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Optimizing Music-Based Interventions through Cognitive Process Leveraging and Utilization

Geetha R. Bhat

Psychologist and Music Therapist, Certified Rehabilitation Personnel from the Rehabilitation Council of India (RCI), Hamsakutira Foundation.

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Abstract: Leveraging cognitive processes in music therapy is a valuable approach to addressing a huge dimension of physical, emotional, and cognitive challenges in individuals. In essence, leveraging cognitive processes in music involves recognizing the intricate relationship between music and the human mind. Whether for therapeutic, educational, or creative purposes, understanding how cognitive processes interact with music can lead to a deeper appreciation of the art form and can be used to achieve various personal and therapeutic goals. Neurodivergent communities including individuals with conditions like AUTISM, ADHD, DYSLEXIA, and other neurological differences, often have unique and diverse relationships with music. The cognitive processes involved in music experiences can help manage sensory sensitivities, enhance emotional expression and regulation, benefit memory and learning, foster social engagement, improve speech, and regulate mood along with many other subsequent and inherent benefits.

Keywords: Cognitive processes, Autism, Metacognition, Attention, Sensory processing, Memory

INTRODUCTION

Cognition pertains to the mental processes engaged in acquiring knowledge and comprehending. These encompass advanced brain functions such as language, imagination, perception, and planning. Cognition encompasses both conscious and unconscious mental processes related to thinking, perception, and reasoning. It involves various activities like focusing on stimuli in the nearest environment, seeking new knowledge, ability to make decisions, processing language, perception of stimuli, problem-solving abilities, and memory utilization. Music cognition delves into understanding how the human brain processes and comprehends music. It is a multidisciplinary field that combines elements of psychology, neuroscience, music theory, and cognitive science to explore how individuals perceive, process, create, and respond to music. Music genres have evolved intricate and diverse musical forms that engage a wide array of cognitive processes in perception, creation, and social interaction. This extraordinary diversity spans cultures, history, and societies, possibly surpassing the variations seen in language (Bohlman, 1999). Beyond its contributions to evolution, social dynamics, and personal development, this wealth of musical variety positions music as an ideal subject for the study of human cognition. It also serves as a model for exploring the interplay of processes across various domains and levels, as recognized by researchers in the field (Koelsch, 2012). At this juncture, it also becomes very important for us to explore cognitive processes through the lens of disorder awareness. Comprehending cognitive processes within the context of disorders is fundamental for accurate diagnosis, productive and functional treatment, and enhanced quality of life for individuals living with these conditions. It also contributes to scientific progress and more compassionate, evidence-based healthcare practices. Music cognition research seeks to understand the cognitive mechanisms and processes involved in musical experiences. Music cognition describes the diverse musical behaviors; determining whether two tones are similar or different, judging the similarity of intervals, remembering pitches, remembering portions of silence in a composition, identifying melodies and octaves, discriminating major and minor notes, long and short durations and many such intricate and innate processes (Serafine, 1983). Overall, this concept involves how our mental processes, such as perception, memory, attention, problem-solving, and emotion, interact with and are influenced by music. Some of the key cognitive processes are,

1. Perception and Sensory Processing: Perception plays a vital role in music learning. Sensory processing involves the reception of information by sensory organs, while perceptual processing pertains to the brain's interpretation of this information. Music perception involves a comprehensive range of psychological and neural processes that come into play when we listen to music. To make sense of a musical stimulus, our perceptual system must construct an internal representation of the structure within a piece of music. This representation includes attributes of individual events, like pitch, rhythm,

timbre, loudness, and timing, as well as groupings of events, such as chords, voices, and phrases. Furthermore, it involves discerning the structural connections between these groups, allowing us to perceive the larger-scale aspects of musical form and thematic structure (Pearce, 2023). Learners develop the ability to discriminate between different musical elements and detect subtle variations in sound. Music involves the alteration of sound for desired effects, and our perception of music largely depends on how our auditory system encodes and retains acoustic information (McDermott, J. H., & Oxenham, A. J., 2008). Auditory Perception is the ability to observe or distinguish and understand the difference between sounds. Pitch stands as a primary dimension across which sound varies within a musical composition. The tone is an important suprasegmental feature of speech, with different patterns of intonation serving to distinguish different types of utterances, such as statements and questions. Melody recognition represents another intricate cognitive process, wherein the brain must perceive, process, and decipher a sequence of musical notes or tones as a cohesive, organized melody. Recognizing a melody hinges on the creation of a structural representation derived from the perceptual characteristics of the presented musical stimulus. Subsequently, this representation is compared to a stored memory representation. Recognition materializes when a correspondence between the perceptual and stored representations is established (Simone Dalla Bella et al., 2003).

In a preliminary investigation by Sharda et al. (2018), an exploration highlighted the affirmative influence of music on social communication and the correlation between auditory perception and motor skills among individuals with Autism Spectrum Disorder (ASD). The investigation noted that children with proprioceptive deficits in ASD exhibited improved performance in visual and auditory attention tasks when they received rhythmic proprioceptive input, compared to those who were given just proprioceptive input. These results emphasize the substantial role of rhythmic input in enhancing attention and sensory-motor coordination among individuals with ASD (Sharda et al., 2018).

Kalas in a separate report, proposed that simple rhythms can enhance attention in individuals with ASD across different functioning levels (kalas, 2012). Furthermore, research has shown that the predictability of rhythmic structures is crucial for facilitating movement and that unconscious motor responses to rhythm have the potential to regulate motor activity. These findings accentuate the significance of predictable rhythmic patterns in influencing and improving motor coordination, particularly in the context of movement-related activities (Molinari et al., 2007). Utilizing rhythmic intervention as a therapeutic approach can effectively enhance the motor function, language skills, and soft skills of individuals with Autism Spectrum Disorder (ASD), ultimately contributing to an improved quality of life for these individuals.

2. Attention and Focus: Attention is the cognitive ability to select and concentrate on pertinent stimuli, allowing individuals to orient themselves toward relevant information and respond accordingly. This crucial cognitive process plays a fundamental role in our daily lives. Music learning requires focused attention to key musical elements, instructions, and the nuances of performance. Learners must selectively attend to specific aspects of music, such as melody, rhythm, or dynamics, while filtering out distractions. Attention is, in fact, a component of executive functioning, covering a variety of goal-oriented activities such as monitoring conflicts, switching tasks, and working memory. These cognitive functions work in tandem to facilitate focused and effective responses to stimuli (Loui, Psyche & Guetta, Rachel, 2018). Within attention, there are various ways we focus and attend to a stimulus.

- Focused Attention: Concentrating on a specific stimulus.
- Sustained Attention: Maintaining focus on a stimulus or task over an extended period.
- Selective Attention: Concentrating on a particular stimulus despite surrounding distractions.
- Alternating Attention: Shifting focus between multiple stimuli or tasks.
- Divided Attention: Attending to multiple stimuli or tasks simultaneously.

Individuals with autism or attention deficit often have challenges in this area. They may exhibit both strengths and challenges in selective attention. Some individuals with autism have intense focus and attention to detail in areas of interest, often referred to as "hyperfocus." However, they may struggle with shifting attention between tasks or stimuli, especially when not related to their special interests. Similarly, some individuals may have difficulty sustaining attention on tasks, while others can engage in extended periods of intense focus. In addition to this, they can also experience difficulties in social attention. For instance, joint attention refers to the ability to share attention with others, such as following someone's gaze or pointing to objects of interest. Many individuals with autism have challenges with joint attention, which can affect their social interactions and communication. Some may have difficulty attending to and interpreting social cues, such as expressions on the face, voice tones, and the language of the body,

***Corresponding Author:** Geetha R. Bhat

while others may be hypersensitive or hyposensitive to sensory stimuli. This can influence their attention, as they may become overwhelmed or fascinated by sensory input, such as lights, sounds, or textures (Poole. D et al., 2018). With cognitive flexibility and attention shifting being another area of concern, intervening with music and combining music with other sensory modalities, such as movement or visual elements, can engage multiple senses and enhance attention. Structured music sessions with clear routines and predictable activities can help individuals with autism maintain attention. These sessions often include singing, playing instruments, and following rhythmic patterns and logical sequences.

3. Memory and Learning: Memory plays a significant role in music, as we remember melodies, lyrics, and musical patterns. Leveraging cognitive processes in music can involve using mnemonic techniques to aid in memorizing music or studying how musical experiences influence memory and learning. Memory is a complex cognitive ability, with three primary types: sensory memory, short-term memory (STM) often called working memory, and long-term memory (LTM). The process of encoding information into long-term memory involves passing it through sensory memory and then STM. STM serves as the active workspace for processing information, but it has a limited capacity, holding only up to about six items simultaneously and retaining them for a relatively short duration, typically ranging from 10 to 60 seconds. Although these memory types have distinct characteristics, they collaborate in the intricate process of memorization (Atkinson, 1971). Musical sounds, as they progress over time, follow a similar pattern to auditory signals. To create a unified musical experience, the auditory system must effectively integrate a sequence of sounds. Essentially, an auditory perception consists of a series of individual units that are combined into a single perception through processes akin to converting series into parallel forms, like melodies, rhythms, or soundscapes. Music, due to its strong emotional and mnemonic connections, actively engages the entire limbic system, which governs memory and emotional processing (Jancke, 2006). However, the majority of research on musical memory has yet to explore the impact of emotions on this specific type of memory.

   Encoding serves as the initial phase in the memory formation process within our brains. It's through repetition that information is encoded into electrical signals. These electrical impulses, in turn, trigger the release of chemicals, facilitating the transmission of information among brain cells through specialized connections known as "synapses." This explains why some information seems to quickly fade away—it hasn't had the opportunity to undergo encoding. Repetition, on the other hand, promotes the formation of more synapses, aiding in the consolidation of memories in our brains. When we learn or experience something involving multiple senses, an array of electrical and chemical processes activate within our brain. The more robust the immediate perception, the greater the likelihood that the information or experience will transition from our sensory perception to our short-term memory, thanks to the involvement of numerous triggers. This phenomenon elucidates why recalling the words and phrases of a song is often easier than reciting a poem—it's because listening to music engages multiple sensory cues that our brain captures. To accommodate additional information and sensory inputs, our brains and their synapses continuously adapt and rearrange. The strength of synaptic connections can impact our ability to recall stored information, and elements that support this process can improve our capability to form and preserve memories. Anything that disrupts these phases can impede our ability to encode a memory. Conversely, anything that supports these processes contributes to our ability to form and retain memories.

   Individuals with Alzheimer's disease, a progressive neurodegenerative condition that primarily affects memory and cognitive function, can sometimes demonstrate remarkable musical abilities, even when other aspects of their cognition are significantly impaired. This phenomenon has intrigued researchers and caregivers and raises several possible explanations. According to Dr. Bonakdarpour, a Neurology Associate Professor at Northwestern University Feinberg School of Medicine, musical memories tend to last longer in the brain even as other memory recalls and language fade in dementia. This is due to certain brain regions responsible for musical memory and processing, such as the cerebellum, being less impacted by Alzheimer's or dementia until the later stages of the disease. Consequently, individuals may preserve the capacity to sing and dance long after their verbal abilities have declined (Paul, 2022). Individuals with degenerative neurological conditions, like Alzheimer's disease and other related conditions, often exhibit a fascinating phenomenon: the preservation of musical processing and appreciation. This stands in contrast to individuals with acquired deficits in music processing, such as auditory agnosia or amusia, where the ability to process music is impaired (Johnson, 2015).

4. Emotional and Psychological Responses: Music has a deep effect on our emotions and psychological states. Recent studies have provided compelling evidence of heightened activity in brain regions linked to emotions and rewards when people listen to pleasurable music. Unpredictable changes in

musical aspects, such as intensity and pace, are supposed to elicit significant emotional responses in listeners, enhancing tension and anticipation. The fundamental dispute on musical emotion centered around two positions: one based on the cognitivist viewpoint and the other on the emotivist viewpoint. Music, according to cognitivists, can represent emotion, but it does not always elicit emotional responses in listeners. (Vempala et al., 2013). In other words, listeners can recognize emotion in music without actually experiencing those emotions, unlike the emotions we encounter in our everyday lives. On the contrary, the emotivist position contends that people who engage in music not only recognize emotion in music but also genuinely sense these emotions. This is supported by the bodily and physical responses observed in listeners during music engagement or just listening, which resemble the responses associated with real, everyday emotions (Vempala et al., 2013). Recent studies in emotivist music psychology have shown that music can evoke responses in multiple emotional components, extending beyond aesthetic or artistic emotions to include utilitarian or functional emotions. This suggests that music has the power to affect us on a deep emotional level.

When music generates emotions, it often starts in subcortical brain regions like the amygdala, known for its role in emotional processing. This emotional response sets off a chain reaction, activating the hypothalamus and the autonomic nervous system, which, in turn, releases arousal hormones like noradrenaline and cortisol. Research employing central measures of emotional responses supports the resemblance between emotions elicited by music and those experienced in real-life situations (Hussain-Abdulah Arjmand et al., 2017). Moreover, brain regions linked to emotions and rewards exhibit responses to emotionally pleasurable music. In a study conducted by Blood and Zatorre in 2001, it was demonstrated that enjoyable music triggered the dorsal amygdala, part of the brain's "positive emotion" network, including the ventral striatum and orbitofrontal cortex. Concurrently, it decreased activity in central amygdala areas associated with unpleasant or aversive stimuli. (Blood, 2001).

Individuals with Autism Spectrum Disorder (ASD) often demonstrate strengths in the realm of music, including aspects like musical pitch perception, musical memory, and the ability to identify emotions evoked by music. When they listen to music, it triggers neural circuits associated with reward and emotional responses. Recent evidence suggests that even adults on the spectrum engage these neural structures while being exposed to music. However, there might be differences in development in how children and adolescents with ASD physiologically and neurally respond to music, despite typical behavioral responses. Research findings from many of these studies support the use of music-based interventions and music education as effective interventions for individuals with ASD. These interventions have demonstrated promise in enhancing social skills and communication, addressing some of the core challenges associated with ASD (Quintin, 2019).

Language and music processing: The exploration of music cognition has increasingly delved into the potential interconnection between how we process language and music. This interest stems from the observed augmentation in auditory regions, which are believed to be inherent and get stimulated through exposure to music training. This stimulation naturally leads to the investigation of the potential intersections and overlays between the neural networks in music and language processing. Beyond the auditory processing benefits associated with music, research has uncovered evidence suggesting a convergence between the networks engaged in music and language. This includes a significant link between musical training and various aspects of language processing, such as syntactic structures, phonetic intricacies, and prosodic elements. This intersection highlights the potential shared mechanisms underlying how we comprehend and interpret both music and language (Patel, 2007). Traditional theories have often described localization of speech functions in the left hemisphere and functions of music in the right hemisphere of the brain. However, advancements in brain imaging technology and our deepening understanding of brain functions have challenged this view. Innovative approaches have unveiled a more nuanced perspective on music and speech; neural and psychological roots. Recent research has highlighted significant similarities between the functions of music and speech. It appears that both music and speech engage many of the same brain modules (Tallal, 2006). Furthermore, emerging evidence suggests a bidirectional relationship between music and speech functions, implying that improvements in one domain can benefit the other. Additionally, the interconnection between music and emotion has been a subject of interest, particularly in the right hemisphere of the brain. This parallels the observation that rhythm and language processing are often associated with the left hemisphere. As Jourdain proposed in 1998, spoken language, with its temporal sequencing, shares rhythmic characteristics with music. Both spoken language and music involve aspects like meaning, articulation, and tone modulation, creating perceptual similarities. Recent neuroimaging studies have unveiled a fascinating similarity between music and language in their capacity to process and generate sequentially ordered information. This common framework allows for the

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exchange and conveyance of meaning and emotion through both music and language. Individuals with autism often experience challenges related to interpersonal communication, interactions, and regulation of emotions, which are associated with dysfunctions in their mirror neuron system. For nonverbal autistic children, the use of music-making techniques in interventions may present a promising avenue for nurturing expressive language (Wan, 2010).

Children facing language disorders might gain significant advantages from intensive musical training, given the shared neural responses to both musical and language stimuli within the brain. Multiple functional magnetic resonance imaging studies consistently highlight the stimulation of the Broca area during different tasks related to music (Koelsch et al., 2002). These tasks encompass music perception activities, active musical tasks like singing, and even mental exercises involving the imagined playing of musical instruments. This shared activation within the Broca area suggests a strong connection between the neural systems supporting both music and language. Furthermore, there seems to be a shared neural network underlying the sensorimotor aspects of both speaking and singing (Pulvermuller, 2005).

While there are differences between language and music, such as their internal-external focus, research increasingly underscores the multitude of similarities that unite these two domains. Language and music are linked through common elements residing in the left hemisphere, and despite distinctions, their shared features often outweigh the differences. This complex interplay between language and music continues to be a subject of deep exploration and understanding in neuroscience and psychology.

5. Neurological and Cognitive Rehabilitation: Music can be utilized to promote cognitive functions and neural connections in therapeutic settings. Recent discoveries of music-induced neuroplasticity have paved the way for music-based therapies that primarily target music's therapeutic potential in a variety of neurological diseases. These treatments have showed promise in treating diseases such as multiple sclerosis, stroke, dementia, Parkinson's disease, and epilepsy. Numerous studies have found these therapies to have positive outcomes. Patients recuperating from stroke, for example, showed improved motor and cognitive recovery when music-based therapies were included in their rehabilitation. Patients with dementia have shown increased cognitive function, as well as improvements in neuropsychiatric symptoms and mood issues. Music has proven to be a non-invasive therapeutic technique in the management of dementia's multiple challenges. People living with Parkinson's disease have benefited from music-based interventions as well. The rhythmic utilization of musical stimuli has been noted to compensate for the extrapyramidal system's loss of control, leading to enhanced auditory perception and improved movement synchronization. Music serves as an external cue, offering a substitute for the impaired internal timing function in individuals with Parkinson's disease.

   To offset the possible harmful effects of aging on brain functioning, it is currently recommended that older adults engage in challenging activities that engage many senses, cognitive functions, and physical abilities. These exercises activate various brain regions, including the prefrontal and frontal lobes, which important for cognitive function and development. In 2007, Bugos and colleagues conducted an experimental study to investigate the positive effects of music-making on older individuals who were new to music and aged 60-85 years. These people were randomly assigned to one of two groups: the experimental group, which received intense piano instruction for six months, and the control group, which received no therapy. Participants in the experimental group got weekly half-hour piano lessons and were required to practise independently for a minimum of three hours. The test findings revealed that the experimental group participants improved significantly in working memory, perceptual quickness, and motor skills. The control group, on the other hand, did not show comparable improvements. The study highlights the potential of music engagement as a powerful tool for improving cognitive function and plasticity in older people, potentially offering a way to fight some of the cognitive deterioration associated with ageing (Bugos et al., 2007).

6. Metacognition and Reflective Thinking: Creating music is often perceived as effortless when witnessed in the hands of skilled musicians, but the truth is, that music-making, irrespective of genre, is a complex endeavor. Musicians need to master various skills—cognitive, emotional, motivational, and strategic—to excel. This demands continuous learning and the search for more efficient practice techniques. The metacognitive dimension encompasses a range of abilities and knowledge essential for orchestrating the higher-order skills needed for execution in music performance. It serves as a foundational element in the organization of musical practice, guiding individual decision-making and focused efforts towards precise strategies, and facilitating the efficient control and management of time and resources. Metacognitive processes involve monitoring and regulating one's own learning. Musicians engage in metacognition by assessing their progress, identifying areas for

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improvement, and developing effective practice strategies. Reflective thinking allows learners to analyze their performance, evaluate their musical choices, and adapt their approach to enhancing their skills. Improving musical practice extends beyond time invested in playing or singing; it involves utilizing metacognitive skills to cultivate productive rehearsal sessions (Bathgate et al., 2012). Frequently disregarded, metacognitive abilities are crucial for accurately self-assessing one's performance.

Because musical activities involve both specific and combined elements, metacognition can be seen as a distinct skill within one's learning and as a facet within the domain of social communication and interaction along with collaborative knowledge (Benton, 2014). These aspects of metacognition can be summarized in three dimensions; self-reflection involving contemplation of the task and individual cognitive processes, self-regulation for managing individual activities, and self-evaluation for assessing individual performance. Individuals with autism spectrum disorder (ASD) often show differences in metacognitive processes compared to neurotypical individuals. Some of the metacognitive differences or challenges observed in individuals with autism include:

1. Theory of Mind (ToM) Deficits: Theory of Mind is a fundamental metacognitive skill that involves understanding and predicting the thoughts, feelings, and intentions of others. People with ASD may have difficulty with ToM, making it challenging to infer what others are thinking or feeling, which can affect their social interactions and relationships.
2. Weak Central Coherence: Certain individuals with ASD have a cognitive style that is focused on minute details rather than the large picture or understanding how specifics relate to the overall context. As a result, they may struggle to grasp the broader meaning or perceive how each detail fits into the greater framework.
3. Executive Functioning: Executive functioning includes metacognitive skills such as planning, working memory, cognitive flexibility, and self-control. Many people with ASD struggle with executive function abilities, making it difficult to organize ideas, create objectives, switch between activities, and regulate impulsive behaviours.
4. Difficulty Self-Monitoring: Others with autism have difficulty monitoring and changing their thought processes. This can have an impact on their ability to self-regulate and adjust when circumstances change.
5. Repetitive Behaviours and Interests: The repetitive behaviours or intense, limited interests that some people with ASD have can occasionally interfere with the development of their metacognitive skills. These behaviours can lead to an over-concentration on certain aspects or routines, making it difficult to explore a broader range of thought processes.
6. Difficulty Generalising: Generalising information and skills from one scenario to another is a metacognitive ability that can be difficult for people with ASD. They could thrive in one area but struggle to apply what they've learned in other situations.

While the beneficial relevance of music therapy for increasing metacognition in individuals with ASD is an under-researched field, the effects could be significant through structured, personalized approaches. Music may be a strong sensory experience, assisting people with autism in developing more sensory awareness. Engaging with musical aspects such as rhythm, melody, and harmony might assist individuals in becoming more attuned to their sensory experiences, which is an important aspect of metacognition. Social interactions through group sessions can help people grasp the perspectives of others, which is a crucial part of metacognition.

Integrating a metacognitive approach into music instruction improves learning efficiency, optimizes practice, and improves memory recall of acquired musical information. (Hart, 2014). This approach to musical performance involves understanding cognitive processes and learning strategies (Nielsen, 1999; Hallam, 2001; Abushanab and Bishara, 2013). It encompasses the skills required to select and use these strategies for cognition and memorization (Nielsen, 1999; Ginsborg, 2002; Lisboa et al., 2015), as well as the ability to assess self-practice, learning goals and results, and performance.

Within the realm of cognitive psychology of music, the intricate interplay between the "Musical Mind" and general cognitive processes has long been a subject of scientific exploration. This area of research is inherently multifaceted. While certain research avenues delve into the connections between music-related aptitudes and other domain-specific skills, such as language, spatial cognition, or mathematics, other studies explore the proposition that music, be it through education and expertise or even as simultaneous processing alongside other cognitive tasks, may potentially augment domain-general capabilities. These encompass attention, memory, intelligence, and emotional processing. By understanding and integrating cognitive processes into music engagement along with the specifics of a disorder, individuals can create more realistic and tailored approaches to their musical goals, whether they involve performance, education, therapy, or personal enjoyment. This can lead to improved outcomes and a deeper connection with music.

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