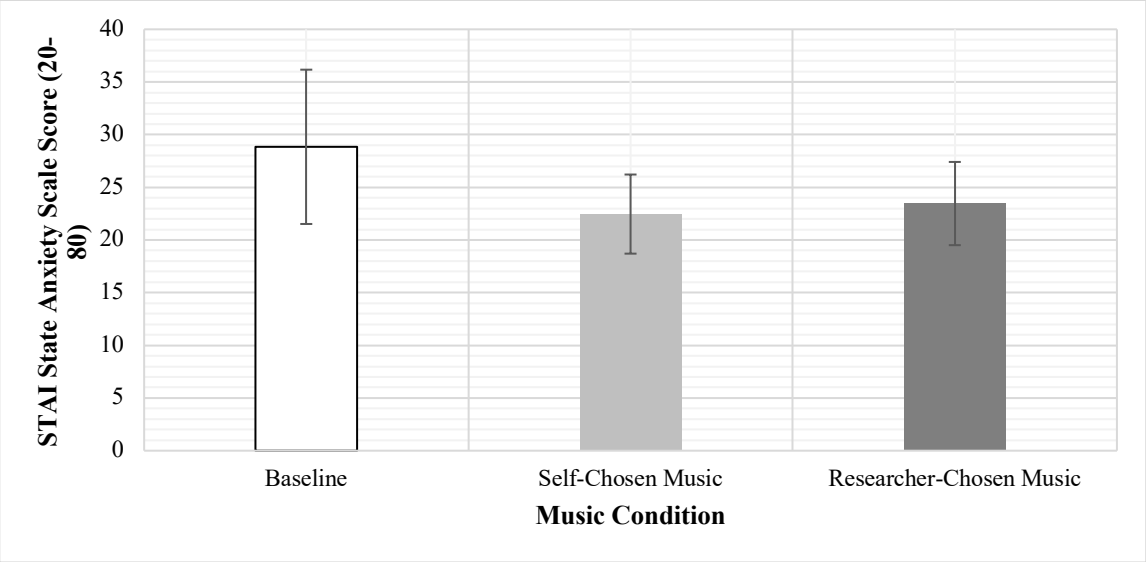

Figure 4. CG average STAI State Anxiety Scale score based on music condition (*n* = 13)

In the event that anxiety either increased or decreased as a function condition order, a one-way repeated-measures ANOVA was also conducted to determine if state-trait anxiety (STAI) scores decreased from baseline to the first music condition and the second music condition. There were no outliers at baseline and for the first music condition as assessed by boxplot; data was normally distributed at baseline as assessed by Shapiro-Wilk test (p = 0.07) but not normally distributed for the first music condition (p = 0.04) and the second music condition (p = 0.001) as assessed by Shapiro-Wilk test. One outlier was detected for the second music condition that was more than 1.5 box lengths from the edge of the box in a boxplot (the box shows the interquartile range, and an outlier is defined as 1.5 box lengths from the median). Visual inspection of the boxplot in the second music condition did not reveal any extreme outlier values (SPSS identified an extreme outlier to be 3 box lengths from the edge of the box and is identified with an Asterix (*)) and they were kept in the analysis (the box shows the interquartile range, and an outlier is defined as 3 box lengths from the median). Data is presented as mean (*SD*). STAI scores decreased from an average baseline score of 29 (*SD* = 7), to the first music condition average score of 25 (*SD*

= 5), to the second music condition average score of 21 (*SD* = 2). However, Bonferroni pairwise comparisons showed that the scored differences were only statistically significant between baseline to the second music condition (p = 0.003) and between the first and second music condition (p = 0.03). See *Figure 5. CG average STAI State Anxiety Scale score based on music condition order (n = 13)* for the control group means and standard deviation bars.

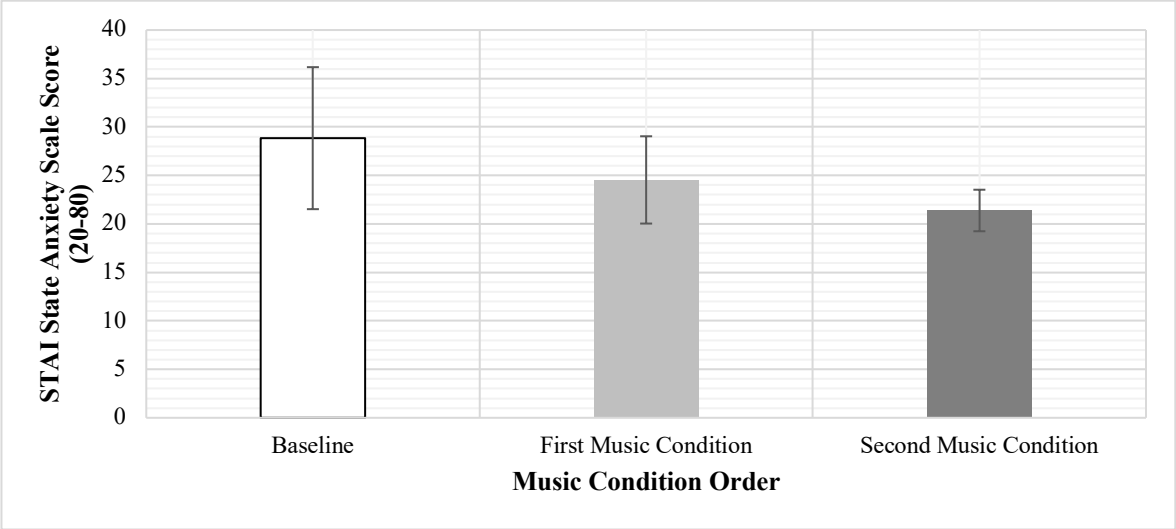

Figure 5. CG average STAI State Anxiety Scale score based on music condition order (*n* = 13)

Mild-to-Moderate Cognitive Impairment (MCI) Case Series

Participant Characteristics

Three participants with MCI (2 females, 1 male; average age of 72.33 years (*SD* = 11.24), between the ages of 60-82) participants took part in the study. Their Montreal Cognitive Assessment (MoCA) scores are presented in *Table 4. MCI group MoCA scores (/30)*. The average MoCA score was 18/30 (*SD* = 7.6). It should be noted that one participant had a score of 25/30. The decision to include this participant in the case series was made because they also self-reported having received a diagnosis of MCI.

A summary of the STAI Trait Anxiety Scale scores for the participants as well as the average and standard deviation (*SD*) can be found in *Table 5. MCI group STAI Trait Anxiety Scale Scores*. The average trait anxiety scale score was 34 (*SD* = 11).

A summary of the Likert Enjoyment Scale for participants MCI1, MCI2, and MCI3 as well as the average and standard deviation (*SD*) can be found below in *Table 6. MCI group Likert Enjoyment Scale (1-5)*. Participants completed each music condition exactly as the control group in a counterbalanced order. Enjoyment level was measured as 1 (no enjoyment), 2 (little enjoyment), 3 (mild enjoyment), 4 (moderate enjoyment), or 5 (high enjoyment). The average Likert enjoyment scale for MCI1, MCI2, and MCI3 at baseline was 3.7/5 (*SD* = 0.6), for self-chosen music 4.3/5 (*SD* = 1.2), and for researcher-chosen music 4.7/5 (*SD* = 0.6).

Table 4. MCI group MoCA scores (/30)

Participant	Montreal Cognitive Assessment (MoCA) Score (/30)
MCI1	10
MCI2	20
MCI3	25
AVERAGE	**18**
SD	**7.6**
LEGEND	**MCI- Mild-to-Moderate Cognitive Impairment, SD- Standard Deviation**

Table 5. MCI group STAI Trait Anxiety Scale Scores

Participant	Trait Anxiety Scale Score
MCI1	23
MCI2	34
MCI3	45
AVERAGE	**34**
SD	**11**
LEGEND	**MCI- Mild-to-Moderate Cognitive Impairment, SD- Standard Deviation**

Table 6. MCI group Likert Enjoyment Scale (1-5)

Participant	Baseline	Self-Chosen Music Condition	Researcher-Chosen Music Condition
MCI1	3	5	5
MCI2	4	5	5
MCI3	4	3	4
AVERAGE	**3.7**	**4.3**	**4.7**
SD	**0.6**	**1.2**	**0.6**
LEGEND: MCI- Mild-to-Moderate Cognitive Impairment, SD- Standard Deviation			

Response Time

In *Figure 6. MCI group response times (msec) based on music condition (n = 3),* the individual response times for MCI1, MCI2, and MCI3 are demonstrated respectively. The mean and standard deviation (*SD*) is presented for each MCI participant. Figure 6 shows the mean and *SD* response times for MCI1 with self-chosen music, 875 msecs (*SD* = 881) and researcher-chosen music, 984 msecs (*SD* = 699); the difference between the two conditions was 109 msecs (984-875), MCI2 with self-chosen music, 602 msecs (*SD* = 192) and researcher-chosen music, 594 msecs (*SD* = 64); the difference between the two conditions was 8 msecs (602-594) and MCI3 with self-chosen music, 580 msecs (*SD* = 163) and researcher-chosen music, 592 msecs (*SD* = 152); the difference between the two conditions was 12 msecs (592-580). Therefore, for two participants there was no change in music condition, whereas for one participant (MCI1) there was 109 msec improvement with the self-chosen music condition.

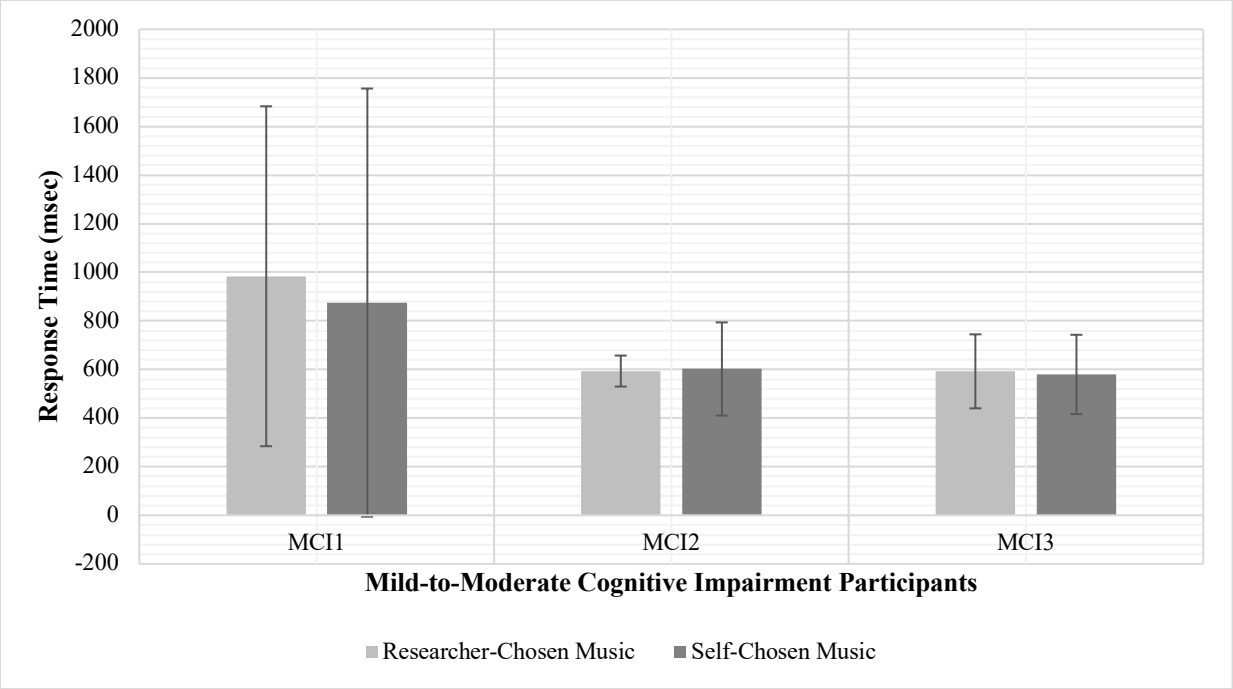

Figure 6. Mild-to-Moderate Cognitive Impairment (MCI) group response times (msec) based on music condition (*n* = 3)

Variable Error

The individual average variable error in the X axis, which includes the mean for MCI1, MCI2, and MCI3 respectively is demonstrated in *Figure 7. MCI group average RX variable error (pixels) based on music condition (n = 3)*. *Figure 7* shows the mean variable error in the X axis for MCI1 with self-chosen music, 15.4 pixels and researcher-chosen music 15.1 pixels; the difference between the two conditions was 0.3 pixels (15.4-15.1), MCI2 with self-chosen music, 13.0 pixels and researcher-chosen music, 12.5 pixels; the difference between the two conditions was 0.5 pixels (13.0-12.5), and MCI3 with self-chosen music, 22.7 pixels and researcher-chosen music 23.7 pixels; the difference between the two conditions was 1.0 pixel (23.7-22.7). *Figure 8. MCI group average RY variable error (pixels) based on music condition (n = 3)* demonstrates the average individual variable error in the RY axis, which includes the mean and *SD* for MCI1, MCI2, and MCI3 respectively. *Figure 8* shows the mean variable error and *SD* in the Y axis for MCI1 with self-chosen music, 21.1 pixels and researcher-chosen music 20.6 pixels; the difference

between the two conditions was 0.5 pixels (21.1-20.6), MCI2 with self-chosen music, 12.4 pixels and researcher-chosen music 11.4 pixels; the difference between the two conditions was 1.0 pixel (12.4-11.4) and MCI3 with self-chosen music, 23.9 pixels and researcher-chosen music 19.0 pixels; the difference between the two conditions was 4.9 pixels (23.9-19.0). For the horizontal axis (RX), two participants had no change in music condition, whereas one participant had a slight 1.0-pixel improvement with self-chosen music. For the vertical axis (RY), all three participants had slightly more consistent movements with researcher-chosen music than self-chosen music, except one participant (MCI3) had a 4.9-pixel difference between conditions.

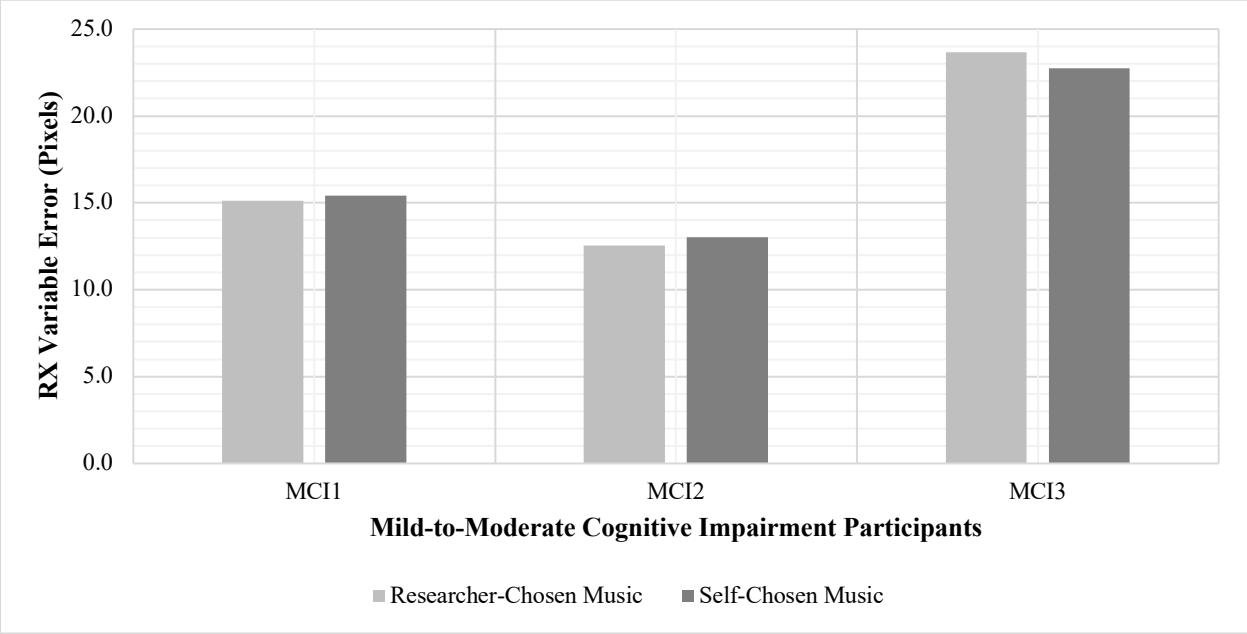

Figure 7. MCI group average RX variable error (pixels) based on music condition (*n* = 3)

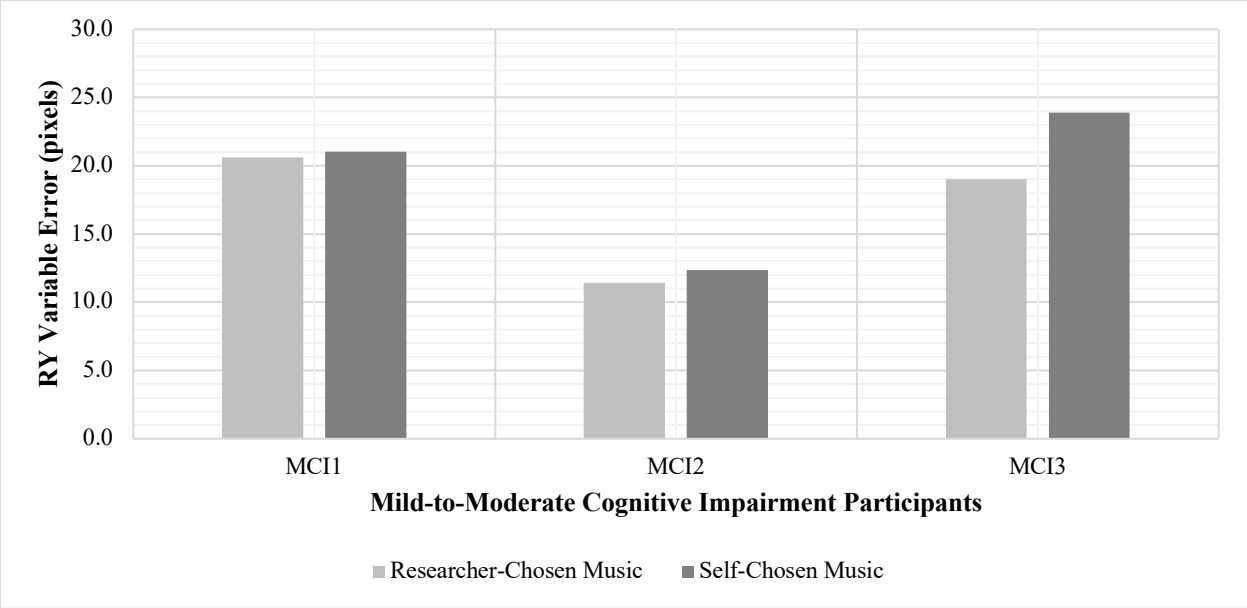

Figure 8. MCI group average RY variable error (pixels) based on music condition (*n* = 3)

Target Misses

Two summary tables can be found in Appendix M - MCI group summary of target misses during self-chosen music condition and Appendix N - MCI group summary of target misses during researcher-chosen music condition. Together these tables outline the total number of target touches missed out of the total number of target touches over 5 blocks of trials (100 total target touches) during the movement task in the self-chosen and researcher-chosen music condition. A target miss was measured in the X axis, Y axis, or both. The target misses were removed before calculating participants means. This was done to present an accurate picture of their movement data when completing the task by hitting the target. On average, 1-2% of trials missed the target in the MCI group.

Anxiety Score

The average STAI State Anxiety Scale scores based on music condition is demonstrated in *Figure 9. MCI group STAI State Anxiety Scale score (20-80) based on music condition (n = 3)*, for MCI1, MCI2, and MCI3 respectively. *Figure 9* the individual state anxiety score for MCI1 at

baseline 32, self-chosen music 21, and researcher-chosen music 30; the difference between the two conditions was 9. For MCI2 at baseline 31, self-chosen music 24, and researcher-chosen music 28; the difference between the two conditions was 4. Lastly, MCI3 at baseline 38, self-chosen music 54, and researcher-chosen music 48; the difference between the two conditions was 6. For two participants there was a decreased anxiety score with the self-chosen music condition, whereas for one participant there was a 6 score increase with self-chosen music. *Figure 10. MCI group STAI State Anxiety Scale score (20-80) based on music condition order (n = 3)* demonstrates the individual state anxiety scale scores based on music condition order, which includes the individual score for MCI1, MCI2, and MCI3 participants. *Figure 10* shows the individual score for MCI1 at baseline 32, first music condition 30, and second music condition 21. For MCI2 at baseline has a score of 31, first music condition 28, and second music condition 24, and MCI3 at baseline 38, first music condition 48, and second music condition 54. For two participants there was a decreased anxiety score with the second music condition, whereas for one participant there was a 6 score increase with the second music condition. The Rating Anxiety in Dementia (RAID) scale was administered to MCI1, MCI2, and MCI3 participants and their caregivers. A score of >11 suggests clinical anxiety. *Table 7. Rating Anxiety in Dementia (RAID) scale scores* shares the results of the RAID scale for each participant and their caregiver.

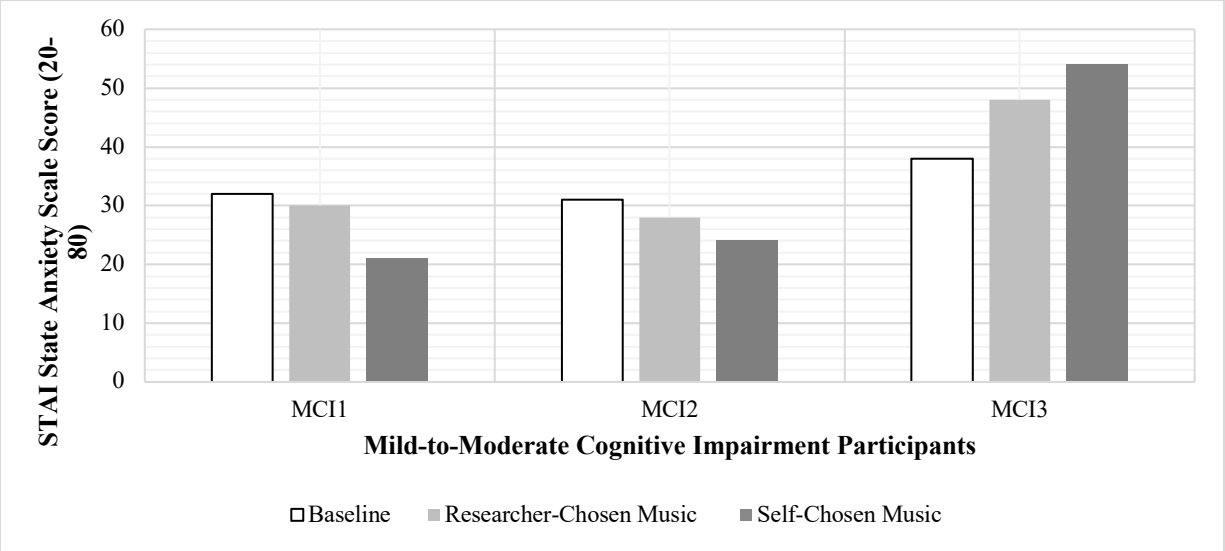

Figure 9. MCI group STAI State Anxiety Scale score (20-80) based on music condition (*n* = 3)

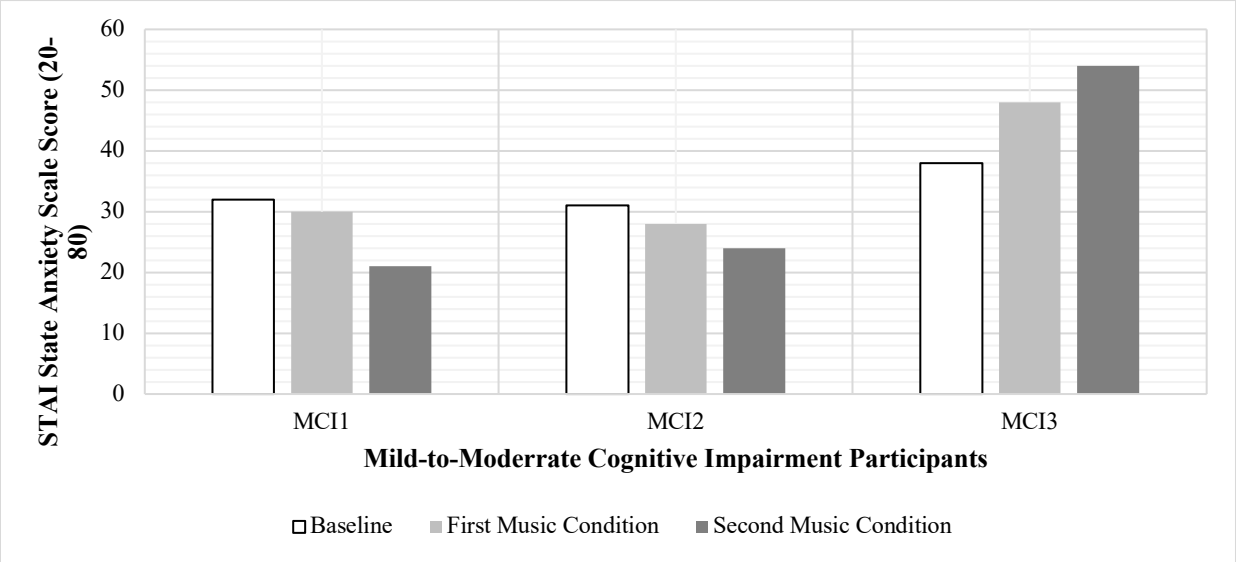

Figure 10. MCI group STAI State Anxiety Scale score (20-80) based on music condition order (*n* = 3)

Table 7. Rating Anxiety in Dementia (RAID) scale scores

Rating Anxiety in Dementia (RAID) Scale Scores		
Participant	**RAID Score**	**Total**
MCI1	Caregiver: 7, CI1: 6	<11 No Clinical Anxiety
MCI2	Caregiver: 15, CI2: 15	>11 Clinical Anxiety
MCI3	Caregiver: 8, CI3: 24	>11 Clinical Anxiety
LEGEND: MCI- Cognitive Impairment		

Discussion

The purpose of the study was to assess if self-chosen music compared to researcher-chosen music would lead to greater improvements in anxiety and movement performance (i.e., response time and variable error) for older adults with and without mild-to-moderate cognitive impairment (MCI). Improved movement performance was defined as more efficient, consistent, and accurate movements. Reduced anxiety was defined as a reduction in state anxiety as measured by the State Trait Anxiety Inventory (STAI). We predicted the positive influence of music on anxiety and enjoyment level would be greater with self-chosen music compared to researcher-chosen music (Davison et al., 2016; El Haj et al., 2015, 2012; Gómez Gallego & Gómez García, 2017; Stork et al., 2015; Sung et al., 2012). In addition, we predicted that older adults without MCI would benefit but would show reduced or no differences between self and researcher-chosen music (El Haj et al., 2015). Due to participants not choosing music for an identified purpose, there were differences in movement performance response time across participants given there were a variety of beats per minute (bpm) across their song choices. Participants were likely linking their movements to the bpm resulting in a wide range of response times as a result of the music (Thaut et al., 2005).

We reported a case series design with a group of 13 control participants and three participants with MCI. Movement performance was quantified using response time (i.e., movement time and reaction time/touch time), variable error (in both X and Y axis). Trait and state anxiety were quantified using the State Trait Anxiety Inventory (STAI) State Anxiety Scale. Enjoyment was also quantified using the Likert Enjoyment scale (1-5) and the Montreal Cognitive Assessment (MoCA) was used to measure cognition level to determine eligibility for the MCI group and control group.

Summary of Results

Music enjoyment levels were 5/5 for 2/3 participants in both conditions whereas 1/3 participants reported a 3/5 enjoyment for the self-chosen music condition and a 4/5 for the researcher-chosen music condition. The latter participant reported that enjoyment level gradually decreased overtime due to pain associated with the repetitive movements within the reaching task. For the control group, we found the average enjoyment level was slightly higher in the self-chosen music condition (Enjoyment level = 4.9; *SD* = 0.3) than the researcher-chosen music condition (Enjoyment level = 4.7; *SD* = 0.6). The lack of separation in the enjoyment scores indicates the control participants enjoyed both songs equally, regardless of music condition and condition order. Given the small difference between both music condition response times and enjoyment levels, music enjoyment may have played a greater role than participant autonomy.

In the control group there was no statistically significant difference in response time and variable error in both the horizontal and vertical axes between self-chosen and researcher chosen music. As indicated above, given the generally high rating of music enjoyment across both conditions, it is possible that music enjoyment may have a played a greater role when engaging in the movement-based task than autonomy of choice.

The case series for the MCI group is smaller and any interpretations must be made cautiously. In the mild-to-moderate MCI group, we found response times to be shorter in the self-chosen music condition than the researcher-chosen music condition for 2 out of the 3 participants. The results from the participant with moderate MCI (right on the edge of severe) (MoCA = 10/30) demonstrate that response times support the original hypothesis where their response time is shorter with self-chosen music. As this is only one participant, additional data focused on participants with moderate MCI specifically should be compared. Based on the pattern of results,

there is some evidence that MoCA score may be an important consideration when deciding if the use of familiar self-chosen music may impact movement performance. That is, one participant had a MoCA score in the moderate range (MoCA = 10/30), and for that participant performance in the self-chosen music was improved by 109 msecs, with slightly less consistency in movements (i.e., VE). Future research with a larger sample size that considers the MoCA score is warranted to further investigate this explanation.

Variable error for the MCI group in both axes demonstrated more consistent movements within the researcher-chosen music condition compared to the self-chosen music, except for one participant who had slightly more consistent movements for the self-chosen music condition in the horizontal axis specifically (1.0-pixel difference). The results show that variable error for the self-chosen music condition barely differed in the horizontal and vertical axes compared to the researcher-chosen music condition. Overall, movement performance showed slightly more consistent movements with researcher-chosen music compared to self-chosen music except for the one participant mentioned in the horizontal axis having a 1-pixel improvement during self-chosen music.

State Trait Anxiety Inventory (STAI) State Anxiety Scale scores based on music condition (baseline, self-chosen music, researcher-chosen music) demonstrated lower scores during self-chosen music than researcher-chosen music for two of the three participants with MCI. For the third the self-chosen music anxiety score was higher than researcher-chosen music. Alternatively, when you look at the STAI State Anxiety Scale scores based on condition order (baseline, first music condition, second music condition), rather than the specific music condition, the anxiety score for two participants decreased with time whereas the third participant's state anxiety score

gradually increased. From this third participant's feedback after the second session, the repeated movement was creating some discomfort, which is consistent with the increase in state anxiety.

For the STAI State Anxiety Scale average scores for the control group based on music condition, there was a statistically significant difference between baseline and self-chosen music regardless of order. However, the order of the music condition was also clearly important. When looking at the STAI State Anxiety Scale average scores based on music condition order, there was a statistically significant difference between baseline and the second music condition as well as between the first condition and second condition. This demonstrates that overtime participants anxiety scores decreased regardless of music condition.

Overall, movement performance (response time and variable error) and anxiety scores supported the original hypothesis where the control group had high enjoyment of the music but showed no differences between self- and researcher-chosen music. Overall, this pattern of results supports the notion of music enjoyment being a key factor influencing movement performance and anxiety scores. In contrast, autonomy may be less important for the control group.

Influence of Autonomy

Exercising choice (autonomy) is an area of the literature that has been extensively researched and has provided great insight into the present study. In the motor learning literature, it has been reported that giving the learner control over certain aspects of the practice conditions or task enhances motor skill learning (Wulf & Lewthwaite, 2016; Ziv & Lidor, 2021). OPTIMAL theory and information processing perspectives support the notion that exercising choice can help to improve motor performance and contribute to motor learning as well as support the benefits of self-controlled practice and feedback schedules (Wulf & Lewthwaite, 2016; Ziv & Lidor, 2021). Providing learners with choices and control over even a small part (or irrelevant feature) of the

task have been shown to improve motor learning. However, for the control participants, this was not the case in the present study. It appears that enjoyment, not autonomy, was the driving factor for performance. Other researchers have also failed to find support for the benefit of autonomy. For example, in St. Germain et al., (2022), exercising choice during practice did not increase perceptions of autonomy, competence, or intrinsic motivation (i.e., enjoyment), nor did it lead to more accurate error estimation skills to improve motor learning. The study suggests that self-controlled conditions (i.e., providing learners with choice) are not a universally effective approach to enhance motor performance and learning (St. Germain et al., 2022). The current results provide additional evidence that the effect of choice and autonomy needs to be considered in the context of enjoyment and other factors known or thought to improve motor performance and learning (Bacelar et al., 2022; Carter & Ste-Marie, 2017; Leiker et al., 2019; McKay & Ste-Marie, 2020, 2022; St. Germain et al., 2022; Yantha et al., 2022).

While each participant provided their top three songs that they would like for their self-chosen music condition, the researcher-chosen music was selected based on the decade and genre that they enjoyed. The decision to keep the researcher music similar was to work to keep as many details of the music as similar as possible. The challenge of this was that participants rated high enjoyment for the research chosen music as well. Given how similar motor performance was between the two conditions, exercising choice does not appear to be significant when engaging with the movement task for both the MCI group and control group. In Stork and Colleagues (2015), participants were asked to provide their top six song choices (ranked in order of preference) that they would enjoy listening to while exercising. These songs were then used to create a personalized music playlist tailored to each participant to engage in sprint interval training (SIT) (Stork et al., 2015). They found that music improved the enjoyment of SIT while enhancing acute exercise

performance as well as perceived enjoyment significantly increased overtime and was consistently higher in the music condition compared to the no music condition (Stork et al., 2015). Therefore, participants had the choice to choose their music and what they would like to listen to, which in turn may have enhanced their perceived enjoyment while exercising. This demonstrates that providing each participant the choice to choose their own music preferences can benefit performance as well as enjoyment. Although, if music preferences were provided and different song choices were selected for a researcher-chosen music condition (within the same decade and genre) rather than a no music condition, this may have demonstrated the same effect. Thus, resulting in music enjoyment being a crucial factor to consider over autonomy.

Hewston et al. (2022), utilized purposeful rhythmic whole-body movement (such as dance) and paired the movement with music from the 1950s and 60s for older adults who were 60+ years-old and with mild cognitive impairment or mobility impairments. These authors provided participants no choice in which music was played during the group dance class. Consistent with the present findings, pairing music based on the age of the population demonstrated enhanced music enjoyment for the GERAS dance program as a result of the feedback received after the program was completed (Hewston et al., 2022). Another interesting factor was the graded approach to learning each step in the dance routine and finding the beat, which maximized the likelihood of success by emphasizing having fun while learning something new (Hewston et al., 2022). Repetition was used to build confidence in movement patterns, which is something that also occurred in the present studies movement-based task (Hewston et al., 2022). Participants engaged in two practice trials to familiarize themselves with the task before engaging in the 5 trials with music. This allowed the MCI group as well as the control group the added confidence to ask questions and feel comfortable with the task in order to perform each of the 5 trials to the best of

their ability. The reduction in anxiety associated with continued practice over the two music conditions (for most participants) is also consistent with the benefit of task practice. Given the nature of the GERAS dance program, which was using a group setting, in can be difficult to include individual choice. Evidence that enjoyment is an important factor, regardless of autonomy, provides additional evidence for the value of working to tailor music based on age and interests. One approach could be using music from specific decades or genres to promote music enjoyment. Additionally, asking participants and/or family members about music preferences beforehand and basing music selection on the majority of participants' preferred or familiar music may be another option to consider for music enjoyment (Sung et al., 2012).

Influence of Enjoyment

Music is quite remarkable and has the ability to induce strong and diverse emotions as well as multiple cognitive functions and neural circuits in the brain (Vuilleumier & Trost, 2015). Music is an ideal medium to promote enjoyment (i.e., intrinsic motivation) and can activate motor networks. Specifically, entrainment of brain activity by music can activate various relays of the motor system, which can be observed as involuntary movements in the listener, such as tapping the foot or swinging the head along to the beat (Vuilleumier & Trost, 2015). Music can also provide connection and possibly entrainment of one's movements to the beat of the music that they enjoy. This research demonstrates music enjoyment may play a critical role in movement performance as participants may have been linking their movements to the beat creating music-induced emotions. These types of emotions have been reported to produce powerful entrainment effects on several bodily and cognitive processes (Vuilleumier & Trost, 2015).

Rhythmic entrainment refers to the synchronization phenomena where neural activity in the brain and/or heartrate are modified by the rhythmic structure and tempo of auditory inputs such

that they may eventually lock onto a common cycle in intervals/periodicity (Galiñska, 2015; Juslin et al., 2010). For example, during the movement-based task participants may have been entraining their movements to sync with the beat of the chosen song producing a consistent tempo. The capacity of music to engage various circuits in the brain makes it a powerful training tool to modulate behaviour and cognition (Vuilleumier & Trost, 2015). For the present study the beats per minute (bpm) were kept as similar as possible, which likely contributed to the similar response's times given the mechanism of entrainment.

Music provides a wide range of benefits as well as a rich cognitive, sensory, and motor experience, with strong affective and motivational components (Galiñska, 2015; Vuilleumier & Trost, 2015). This information may support the music enjoyment results of the present study for the 2/3 participants with MCI as well as the control group. Besides feelings of joy and sadness, music tends to evoke a wide range of complex emotions that are also considered from a neurobiological point of view as wonder, transcendence, or nostalgia (among others) (Vuilleumier & Trost, 2015). These emotions may constitute a particular kind of aesthetic experience, which are associated with feelings of sublimity and engagement of more cognitive components, unlike more basic emotions (Vuilleumier & Trost, 2015). Each participant in the present study had their own unique music experience for each condition, and they likely experienced music-evoked emotions that may have resulted in high enjoyment of both self-and researcher-chosen music.

Additionally, participants did not have the choice to choose which music condition they would like to perform first. The conditions were randomized and counterbalanced to see if music order had any effect on the dependent variable measurements. In the mild-to-moderate MCI group, by virtue of the pre-determined randomization all participants had researcher-chosen music presented first followed by self-chosen music. Therefore, this may have had a practice effect and

allowed participants to become familiar with the task to improve their dependent variable measurements and therefore task enjoyment overtime when the self-chosen music condition was administered in the second session. For the control participants, there were seven individuals who had the self-chosen music condition for their first session and six individuals who had researcher-chosen music for their first condition. Based on the results gathered, there was no statistically significant difference between the music conditions demonstrating that even though music condition order was counterbalanced, it may have not been a factor given the high enjoyment levels throughout. In related research, self-chosen music over a no music condition has demonstrated enhancements in 18–30-year old's performance and perceived enjoyment of sprint interval exercise (Stork et al., 2015). Additionally, increasing exercise enjoyment may have an effect to increase adherence to exercise in the long term (Stork et al., 2015). Applying this knowledge to the present study, this supports the notion that music enjoyment may be a key factor to continue engaging in movement performance activities to improve motor learning.

To summarize, the present studies results do not align with OPTIMAL theory specifically with the control group because it appears that enjoyment, not autonomy, was the driving factor for performance.

Limitations

A major limitation that presented difficulty throughout the study was the COVID-19 pandemic resulting in a small sample size. This caused the study to take a drastic turn from being in-person originally to an online format over Zoom. Due to the quick change, the world had to adapt to this new reality based on online platform technology many were not familiar with such as the older adult population. This population already has a stigma surrounding them regarding the limited knowledge, and performance they have around technology but providing educational

resources to promote awareness and perception may help older adults grow to fight the stigma (Chen, 2020; Tam et al., 2017). Therefore, difficulties were presented regarding recruitment when it came to the target population with the repeated COVID-19 waves throughout the timeframe of the study and the huge reliance on technology as a result.

Another limitation was the variability in the testing laptop screen angle. During the second session, when the testing laptop was dropped off with the participant, it was recommended they find a comfortable seated position preferably at a table the laptop can rest on such as at a dining room table. Throughout the study, the principal investigator verbally asked each participant if they felt they were reaching to touch the targets on the screen during the practice trials without music. Once participants angled the screen to make any adjustments and confirmed they felt they were reaching to touch the targets, the session continued. The issue here was a large amount of variability may have occurred due to the different screen angles that were comfortable for each participant and may have affected the results gathered.

The last limitation found was for the MCI group, each participant received the researcher-chosen music condition first followed by self-chosen music in the second condition. Music condition was randomized and counterbalanced by pulling an envelope out of a box that contained a slip of paper with the music condition written on it. Therefore, additional data is needed to clarify if anxiety level continued to decrease because their self-chosen music song was in the second condition. If the self-chosen music condition was presented first, we may have seen a different pattern of results.

Future Directions

Given the evidence for the importance of music enjoyment, one future recommendation for the present study is to look at music selection that participants do not enjoy. For example,

instead of finding music within a genre they did select from their music selection questionnaire, we could select music from a genre they did not select and find a song within the same decade and within 5 bpms. This would allow us to understand if music choice may factor in more than music enjoyment.

Also, selecting a genre they enjoy and selecting three songs with distinct bpms (slow, moderate, and fast) and seeing how each participant moves at different speeds may be another direction for future research. Humans are known to entrain their movements to the beat of the music, which may result in a variety of movement speeds (various response times). Therefore, this creates added variability due to bpm that could be controlled. For instance, making sure each song played is within 5 bpm of a certain set bpm limit range for slow, moderate, and fast beats. Participants can provide at least three genres they enjoy on the music selection questionnaire and provide at least 3 songs from each genre. Then during the task, one song will be played from each genre to see if participants movements are different based the different bpm. Additionally, we can measure if participants are linking their movements to the beat of the music or focusing on completing the task and not the beat. In this case, we may show bpm is a factor when it comes to creating an accurate representation of response time.

Another recommendation may be adding a no music condition with the self and researcher-chosen music conditions. We only had 2 practice trials without music present before the 5 music trials. The two practice trials were included so participants had time to familiarize themselves with the task and setup before dependent variable measurements were recorded. In an effort to keep data collection to a reasonable duration a separate no music condition was not included. Considering how a no music condition could be included would be beneficial to see if no music present in the movement task had any differences with the self- and researcher-chosen music

conditions. Based on the previous research, we expect conditions with music to be improved relative to no music (El Haj et al., 2015, 2012; Stork et al., 2015; Thompson et al., 2005).

Future research may also look to focus on whole body and multi-limb movements such as dance and or other movements participants enjoy in a 1:1 setting. Participants could engage in a similar sequential movement task as the one presented in the current study but adapted for the lower body. Lastly, this may contribute to the literature as a potential new line of research to help persons with MCI interact with their environment and improve their activities of daily living all through engaging with the music they enjoy.

Conclusion

Although preliminary, the results of the present study can help guide evidence informed practice for nurses, recreation therapists, and many other health care professionals to understand the best ways to use music for activities to engage seniors with mild-to-moderate cognitive impairment (MCI). Specifically, according to the results of the current thesis, music enjoyment appears to play a larger role than autonomy for promoting task performance and reducing anxiety. The case series presents a similar pattern of results. The value in continuing future-controlled trials is needed to explore the benefits of participant/caregiver music selection, music enjoyment and participation in music and movement programs with larger sample sizes to better understand the relationship between MoCA score and the influence of familiar self-chosen music. The effective combination of music and movement may have the potential to overcome barriers to participation in physical activity, promote the benefits of cognitively engaging physical activity and to improve overall quality of life for individual and their families living with MCI (Kattenstroth et al., 2013; Müller et al., 2017; Rehfeld et al., 2018b, 2018a; Verghese et al., 2003; Weise et al., 2018).

With the growing population of older adults, non-pharmaceutical therapeutic interventions are needed to help society cope as chronic disease levels also increase. Combining meaningful music with movement may access alternative neural pathways to engage in various activities, providing benefits for physical, cognitive, and mental health. Future research will investigate possible neural sources for improvements in motor performance and anxiety when hearing a personal song as well as potential improvements in quality of life. In addition, potential studies will compare dance, music production and cognitive social activity interventions to determine if playing music (i.e., drumbeat) can improve outcomes more so than engaging in an activity with music, such as dance. Music combined with movement may improve the quality of life, enjoyment, and independence of those diagnosed with MCI. Future research is this area is warranted to develop the necessary knowledge and understanding to continue to make a positive impact in the growing dementia community.

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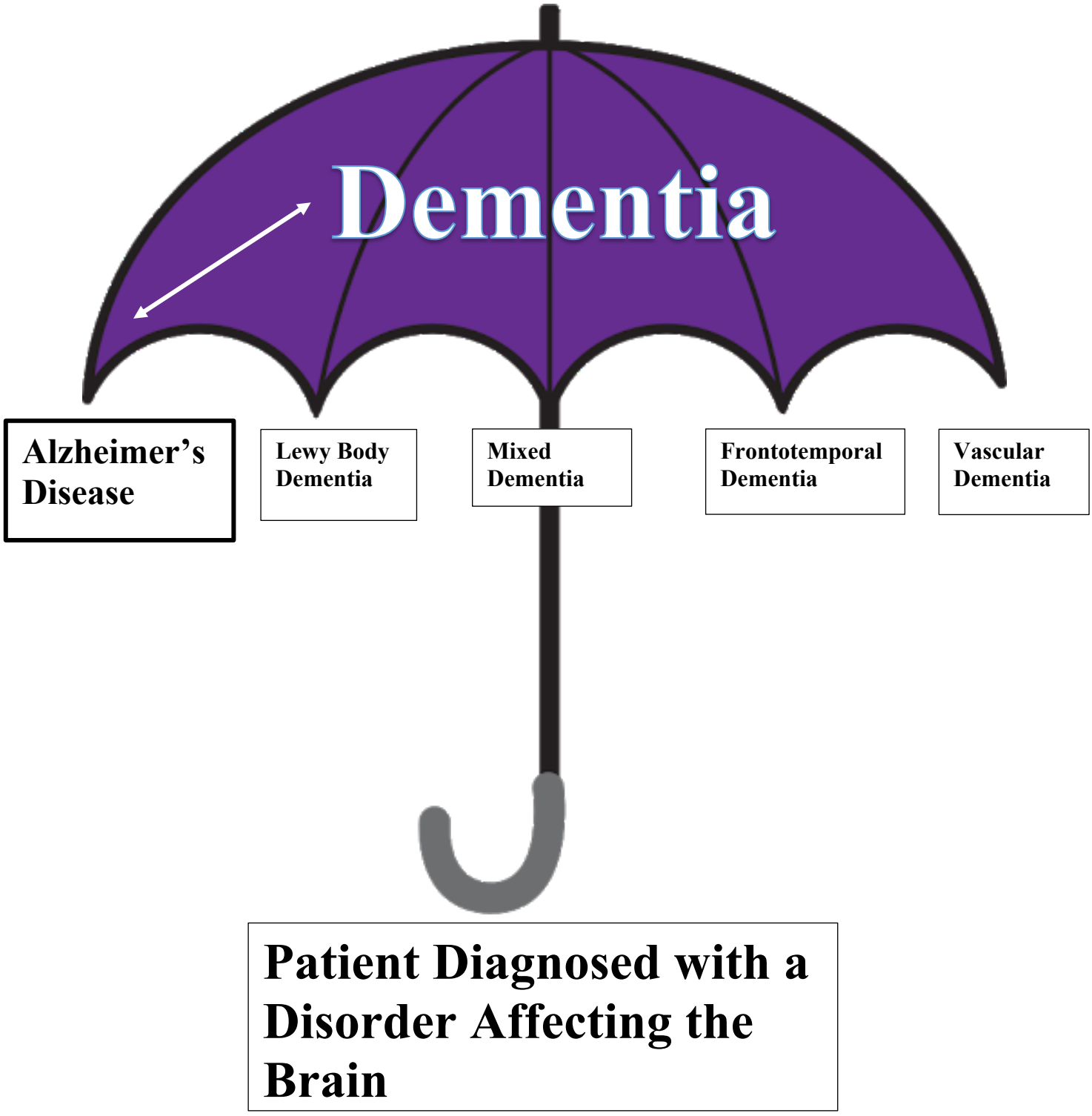
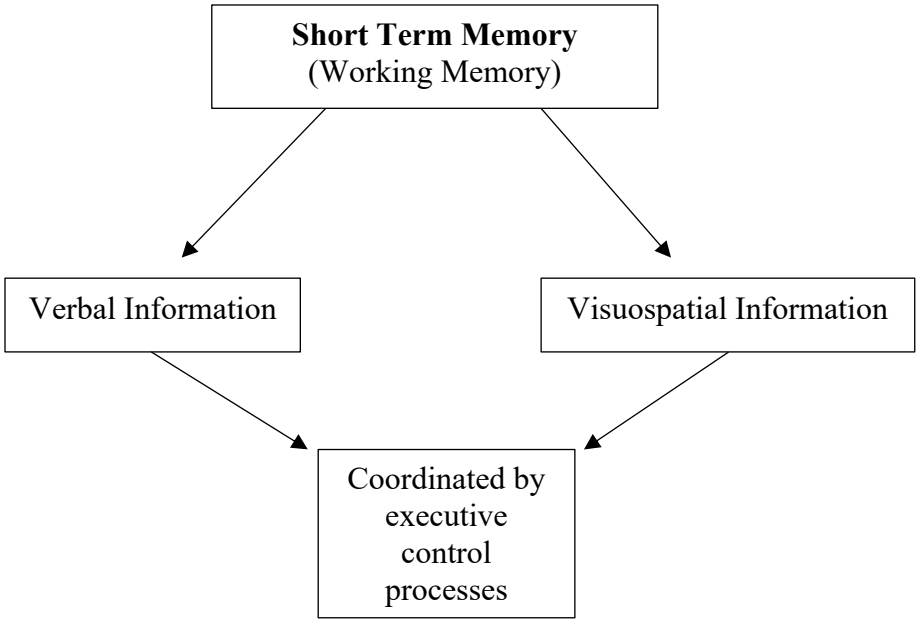
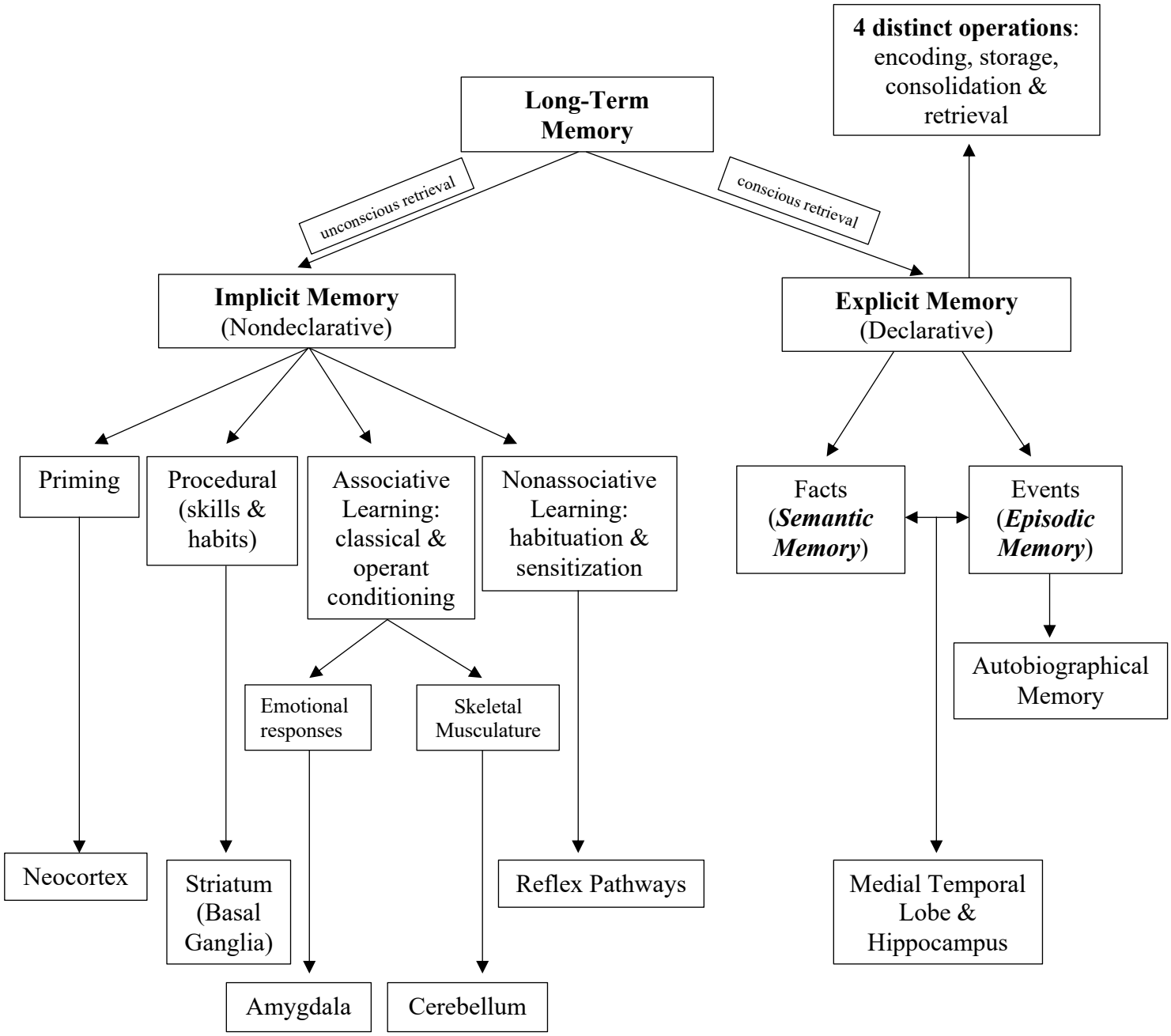
Appendix A – Defining Dementia



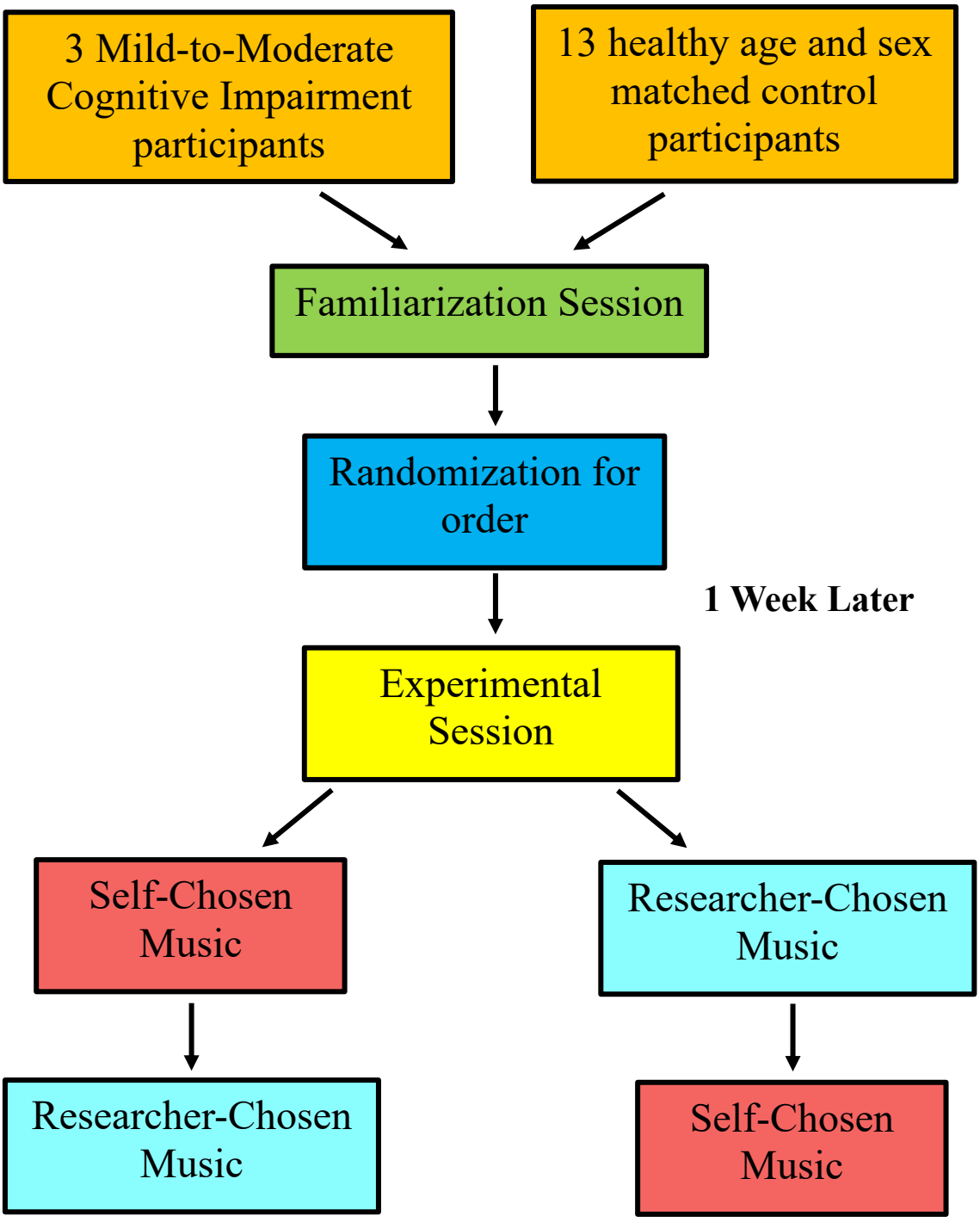
Appendix B: Short Term Memory



Appendix C: Long-Term Memory



Appendix D: Program Design



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Appendix E

INFORMED CONSENT (Control Participants)

Research Study: Finding Memories Through Music and Movement in Cognitive Impairment

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This consent form, a copy of which will be left with you for your records and reference, is only part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. If you would like more detail about something mentioned here, or information not included here, you should feel free to ask. Please take the time to read this carefully and to understand any accompanying information.

PURPOSE: It is important to understand how rhythm and music affect the movements of those diagnosed with cognitive impairment as music may provide an affordable and culturally relevant intervention to promote meaningful and active social engagement that can reduce anxiety. The current study will examine how pre-recorded music chosen by you versus pre-recorded music chosen by the researcher can influence those diagnosed with and without mild-to-moderate cognitive impairment when performing a movement-based task. Current research has explored potential therapeutic effects of music on anxiety, emotion, and memory in this target population. However, it is unclear how moving to pre-recorded music may yield benefits in movement performance and anxiety. Therefore, the present study will investigate if and how movement performance and anxiety change when individuals with and without mild-to-moderate cognitive impairment move to self-chosen music versus researcher chosen music.

DESCRIPTION: You will attend two 60-minute virtual or in-person sessions at a location convenient for you. Remote testing will be done online through the platform Zoom while in-person testing will be conducted at the University of Manitoba in IGAC room 234 (Perceptual Motor Integration Lab) or at an alternative location that is convenient for you. The familiarization session will include eligibility for the study followed by informed consent, COVID-19 consent, and study summary documents. Once completed, a demographics questionnaire and a music-selection questionnaire will be administered to you through email or hardcopy. The demographics questionnaire will be completed first, which inquiries about your age, gender, whether or not you have any vision or hearing problems/sensitivities (glasses, contact lenses, hearing aids), and asks for your Montreal

Cognitive Assessment (MoCA) score. If you do not have an MoCA score, a research assistant trained to run such assessment will perform it, which will take no more than 10 minutes to complete. Next you will fill out the musical selection questionnaire, which will ask you about your musical preferences. Lastly, you will be administered the Trait Anxiety scale from the State Trait Anxiety Inventory (STAI) to determine your general anxiety level.
The experimental session will take place one week later virtually on Zoom or in-person in a location convenient for you. Testing can be collected in one session but can be extended from one to three sessions to accommodate any concerns such as fatigue. On the day of the experimental session, you will screen yourself for COVID-19 symptoms using the Manitoba COVID-19 Shared Health Screening Tool. The research staff involved will do the same. If all parties do not show symptoms according to the tool, for remote testing, the research equipment (a bag containing the computer, and its charging block) will be delivered contactless to your preferred place of testing. Research staff will not enter your place of testing at any time, and they will sanitize all equipment prior to delivery and handle while wearing gloves and a face mask. Equipment delivery will be to your doorstep at a mutually agreed upon time (15 minutes prior to your scheduled session time). Then they will return to their motor vehicle and stay there until the experimental session is complete. Once the session is finished, the research staff will pick up the equipment.

The experimental session will commence with the researcher asking you for verbal assent. Once you confirm you would like to continue with the study, baseline measures will be taken before the first condition. First, we will measure your enjoyment level through the Likert Enjoyment scale with five different facial expressions. We will provide you with a hardcopy of this scale. You will be asked to indicate on a scale, with 5 different facial expressions, which facial expression best describes how you feel right now on a scale from 1 to 5. You can indicate an expression from no enjoyment all the way to high enjoyment. Then we will measure anxiety through the State Trait Anxiety Inventory questionnaire, (State Anxiety Scale only) which will be provided to you in a hardcopy and asks you about your current anxiety level in the moment. This should take no more than 10 minutes to complete. If you need assistance, you may ask the researcher. Once all baseline measures are collected, you will perform a movement sequence task where you touch 5 targets on a touchscreen while listening to music in two separate conditions (self-selected music for one and researcher chosen music for the other). Before the first condition, an acquisition trial video will be played to familiarize yourself with the task. Additionally, before each condition, you will perform two practice trials without music. The State Anxiety scale will be collected again after you complete the first musical condition as well as after the second condition. Additionally, after each condition, the Likert Enjoyment scale will be provided to you at the end of the task on the data collection laptop. This will indicate how much you enjoyed yourself during that particular condition.

For in-person testing at the University of Manitoba, participants will meet a member of our research team either outside or inside IGAC at the University of Manitoba. The research team member will guide the participant (and caregiver who is with the cognitive impairment participant) to room 234 within IGAC, which is the Perceptual Motor Integration Lab. Research staff will be wearing a mask, face shield, and gloves. Also, research staff will enforce physical distancing (6ft) between themselves and the participant. The familiarization and

experimental sessions will follow the same procedure as remote testing except everything will be performed in person with physical distancing and appropriate PPE measures. Testing will be conducted on a flat table with the participant sitting on one side and the research staff member on the opposite side. Once testing is complete and the research staff member helps the participant leave (if necessary), all equipment will be sanitized.

If you wish, a friend, family member or trusted person can be present during testing.

RISKS AND BENEFITS: Some risks include mild muscle fatigue. While this may be frustrating, the investigator conducting the study will provide breaks throughout and you may request a break at any time. Lastly, eye and ear sensitivities may be a physical limitation. If the tablet screen is too bright the investigator will instruct the participant to reduce the brightness on the screen. For ear sensitivities, due to the music being played through speakers, the investigator will test the volume level before each condition with each participant so they can gauge what level is suitable for them.

Participants may experience temporary improvement in movement performance and anxiety with the addition of self-chosen music. Indirect benefits include developing evidence to help guide evidenced informed practice to various health care professionals to understand the best ways to provide music for activities to older adults with and without cognitive impairment. This may lead to improved quality of life for participants, providing a low-cost culturally relevant physical activity that is meaningful and fun.

COSTS AND PAYMENTS: There are no fees or charges to participate in this study. You will receive a small honorarium as a thank you for your time ($20). Any additional costs for parking will be reimbursed.

CONFIDENTIALITY: All information will be kept confidential. Once you have begun the study, your name, information, and results will be referred to by a code number. All files containing identifying information will be stored in a locked cabinet separate from data with the participants code number. Files will only be accessible by the investigators and will be destroyed by Courtney Addison and Dr. Glazebrook seven years after the completion of the study (approximately Dec., 2028). As PI for the project, Courtney Addison may be present during testing for in order to assist with the data collection process as well as her advisor, Dr. Cheryl Glazebrook. All papers containing personal information will be shredded. All electronic files will be deleted. Only Courtney Addison and Dr. Cheryl Glazebrook will have access to any lists that contain identifying information.

Results will be presented at academic conferences, invited presentations (including community organizations), my master's thesis and published in peer-reviewed academic journals. In almost all cases only group averages will be presented. In some cases, individual movement data may be presented. This data contains no identifiable information and therefore your anonymity will be maintained.

DEBRIEFING: Upon completion of the study the experimenter will describe the research questions being considered. If you would like to know the results of the study please indicate 'yes' on the consent form where indicated and the student research assistant will contact you with a summary of the findings in approximately 4 months.

VOLUNTARY CONSENT: If you *do not wish to participate* in the study or wish to withdraw from the study, you are free to leave without consequence at any point in time and we thank you for your consideration. If you decide to leave at any point in the study, you will still receive the $20 honorarium.

Your signature on this form indicates that you have understood to your satisfaction the information regarding participation in the research project and agree to participate as a subject. In no way does this waive the participants legal rights nor release the researchers, sponsors, or involved institutions from their legal and professional responsibilities. You are free to withdraw from the study at any time, and /or you may refrain from answering any questions you prefer to omit, without prejudice or consequence. Your continued participation should be as informed as their initial consent, so you should feel free to ask for clarification or new information throughout your participation. If you choose to withdraw from the study, you will still receive compensation for the time you have participated. The University of Manitoba may look at your research records to see that the research is being done in a safe and proper way.

A copy of this consent form has been given to you to keep for your records and reference. This research has been approved by the Education/Nursing Research Ethics Board. If you have any concerns or complaints about this project you may contact any of the above named persons or the Human Ethics Coordinator (HEC) 474-7122 or humanethics@umanitoba.ca.

Participant Name _____ Date _____

Participant Signature _____ Date _____

AND/OR (if appropriate)

Signature of Guardian/Substitute Decision Maker _____
Relationship _____ Date _____

Researcher/ Delegate's Signature _____ Date _____

Comments:

SUMMARY OF FINDINGS: Would like to be contacted with a summary of the overall findings of this study? □ YES □ NO

If yes, please complete the following:

Name: _____

Phone Number: _____

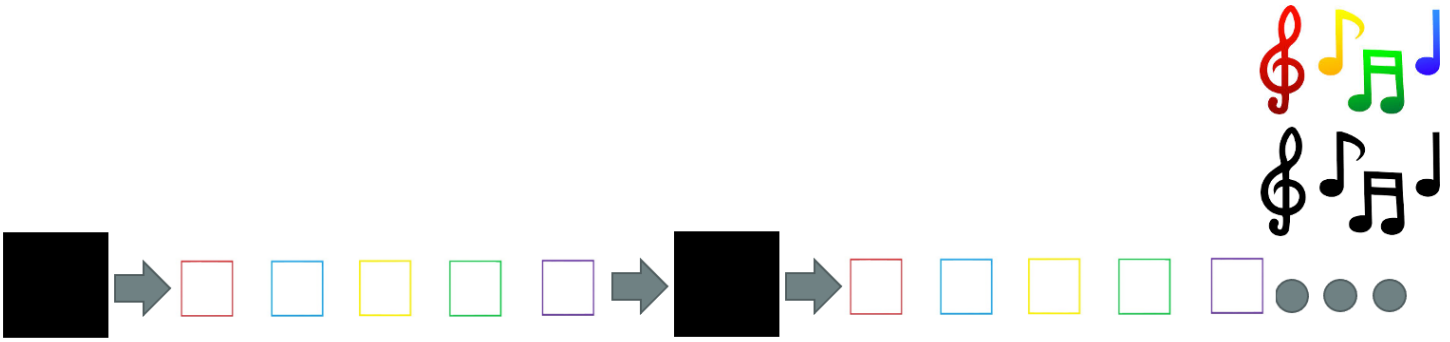
Email Address: _____

If yes, how would you like to receive your results? Please indicate one option below.

- ☐ **Email**
- ☐ **Mail**
- ☐ **Phone**

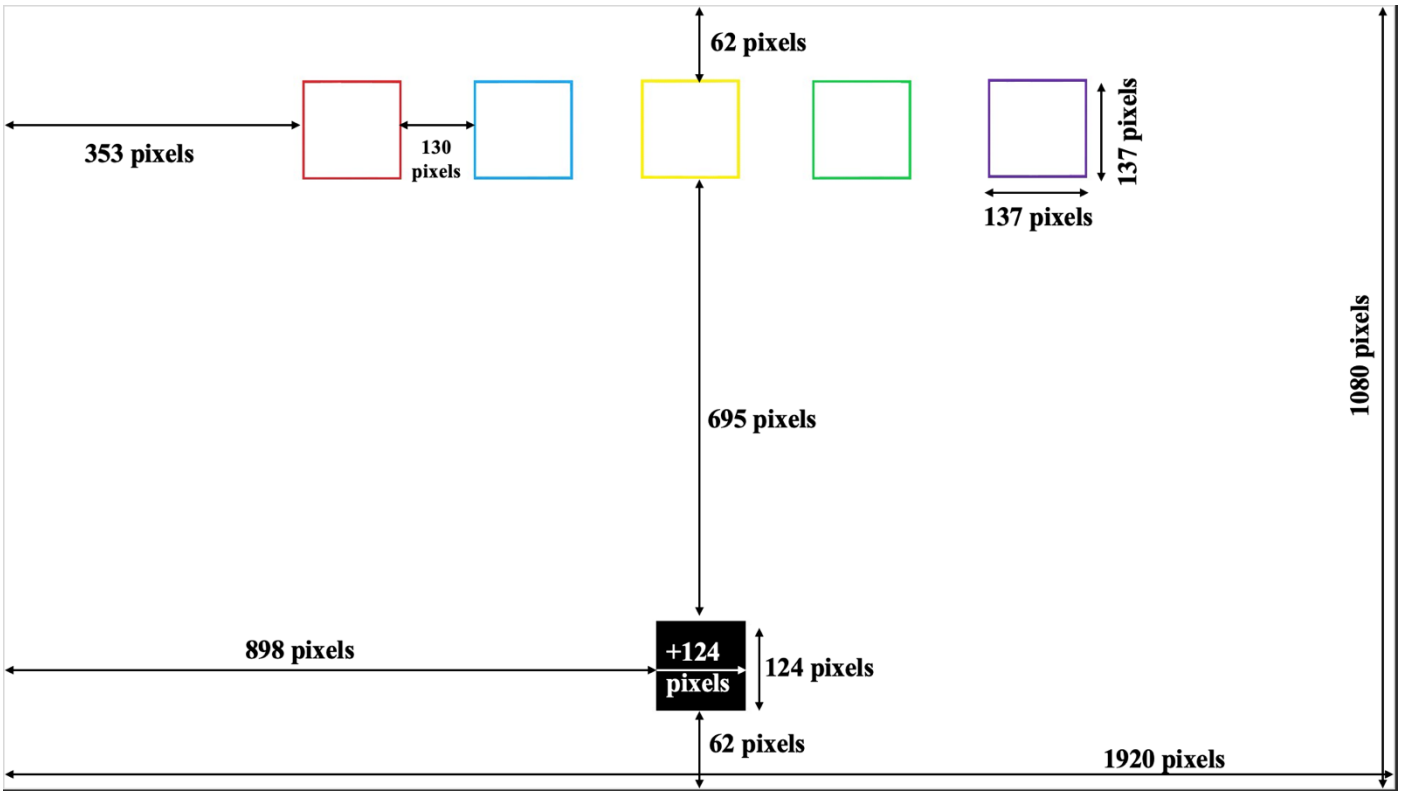
Appendix F: Experimental Session- Movement Task Design

Appendix G: Movement-Sequence Task

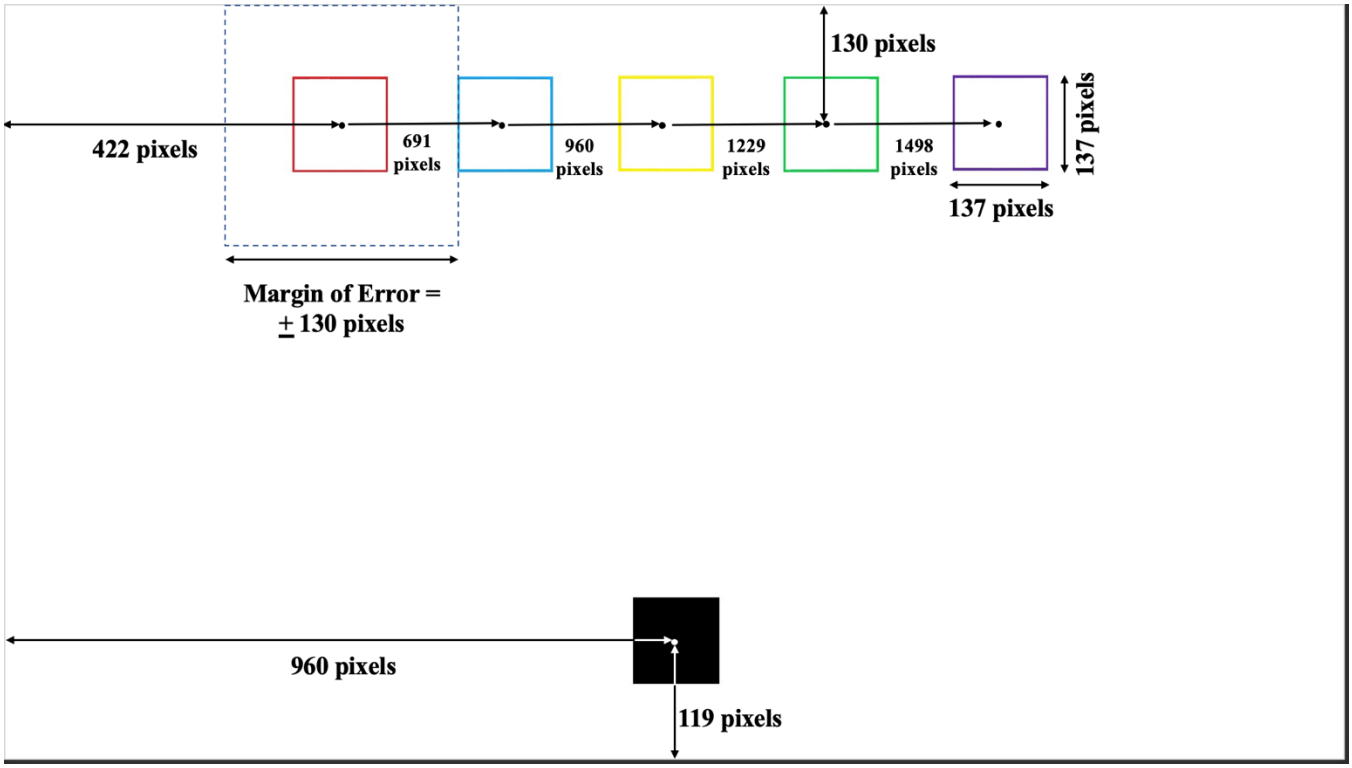


20 Target Sequence (Random Order)

Appendix H: Task Diagram

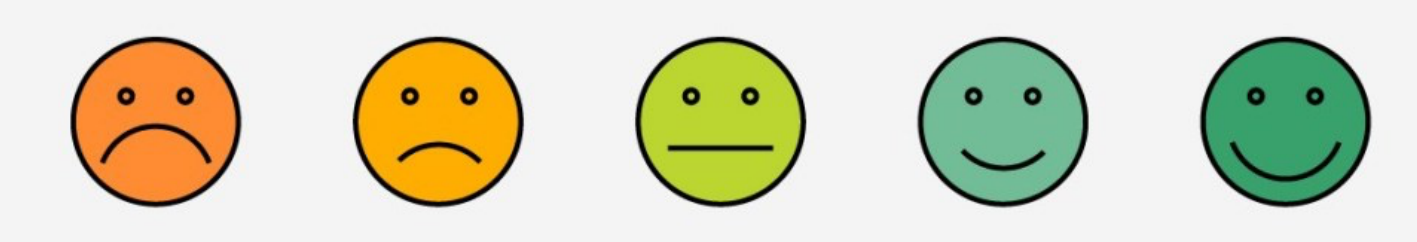


Appendix I: Task Diagram Target Margin of Error



Appendix J: Likert Enjoyment Scale

Which facial expression best describes how you feel right now?



No Enjoyment	Little Enjoyment	Mild Enjoyment	Moderate Enjoyment	High Enjoyment
1	2	3	4	5

Appendix K- Control group target misses during self-chosen music condition

Participant	RX Axis Outliers	RY Axis Outliers
C1	-	-
C2	-	-
C3	-	-
C4	-	-
C5	2/100 touches (Blue- 976 pixels; Red- 956 pixels)	3/100 touches (Blue- 940 pixels; Red- 963 pixels; Yellow- 991 pixels)
C6	-	1/100 (Yellow- 980 pixels)
C7	1/100 touches (Green- 953 pixels)	1/100 touches (Green- 990 pixels)
C9	-	-
C10	-	-
C11	-	-
C12	-	-
C13	2/100 touches (Blue- 357 pixels; Green- 709 pixels)	-
C14	-	-
LEGEND: C- Control		

Appendix L- Control group target misses during researcher-chosen music condition

Participant	RX Axis Outliers	RY Axis Outliers
C1	-	-
C2	-	-
C3	-	-
C4	-	1/100 touches (Yellow- 944 pixels)
C5	-	-
C6	-	-
C7	-	-
C9	-	-
C10	-	-
C11	-	-
C12	-	-
C13	-	-
C14	-	-
LEGEND: C- Control		

Appendix M- MCI group target misses during self-chosen music condition

Participant	RX Axis Outliers	RY Axis Outliers
MCI1	2/100 touches	1/100 touches
	(Blue- 1515 pixels; Purple- 966 pixels)	(Purple- 924 pixels)
MCI2	1/100 touches	1/100 touches
	(Purple- 963 pixels)	(Purple- 951 pixels)
MCI3	1/100 touches	2/100 touches
	(Red- 940 pixels)	(Red- 953 pixels; Yellow- 952 pixels)
LEGEND: MCI- Mild-to-Moderate Cognitive Impairment		

Appendix N- MCI group target misses during researcher-chosen music condition

Participant	RX Axis Outliers	RY Axis Outliers
MCI1	-	-
MCI2	-	-
MCI3	1/100 touches	2/100 touches
	(Blue- 982 pixels)	(Blue- 963 pixels; Yellow- 940 pixels)
LEGEND: CI- Mild-to-Moderate Cognitive Impairment		