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Bridging internal states with music: An exploratory analysis of music-induced embodied emotion regulation in autistic youth and young adults

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ABSTRACT

Emotion dysregulation in autistic individuals often manifest as atypical reactivity or maladaptive expressions, frequently accompanied by dissociation or detachment from self-experiences, avoidance, suppression, or rigidity in response to external and internal experiences. These challenges highlight the need for population-specific approaches to emotion regulation (ER). This study explored the potential of music to integrate interoceptive and exteroceptive processes for embodied ER. We proposed the Music-Induced Embodied Emotion Regulation (M-EER) model, a conceptual framework that guides sequential regulation through synchronization with modulated musical stimuli, and outlined step-by-step procedures for its implementation. Pilot interventions were conducted with three autistic individuals, one youth and two young adults, aged 19–25. Each participated in two 1-hour trial sessions, including pre-intervention interviews. During structured M-EER sessions, participants engaged with sequentially modulated music and developed self-directed plans for applying ER in everyday life. Following the sessions, participants provided self-reports of their regulatory experiences, which were transcribed and analyzed using thematic analysis to capture first-person perspectives. Findings suggest that the M-EER model facilitated regulated emotional changes by mapping sensory processing onto motor expression (e.g., instrument playing) and promoting embodied internal state shifts (e.g., arousal modulation). Empirical insights from lived experiences were summarized with the core themes of "agency in creating expressive space" and "music-self connection" emerged. The thematic framework of ER derived from this study suppots the role of music as a bridge between bottom-up sensory mechanisms and reflective, top-down processes (e.g., reflection on emotional changes). Although exploratory in scope, these findings also highlight the potential of the M-EER model as an integrative paradigm that combines structured clinical guidance with individual agency to address ER challenges on the autism spectrum, offering promising directions for future research and clinical application.

1. Introduction

Emotion regulation (ER), defined as the intentional modulation of emotional processes to achieve personal goals and adapt to

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contextual demands (Eisenberg & Spinrad, 2004), has been increasingly recognized as a critical concern among autistic individuals (Weiss et al., 2017). Research consistently demonstrates that autistic individuals experience significantly greater difficulties with ER skills compared to their neurotypical peers, often resulting in pronounced deficits in managing emotional responses in adaptive ways, commonly referred to as emotion dysregulation (Cai et al., 2018; Restoy et al., 2024). Specifically, autistic individuals frequently exhibit inadequately modulated emotional reactivity, such as overly intense or rapidly escalating responses (e.g., emotional outbursts), and persistent negative affective states, such as sustained sadness and diminished positive affect (Mazefsky et al., 2018; Samson et al., 2015). These difficulties often manifest in maladaptive behavioral expressions (Beck et al., 2020), including internalizing symptoms (e.g., depression and anxiety) and externalizing behaviors (e.g., aggression, irritability, and self-injurious behavior). Furthermore, when attempting to regulate their emotions through deliberate efforts, they tend to rely more on maladaptive strategies than adaptive ones (Restoy et al., 2024; Samson et al., 2015).

ER difficulties in autistic individuals typically emerge in early childhood and persist into adulthood, spanning the lifespan. Although ER skills are not considered core diagnostic features of autism, their close relationship with social competence has been consistently documented in autistic children and adolescents (Jahromi et al., 2021; Reyes et al., 2020). Stronger ER skills are correlated with higher social skills and increased prosocial behaviors, indicating that children with better ER skills may be more effective in coping with social challenges and engaging in positive peer interactions. Conversely, deficits in ER may intensify social difficulties, increasing the risk of social rejection. Recent empirical studies have extended these discussions to the transitional period from adolescents to adulthood, highlighting its continued importance for quality of life and social adaptation (Dijkhuis et al., 2017; Dell'Osso et al., 2023). As ER difficulties persist into adulthood, their adverse impact is often most pronounced during this developmental stage, which is characterized by growing demands for increased independence and more complex social responsibilities. These developmental challenges may further exacerbate existing ER difficulties, supporting the need for greater attention to ER processes in youth and young adults on the spectrum.

Despite growing interest in interventions for ER in autistic adults, they constitute a relatively small proportion of the literature. When examining the collective evidence on 28 commonly used interventions for this population (Hume et al., 2021), only 20.6 % targeted adolescents and young adults aged 15–22 years, compared to those targeting younger children. Furthermore, among the studies, only 2.5 % addressed emotion-related outcomes. In another review of psychosocial interventions for autistic adults (Bishop-Fitzpatrick et al., 2013), of 13 included studies, five targeted repetitive or adaptive behaviors, domains that may be indirectly related to dysregulated emotions but did not directly address emotion-related concerns. The remaining studies primarily focused on social cognition and communication, which are core diagnostic features of autism. Although there have been increasing attempts to understand the characteristics and mechanisms of ER, research on targeted interventions remains limited. It should be noted that the small proportion of emotion-related interventions reported in review studies does not necessarily reflect a lack of such attempts in practice, as the inclusion criteria in specific review studies may exclude interventions that are in fact implemented in real-world settings. Nevertheless, the available evidence suggests that systematic approaches to ER in adults on the spectrum remain insufficient and require further development.

Among the limited interventions examined for autistic adults, those targeting emotional well-being and quality of life typically adopt either a cognitive-focused or a response-focused approach (Schweizer et al., 2024). These approaches align with distinct modes of emotion processing: top-down and bottom-up. Top-down processing involves the cognitive interpretation and appraisal of emotional situations, whereas bottom-up processing involves the automatic perception of sensory input that elicits emotional responses (McRae et al., 2012). In terms of ER, when reappraisal is applied to alter the meaning of emotional inputs or situations, thereby reshaping emotional responses, the process is primarily governed by top-down mechanisms. In contrast, when regulation occurs by directly modifying the perception of sensory input (e.g., via suppression, avoidance, or modulation of the experience itself), it is more dependent on bottom-up mechanisms. Autistic individuals tend to rely more on bottom-up than top-down emotion processing, showing attenuated top-down expectations and increased attentional focus on sensory stimuli (Bonete et al., 2023; Case-Smith et al., 2015; Proff et al., 2022). Because of this tendency, they may face challenges in adopting top-down regulatory strategies and are more vulnerable to sensory-driven dysregulation.

Bottom-up regulation encompasses responses to both external sensory input (exteroception) and internal bodily signals (interoception). In terms of exteroception, individuals on the spectrum may struggle to select relevant external cues while filtering out irrelevant ones. With regard to interoception, they often show reduced objective interoceptive accuracy but heightened subjective interoceptive sensibility (Garfinkel et al., 2016). This discrepancy can lead to misinterpretation of bodily signals (Butera et al., 2023). Such processing differences may present as hypo- or hypersensitivity to internal sensations and difficulty differentiating between bodily and emotional responses. This impairment limits the ability to become aware of and identify emotions, which is widely regarded as a critical initial step in the process of ER (Gross, 2015). Sensory processing dysfunctions are not merely co-occurring symptoms of autism (American Psychiatric Association, 2022) but represent foundational constraints on ER. Atypical sensory processing, whether internal or external, often disrupts the integration of emotional cues and leads to insufficiently modulated sensory states, thereby intensifying ER difficulties before high-level cognitive regulatory control can be effectively engaged.

Given this context, many existing interventions emphasize sustaining adequate attention to both external and internal input, while fostering conscious awareness of emotions and their bodily changes. Within this approach, individuals learn to use bodily signals as cues to their emotional experiences (Mahler et al., 2022). Early detection of these cues enables more timely and balanced responses, supporting effective regulation strategies. Another important focus deals with the increased intolerance of uncertainty often observed in autistic individuals, which has been identified as a critical factor influencing ER skills (Dell'Osso et al., 2023). To address it, interventions have incorporated structured external sensory stimulation as a means of reducing uncertainty, thereby enhancing predictability and facilitating the modulation of internal states (Healy et al., 2022).

Music has been increasingly recognized as a powerful medium for supporting ER, by providing an active outlet for emotional expression through improvisational experiences (Hertanto, 2024) or by improving emotion recognition via musically salient cues (Pedregal & Heaton, 2021; Sivathasan et al., 2023). Furthermore, functioning as a mediator for sensory processing, music provides a stable framework for processing and interpreting emotions by modulating both external and internal sensory input. In autism, where top-down expectations are often attenuated, reliable sensory input can enhance the accuracy of perception and prediction (Proff et al., 2022). The structured nature of music offers temporal consistency that enhances the predictability of tracking and processing sensory information. In this process, music promotes the alignment of internal physiological states with external stimuli, as well as the coordination of external stimuli with somato-motor responses. Such embodied experiences facilitate the integration of internal and external cues, along with auditory and motor information (Molnar-Szakacs & Overy, 2006). Moreover, when music engages multiple sensory modalities such as auditory, visual, and tactile input, it strengthens the reliability of exteroceptive information and provides a reference for integrating it with interoceptive signals (Putkinen et al., 2024). Within this predictable structure, variations in musical elements allows for detecting and assessing discrepancies between expected and actual sensory input, thereby coordinating top-down expectations with bottom-up sensory information and mitigating the overweighting of error signals.

With regard to its effects on sensations, research indicate that music immediately and effectively influences arousal levels. Music naturally activates bodily sensations and triggers emotional responses, modulating autonomic regulation in relevant brain regions. Music-induced shifts in arousal affect emotional reactivity, thereby promoting autonomous ER. For example, for individuals who experience sensory hypersensitivity, repetitive and structured rhythms can facilitate bodily synchronization, helping to regulate energy levels and prevent sensory overload (Bharathi et al., 2019; Kern et al., 2008). Prior studies demonstrate that adults on the spectrum spontaneously engage with music for ER in their daily lives (Allen et al., 2013; Korošec et al., 2024; Matsuno et al., 2021; Venter et al., 2023). As a sonic environment, music mediates emotional arousal and regulatory states. The active use of music allows autistic individuals to control their sensory exposure and modulate the level of stimulation, either connecting with or blocking external sounds (Korošec et al., 2024; Venter et al., 2023). Notably, for this study, music-based ER is more closely linked to managing arousal levels than to altering emotional valence (Allen et al., 2013; Matsuno et al., 2021). However, uncontrolled musical stimulation can trigger sensory overload and stress, particularly when individuals lack agency over the music selection or context (Korošec et al., 2024). These findings suggest that individuals on the spectrum, particularly those capable of recognizing and articulating their emotions, acknowledge that music significantly modulates their emotional experiences, whether positively or negatively. Consequently, music serves as an effective and accessible tool for self-directed ER, highlighting its ecological relevance for this population.

Beyond these sensory and predictive mechanisms, previous studies have demonstrated that music can directly facilitate core processes of ER, particularly emotion identification. Evidence indicates that music enhances emotion recognition through identifying the emotion expressed in music (Pedregal & Heaton, 2021), pairing music with emotional pictures (Tan & Khetrapal, 2016), and enabling the expression of emotions through improvisation (Hertanto, 2024). These approaches effectively address some of the limitations associated with linguistic labeling of emotions, which can be particularly challenging for autistic individuals. Neuroimaging evidences indicate that when emotional information is embedded in music, it increases emotional salience, thereby recruiting frontal regions associated with cognitive processing. These findings demonstrate that autistic individuals are capable of cognitively processing emotional information, particularly when it is structured within musical contexts (Gebauer et al., 2014). Nevertheless, it is important to note that the emotions being identified in these contexts are external, reflecting an indirect pathway; the critical bridge between recognizing external emotions and perceiving or understanding one's own emotional states remains to be addressed.

Based on these considerations, the purpose of this study was to propose the Music-Induced Embodied Emotion Regulation (M-EER) model, a conceptual framework that integrates interoception and exteroception to guide ER in autistic individuals through sequentially modulated music. Furthermore, the study aimed to examine the applicability of this model in practice. We conducted pilot interventions with autistic youth and young adults, using qualitative interviews to explore their lived experiences. Regarding terminology, identity-first language (e.g., "autistic individuals") is used throughout this study, in line with research indicating that it recognizes autism as an integral part of identity (Dwyer, 2022). We also interchangeably use terms such as "individuals on the spectrum" to acknowledge the diverse language preferences within the autistic community. This first-person, experience-based approach was applied to capture the internal complexity of ER processes, offering insights that extend beyond the external perspectives (e.g., parental reports), commonly found in the literature (Cai et al., 2018; Restoy et al., 2024; Weiss et al., 2014). Such insights provide a comprehensive understanding of the internal dynamics underlying ER in this population.

Therefore, this study addressed the following research questions:

Is the Music-Induced Embodied Emotion Regulation (M-EER) model valid and applicable to autistic youth and young adults?

How do autistic youth and young adults experience the M-EER process, and how do they perceive the role of music in supporting their emotion regulation?

2. Proposal of the music-induced embodied emotion regulation (M-EER) model

This study proposes a framework in which music provides structured, embodied experience that integrate bodily signals and external sensory input, thereby facilitating the awareness and regulation of emotions. This framework is specifically designed for autistic individuals, particularly youth and young adults, who often need to develop self-directed strategy for ER. For this purpose, it incorporates processes that foster embodied experiencing of ER and link these experiences to their practical application to everyday life. The following sections introduce (1) the ER Mapping Matrix, which conceptualizes the dimensions of dysregulated and regulated emotional states, and (2) the implementation steps of M-EER, which outline the sequential procedure for implementing the framework including structured experiences of embodied regulation and the development of self-directed strategies.

(1) ER Mapping Matrix

The M-EER model is conceptualized as a structured process in which specific musical elements are used to induce targeted emotional states and gradually guide them toward a more regulated state through systematic modulation. We propose conceptualizing emotional states within the ER Mapping Matrix, a two-dimensional framework defined by arousal level (y-axis) and mode of expression (x-axis) (see Fig. 1). The central zone, located around the origin (0, 0), represents balanced, well-regulated emotional states. Beyond this zone lie dysregulated state. Along the y-axis (arousal), states range from hypoarousal (diminished reactivity) to hyperarousal (heightened reactivity). Along the x-axis (expression), states range from inwardly suppressed (internalizing) to overtly expressed (externalizing). In this framework, four quadrants of dysregulation exist and ER refers to transitions from dysregulated states toward the balanced central zone. This visualization illustrates the conceptual process of ER and provides a systematic classification framework that ensures structural clarity for clinical applications.

Embodied emotion regulation is facilitated by mapping these emotional dimensions onto corresponding musical dimensions and providing music that is sequentially modulated to trace a process from an initial dysregulated state toward the regulated zone. The axes of arousal can be translated into temporal elements (rhythm and tempo) and dynamic elements of music, while the axes of expression can be reflected in the regularity or variability of musical patterns and structures. For example, to reduce heightened reactivity (upper-right quadrant), tempo can be progressively slowed and loudness gradually decreased, while rhythmic regularity is simultaneously increased through the more frequent use of repetitive rhythms and the gradual reduction of varied motifs, ultimately highlighting rhythmic stability. Conversely, to address flat affect and hyporeactivity (lower-left quadrant), tempo can be gradually increased and loudness raised to a moderate (but not excessive) level, while greater rhythmic variability is introduced (e.g., subdivided beat or syncopated rhythm), together with the use of more diverse musical motifs in which melodic features and harmonic changes are relatively emphasized. Table 1 and Fig. 2 displays more specific examples how musical elements can be gradually modulated while reflecting the emotion regulation processes and how it differs depending on the target pathways of regulatory processes.

(2) Implementation steps of M-EER model

The implementation steps of M-EER model outline its application to autistic youth and young adults. These steps consist of structured musical experiences and the personalization of self-directed strategies, designed to gradually support the spontaneous and independent use of regulation in daily life. The first step, music-based regulation exercises, involves expressing current emotional states through active musical engagement (e.g., instrumental playing) within structured sequences aligned with ER processes. The second step, personalization of self-directed strategies, focuses on reflecting upon the structured exercises to identify the most effective musical elements for regulation. Based on this reflection, participants design individualized strategies for everyday application. The detailed procedural steps are presented in Table 2.

3. Pilot implementation and exploratory analysis of participant experiences

3.1. Participants

This M-EER model–based intervention was conducted with autistic youth and young adults. The inclusion criteria were: (1) a medical diagnosis of autism, (2) age over 18 years, and (3) the cognitive ability to recognize and verbally express emotional

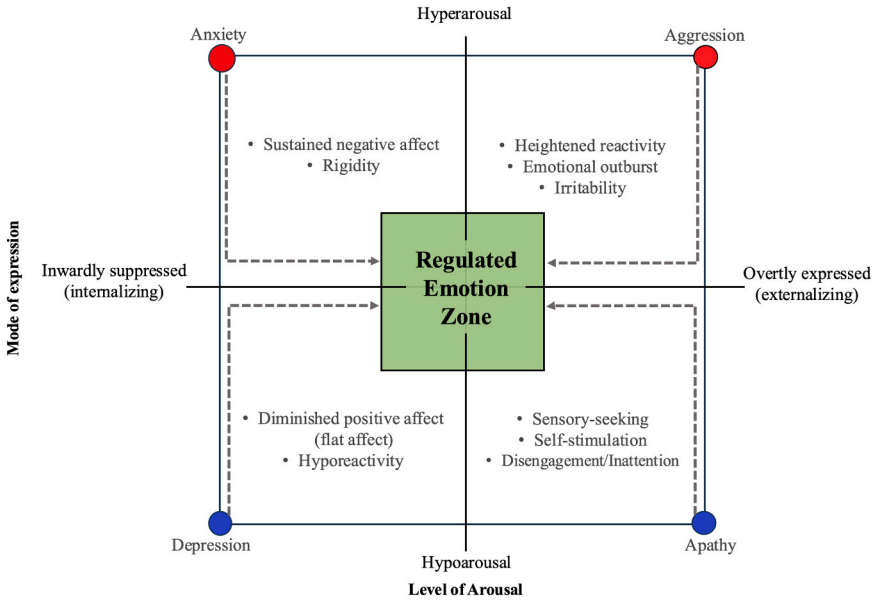


Fig. 1. Emotional dysregulation states in autism within the ER Mapping Matrix.

Table 1
Components of music-based regulatory processes.

Initial dysregulated emotional state	Matching quadrant in ER Mapping Matrix	Targeted regulatory process	Sequential modulation of musical elements			
			Temporal			Structural
			Tempo	Dynamics (loudness)	Rhythm	Motif development (regularity/ variability)
Heightened activity/ emotional outburst	High arousal/ Externalizing (Upper-Right)	Decreasing arousal level; coordinating expression	↓	↓	Stable, predictable pattern	Repeated motifs (stable rhythmic features) ↑
Anxiety /Rigidity	High arousal/ Internalizing (Upper- Left)	Decreasing arousal level; supporting expression	↓	↓	Stable, predictable	New motifs (melodic/ harmonic features) ↑
Hypoactivity/ flat affect	Low arousal/ Internalizing (Lower-Left)	Increasing arousal level; supporting expression	↑	↑	Variable (subdivided, syncopated)	New motifs (melodic/ harmonic features) ↑
Sensory-seeking/ disengagement	Low arousal/ Externalizing (Lower-Right)	Increasing arousal level; coordinating expression	↑	↑	Variable (subdivided, syncopated)	Repeated motifs (stable rhythmic features) ↑

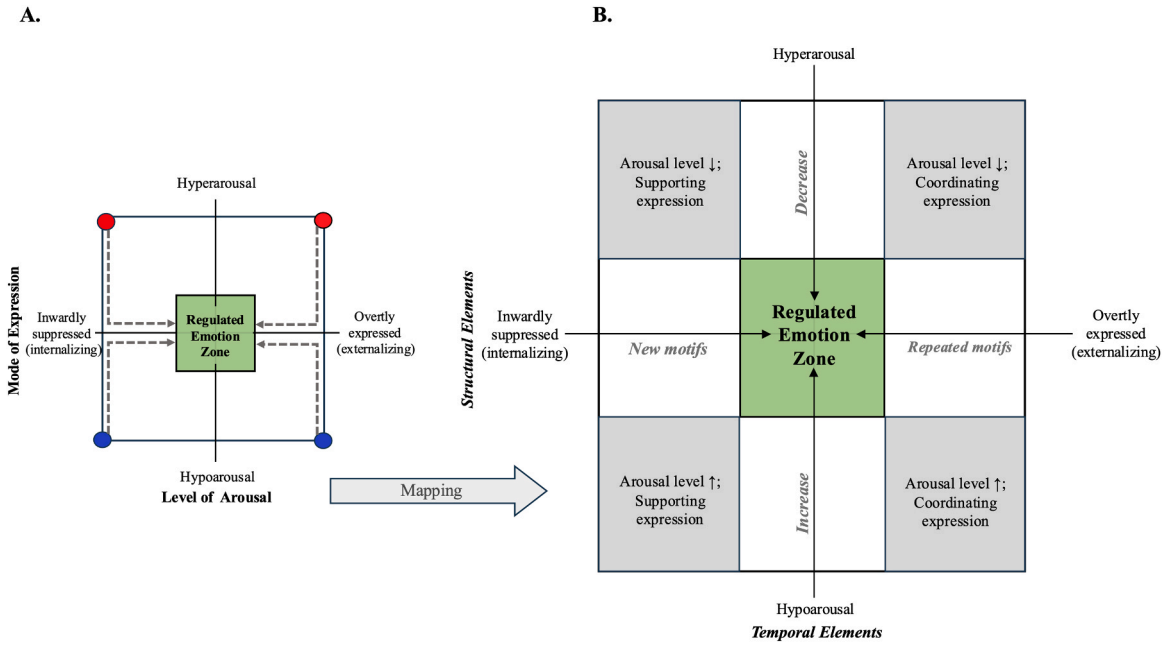


Fig. 2. Mapping music-based regulatory processes to the ER Mapping Matrix. *Panel A* shows emotional dysregulation states in autism placed within the Matrix, and *Panel B* displays the mapping of music-based regulatory processes onto the Matrix.

experiences without difficulty. Given that the purpose of this exploratory study was to capture the subjective experiences of autistic individuals during M-EER, we limited the criteria to participants capable of verbal articulation. Although we acknowledge that the autistic community includes individuals with a broader range of verbal skills and that this model may benefit individuals with varying communication profiles, this specific criterion was necessary to ensure the collection of detailed first-person accounts. Information about the study procedures and participant criteria was posted at the university's center for students with disabilities and at high schools including students with and without disabilities. Participants who read and understood the study information and voluntarily agreed to participate were recruited. Additionally, one participant was recruited through snowball sampling via a previously enrolled participant.

Demographic information of the participants is presented in Table 3. Three participants completed the implementation of the M-EER model. Their mean age was 21.7 years (range = 19–25 years). As part of the screening process, the SRS-2 and K-DERS were administered to assess social skills and emotion dysregulation, respectively. The average SRS-2 T-score was 59.3 (SD = 14.5, range =

Table 2
Structure and contents of implementation steps of the M-EER model.

Step	Implementation Content
Music-based regulation exercises	1. Expressing current emotional states through instrumental playing • Use a self-selected instrument to musically express the current emotional state • Evaluate whether the expression accurately reflects the intended state; if not, adjust by modifying tempo, rhythm, or instrument choice with guidance from the investigator (i.e., music therapist) • Confirm alignment between the musical expression and the internal state, and explicitly acknowledge this recognition 2. Selecting music and designing ER processes • Listen to participant-preferred and investigator-selected samples with varying rhythmic and melodic elements to observe emotional and physiological responses • Reflect on changes in arousal, comfort or stability • Select music options with guidance from the investigator, for use in ER • Plan a sequence of three pieces for the target regulation process, either pre-determined from the pre-intervention interview or collaboratively selected through discussion with the participant 3. Engaging in sequential instrumental playing aligned with ER processes • Play three music pieces in sequence (recorded or live) to represent the targeted regulation process through modulation of temporal elements, dynamics, and musical structure • Monitor changes in emotional state and arousal during playing. When needed, visual aids based on the ER Mapping Matrix may be provided to concretely support recognition of regulatory processes
Personalization of self-directed strategies	1. Identifying effective factors for self-directed exercise • Reflect on previous structured regulation exercises to identify musical elements that the most effectively supported regulation • Design a personalized strategy for daily use by selecting specific actions (e.g., instrument playing when possible, body movements, singing short lyrics, or other methods such as breathing) • Discuss when and how to apply the strategy and outline a practical plan for implementation 2. Apply personalized strategies with live music accompaniment • Practice the chosen exercise with live music provided by the investigator • Reflect on the experience and discuss its applicability and feasibility for real-life implementation

50–76). Based on the established cut-off criteria (where a T-score < 60 indicates intact reciprocal social behavior), two participants fell within the mild range of sevirity, while one participant scored in the severe range. This indicates that, although most participants were able to maintain relatively functonal communication with only mild symptoms, one participant experienced more pronounced difficulties, particularly involving severe repetitive behaviors. The average K-DERS score was 76.0 for these participants. Given that scores over 70 usually indicate significant impariment in ER, these participants exhibit moderate to severe difficulties in ER.

3.2. Procedures

Prior to the M-EER model-based intervention, the first author conducted pre-intervention interviews to gather background information. These interviews focused on daily emotion dysregulation issues, specifically exploring situations and triggers associated with emotional difficulties, perceived physical and emotional states during dysregulation, existing coping strategies, and the use of music in these contexts (e.g., preferred music and music-related activities for ER). Table 4 presents the participants' current dysregulation issues, typical coping strategies, music background, and preferences. All participants were able to articulate specific dysregulation triggers and describe their existing strategies. It demonstrates that they acknowledged their own emotional challenges and the necessity for regulation. Specifically, participants clearly recognized how dysregulation impacts both their internal states and their relationship with others, and they have actively sought to develop personal coping mechanisms. Notably, when describing these experiences, participants frequently referenced music-related activities, indicating that they already recognize the potential of music to affect their emotions.

Subsequently, participants individually completed two trials of the intervention, each lasting approximately one hour. The intervention goals, selected music sequences, and music examples for each participant are detailed in Table 5. Regarding the musical stimuli, the intervention used both participant-preferred music (PM) and therapist-selected music (TM). Selection was determined based on the ER Mapping Matrix, specifically focusing on temporal elements (i.e., tempo, rhythm, and intensity) and structural elements (i.e., regularity or variability of motif development). For PM, the first author selected options from the participants' playlists that matched the required musical elements of the Matrix. These options were then discussed with the participants to ensure their agreement. In contrast, for TM, a repertoire ranging from popular to classical genres, was pre-validated by five music therapists, each

Table 3
Demographic information of each participant.

Participant	Age	Sex	Current Status	SRS-2	K-DERS
P1	19	Male	High school student	50	80
P2	25	Female	University student	76	75
P3-	21	Male	Office worker	52	73

Note. SRS-2 = Social Responsiveness Scale, Second Edition; K-DERS = Korean version of the Difficulties in Emotion Regulation Scale.

Table 4
Self-reported participant profile: emotion dysregulation characteristics and music background.

Pt	Dysregulation issues	Triggers for dysregulation	Existing coping strategies	Prior music experiences	Preferred music
P1	• Persistence of anxious feeling • Easily triggered sadness leading to inactivity • Difficulty alleviating sadness, even with pleasant events	"When I feel like nothing makes me happy" "When it rains" "When listening to certain music"	• Going for a walk	1 year of drum lessons 1 year of music therapy	Winter songs (e.g., Felis Navidad, Jingle bells)
P2	• Intense anger and self-destructive urges in unexpected or guilt-inducing situations • Physical freezing and mental blankness due to excessive arousal • Feelings of humiliation or a sense of being gaslighted following loss of control	"When things do not go as expected" "When friends say negative things to me" "When going to a new or dark place	• Whistling • Playing the ocarina or piano	3 years of piano lessons	Animation soundtracks (e.g., Studio Ghibli films, films by Makoto Shinkai)
P3	• "Blank mind" and blurred boundaries with reality during high stress • Feeling of rejecting one's own existence • Delayed recognition of emotions	"When stress builds up" "When others get upset with me for no reason" "When a teacher scolded me"	• Playing background music • Watching videos • Listening to sad music for anticipatory anxiety	No prior music experiences	Usually gentle music; upbeat music when exercising

with over eight years of clinical experience with autistic individuals, to ensure alignment with the Matrix dimensions. Only selections that received valid ratings from all experts were included for the intervention. Notably, when introducing TM selections during the intervention, the first author more carefully monitored and confirmed that the music did not induce discomfort or feelings of uncertainty due to unfamiliarity.

The intervention was implemented by the first author, a graduate music therapy student with two years of supervised clinical practicum experiences at the time of the study. The second author, a board-certified music therapist and professor with over 15 years of clinical experiences working with individuals on the spectrum, provided close supervision throughout the sessions.

After the intervention, each participant engaged in an interview with the first author. Interview questions include participants' experiences during the entire intervention process and their perceptions of themselves, their emotions, and their experiences with music. The interview adopted a semi-structured approach, beginning with the open-ended questions about experiences and perceptions, followed by additional questions to clarify or elaborate on their responses as needed.

3.3. Data analysis

This study applied thematic analysis as the analytic framework, aiming to investigate participants' experiences and meanings from a first-person perspective. Themes were identified inductively at the explicit, semantic level, grounded in the participants' verbatim transcripts. The analysis followed the six-phase process (Braun & Clarke, 2006): familiarization with the data, generating initial codes, searching for themes by comparing and contrasting codes across participants and categorizing them into similar code groups, reviewing themes, and defining and naming themes, and producing the final report. All verbal responses collected during intervention

Table 5
Intervention components and details for each participant.

Pt	Assessed dysregulation: Placement in ER quadrant (ER Mapping Matrix)	Target intervention goal	Selected music sequence	Examples of music used in each sequence of ER process
P1	Upper-left (Hyperarousal/ internalizing)	Decreasing arousal level and supporting expression	Tempo ↓, Loudness ↓, Stable rhythm pattern ↑, New motifs (melodic/ harmonic features) ↑	[TM-RM] C. Orff, "Carmina Burana" [TM-LA] Jason Mraz, "I'm Yours" [PM-LA] Elvis Presley, "Can't Help Falling in Love"
P2	Upper-right (Hyperarousal/ externalizing)	Decreasing arousal level and coordinating expression	Tempo ↓, Loudness ↓, Stable rhythm pattern ↑, Repeated motifs ↑	[TM-RM] S. Prokofiev, "Dance of the Knights (Montagues and Capulets)" [TM-LA] Percussion improvisation with tempo and rhythm modulation [PM-LA] Harold Arlen, "Over the Rainbow"
P3	Lower-left (Hypoarousal/ internalizing)	Increasing arousal level and supporting expression	Tempo ↑, Loudness ↑, Variable rhythm pattern ↑, New motifs (melodic/ harmonic features) ↑	[TM-RM] P. Kater, "Quietude" [TM-LA] P. Kater, "Quietude" with tempo and rhythm modulation [PM-LA] Michael Jackson, "Heal the World"

Note. RM = recorded music; LA = live accompaniment; PM = participant-preferred music; TM = therapist (investigator)-selected music.

sessions and post-interviews were transcribed and segmented into meaningful units. The first author performed the initial coding. To ensure inter-rater reliability, the analysis was cross-checked by the second author, and any discrepancies were resolved through discussion until consensus was reached. To enhance the confirmability and trustworthiness of the findings, an audit trail was created and maintained (Bowen, 2009), systematically documenting the progression of data analysis, including raw data, coding frameworks, theme development, and analytic memos.

4. Final thematic framework of the M-EER model

This study proposed the M-EER Model and its implementation steps, and three autistic youth and young adults participated in two intervention trials. Following the intervention, participants' verbal responses were analyzed to identify the core themes of their experiences, highlighting the meaning of these experiences and the role of music. A total of 11 themes were generated and organized into five categories representing the core processes, and one category reflecting a facilitative condition (see Table 6). The core process categories included *Interoceptive Monitoring*, *Affective Appraisal*, *Exteroceptive Monitoring*, *Integration*, and *Interpretation of Regulatory Outcomes*.

An analysis of each participant's primary experience based on their self-reports showed distinct regulatory processes. P1 demonstrate a notable shift from initial discomfort to a sense of stability and calm. Specifically, he exhibited increased sensory tolerance for intense sounds (e.g., the drum) and successfully mapped his internal states onto specific instruments. Consistent with his goal of decreasing arousal and supporting expression, his perceived change was characterized by an ability to accept a wider range of emotions and express them through active playing. P2's experience was characterized by agency and emotional release. Her reports centered on the value of 'creating her own space' and the release of built-up emotional tension. She specifically highlighted the role of slower tempo in providing her with stability. Aligning with her goal of decreasing arousal and coordinating expression, she appeared to use the stable musical structure to facilitate the creative release of emotion. P3 used vivid positive imagery (e.g., sunshine, stars, a lake) to articulate his perception of the experiences. He described the interconnectedness of music, emotion, and regulation, accepting his experiences as joyful. Reflecting the goal of increasing arousal and supporting expression, the varied musical qualities triggered his emotional expression in a creative but safe way, significantly reducing his sense of being overwhelmed.

Based on the hierarchical and sequential relationship among the themes, a thematic framework of the M-EER model was developed (see Fig. 3). The framework illustrates that the ER process in autistic individuals begins with interoceptive and exteroceptive

Table 6
Thematic analysis results: categories, themes, and excerpts.

Category	Theme	Excerpts
Interoceptive monitoring	Perception of internal bodily states	It feels good, like my heart is pounding (P1); It feels like I'm worn out (P2); A sense of chaotic anxiety overwhelms me, as if soldiers are marching toward me; Being startled feels unpleasant, like my heart suddenly dropped (P3).
Affective appraisal	Recognition of affective changes	With the first piece of music, I felt uncomfortable. Now I feel stable and calm (P1); I felt a sense of urgency, as if I had to do something right away; It felt increasingly intense, as if obstacles disappeared and catharsis reached its peak (P2); After a huge explosion, waves of aggression slowly started to creep in; The aggression is gradually sinking down under a lake (P3).
	Emotional resonance with music	Even if the drum is loud, I'm okay with it; I hate the sound of balls bouncing or volleyballs in a crowded gym, but I can tolerate the drum (P1); As the music sped up, I found myself speeding up too. I was aware of it, but I just let it happen because it felt so joyful (P3).
Exteroceptive monitoring	Directed attention to musical features	It felt very stable, with the music sounding calm and soft; I felt like the melody was moving through the music (P1); I like the song where the melody flows smoothly; It felt like slowly building up and then bursting all at once (P2).
	Differentiation of musical qualities	Fast and slow music feel quite different; This one makes me feel better than the previous song (P1); This song feels completely different from the previous one (P3).
Integration	Mapping personal states onto specific music	My current feeling fits the egg shaker; This heavy feeling fits the ocean drum (P1); When I was really upset, it felt similar to the song, '*Take on Me*'; Not exactly, but it felt similar to when I get tense and angry; When I'm feeling stable, it feels similar to flute music (P2); 'Over the rainbow' fits the feeling like I'm flying in the warm sunshine, like soaring through the clouds (P3).
	Linking emotional changes to musical elements	It's because the sound was loud (P1); Slower tempo makes me feel calmer and settles my mind (P2); The song feels like the warmth of sunlight and the calmness of stars at the same time. It makes me feel serene. That feeling was due to changes in timbre and dynamics; The fast tempo and strong dynamics were the main reason. The intensity of the music seemed important (P3)
Interpretation of regulatory outcomes	Agency in creating expressive space	It felt like my feelings were expressed (P1); It helps me express myself when I find the right pitch and create a melody by following my sense; As I followed and created melodies, it felt like I was creating my own space and becoming one with the music (P2); I just followed my feelings; I just played what I felt, and it felt like I played really well (P3).
	Music-self connectedness in regulation	It feels like music ties my feelings together into one (P2); Perfectly, completely, I felt like my feelings and the music were connected as one; It was fascinating and nice that music, emotion, and emotion regulation were all mixed together (P3).
Facilitative condition	Emotional self-awareness	Today, I felt heavy-hearted (P1); I felt a little uncomfortable (P2); On my way here today, the crowd stressed me out and I felt tension building up (P3).
	Co-regulation through partner connection	Playing along with you made me feel better. It felt good to do it together. When you sped up, I sped up (P1); I felt like we became one together (P3).

monitoring. Interoceptive monitoring leads to affective appraisal, after which the two monitoring processes are integrated. This integration encompasses mapping personal states onto specific music and linking emotional changes to musical elements. The regulatory outcomes were characterized by two key themes: agency in creating expressive space and music-self-connection in regulation. Within this process, emotional self-awareness facilitated the beginning of the entire sequence, while co-regulation through partner connection (i.e., the investigator in this study) functioned as a facilitative condition that strengthened both connection and regulation. Participants described the core experiences by stating, "It felt like I was creating my own space and becoming one with the music," "I just followed my feelings. I just played what I felt," "I felt like my feelings and the music were connected as one," and "It feels like music ties my feelings together into one." This sense of agency and connection emerged as a core theme in how participants experienced ER through music.

During the intervention and post-interview, participants discussed how they intended to use music as a self-strategy for ER in daily life. P1 indicated that he would practice deep breathing and positive self-talk (e.g., saying "I love you") accompanied by handclapping using it as a substitute for instrument playing. P2, conversely, was unable to articulate a specific independent strategy. Although she identified creating melodies with self-selected notes as the most satisfying aspect of the sessions and possessed prior musical training, she expressed reluctance to play on her own. She explained that when her playing did not go as expected and was interrupted by mistakes, it often intensified her negative emotions. P3 reported that he would use the specific rhythm he created during the sessions. He planned to use this rhythm to help him stop and manage his feelings whenever he felt distressed.

5. Discussion

This study proposed the M-EER model as an approach for autistic youth and young adults, highlighting how emotional processes can be embodied and regulated through music-integrated sensory experiences, which are often dysregulated in this population. It also demonstrated the practical relevance of this model for individuals in the transition to adulthood or early adulthood. Furthermore, by investigating and analyzing participants' first-person experiences, the study provided valuable insights into how these theoretical proposals can be translated and enacted within this population, as well as the role of music in their lived experiences and how it is perceived to function within the regulatory process.

First, the findings of this study present a systematic framework for understanding dysregulated emotional states and ER processes, illustrating how these can be mapped onto musical experiences. Emotion dysregulation manifests in distinctive ways in autistic individuals, often through atypical reactivity or maladaptive expressions, supporting the need for a population-specific framework (Beck et al., 2020; Mazefsky et al., 2018). Commonly used assessments of ER strategies rely primarily on top-down cognitive mechanisms requiring conscious appraisal and intentional action choices. Research indicates that individuals on the spectrum are capable of using this mechanism, and particularly demonstrate improved cognitive processing of emotional information when provided with external guides, particularly through music (Pedregal & Heaton, 2021). Specifically, music offers salient affective cues that reduce the ambiguity of emotional signals. However, such cognitive mechanisms may not always be accessible during states of dysregulation, especially for individuals on the spectrum who often exhibit predominant sensory processing features, where immediate and automatic sensory experiences may override top-down predictions (Robertson & Baron-Cohen, 2017). To address this, the proposed M-EER model employs a sensory-driven approach to conceptualize how music serves as a structured external stimulus to modulate sensory experiences, potentially scaffolding the functioning of cognitive control. Neuroimaging studies suggest that for autistic individuals, the cognitive enhancement observed during musical emotion processing is intrinsically linked to heightened physiological arousal; this arousal increases emotional salience, thereby making the emotional content more accessible for subsequent cognitive processing (Gebauer et al., 2014). Aligning with this perspective, the M-EER model highlights the value of bottom-up strategies, positioning them as a prerequisite for subsequent top-down cognitive control in ER.

Specifically, the proposed ER Mapping Matrix, provides a conceptual foundation for approaching their emotional processes and sensory experiences in an integrative way. By considering both arousal level and mode of expression, the Matrix effectively maps diverse emotion dysregulation issues frequently observed in individuals, which was further supported through the validation by professionals. This framework can offer practitioners systematic strategies for understanding and assessing emotional states and for designing structured regulatory processes with intuitive and clear goals. It can also empower participating individuals by providing concrete ways to conceptualize their regulatory processes, monitor their experiences, and strengthen the development of self-strategies.

Second, this study contributes to the conceptualization of embodied ER for autistic individuals. Hypo- or hypersensitivity to internal sensations and the difficulty distinguishing bodily from emotional responses make it critical to support individuals in recognizing and accepting emotional processes. Furthermore, heightened intolerance of uncertainty and unexpectedness are influential factors in emotion dysregulation for this population, which calls for structured external sensory stimulation as a scaffold for detecting bodily cues and reducing uncertainty. Music, as an effective medium for inducing and altering physiological, emotional, and behavioral experiences by facilitating the synchrony between auditory (external) and sensorimotor (internal) experiences, has been repeatedly documented as a valid response modulation strategy (Molnar-Szakacs & Overy, 2006). Given that bodily sensation is a key source and resource of emotional experiences in bottom-up mechanisms (Schoeller et al., 2024), music that effectively triggers and strengthens such sensations can demonstrate how ER processes unfold in sequence from dysregulated to regulated states. Within the M-EER model, sequential modulation of musical stimuli as external cues, beginning with sensory stimulation similar to dysregulated states, and gradually guiding toward a regulated state, combined with active musical engagement (e.g., playing instrument), provides practical and concrete strategies for embodying ER in real-world applications for this population.

Third, the step-by-step implementation process is an important contribution of this study, as it enhances both replicability and

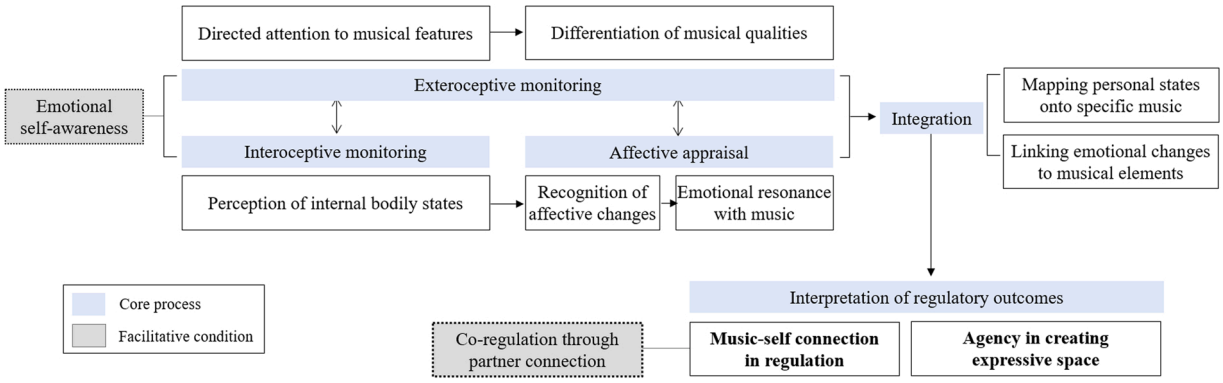


Fig. 3. Thematic framework of music-induced emotion regulation processes.

applicability in clinical contexts. Each procedural step, along with practical guidelines for modulating musical elements depending on specific ER goals, was clearly delineated, and strongly validated by professionals. Specific examples of music and musical behaviors applied with autistic youth and young adults further demonstrated the applicability of this model to this population. Participants reported the intentional use of personal strategies for dysregulation, which aligns with previous qualitative studies on everyday music use for ER among autistic adults (Allen et al., 2013; Korošec et al., 2024; Matsuno et al., 2021). However, prior studies primarily demonstrated patterns of spontaneous music use in this population, offering limited systematic guidance on structured regulation. In this context, this study provides meaningful implications by presenting a systematic framework that guides and extends existing strategies. Furthermore, consistent with literature indicating that autistic adults prioritize arousal regulation (Korošec et al., 2024), the proposed framework, by facilitating the embodiment of regulatory processes, serve as a feasible approach for developing self-directed ER strategies. This approach thereby strengthens the sustainability of the intervention. However, it should also be noted that the model and implementation steps proposed in this study are more relevant for youth and young adults who are able to communicate their experiences and cognitively process intervention contexts. This limitation reflects the scope of this study, which focused on exploratory conceptualization of a theoretical approach and relied on self-report to capture internal dynamics. Future research should validate the applicability of this model across the broader autism spectrum and explore modifications for individuals with greater impairments in cognitive processing or verbal communication, who may face challenges in independently implementing the process.

Finally, the analyses of participants' self-reports and reflections on the M-EER processes provided valuable insights into how music is realized and processed in their regulatory processes. The key themes emerged regarding the role of music: "agency in creating expressive space" and "music-self connection". Notably, all three participants consistently reported a sense of connection with music, describing music, the self, and emotion as being tied together. This finding is particularly meaningful given that emotion dysregulation in individuals on the spectrum is often associated with dissociation and detachment from self-experiences. Such tendencies may manifest as avoidance, suppression, rigidity in defending against external experiences, or difficulty in adequately processing internal experiences within integrative contexts. The potential of music to restore a sense of connection and to create a safe space for self-experience therefore holds significant implications for addressing ER challenges in this population.

Another important finding is that although this model is primarily grounded in sensory experiences, participants also described mapping their experiences onto music through cognitive analysis of musical elements and reflection on their emotional changes in response to music. This suggests that music, as an exteroceptive stimulus, can activate bottom-up mechanisms that directly influence emotions, while simultaneously engaging interpretative and appraisal processes aligned with top-down mechanisms. This dual action underscores music's unique potential to bridge bottom-up and top-down pathways, thereby offering an integrative paradigm for ER that can inform the future development of assessment systems and interventions.

A notable aspect of this study is the observation of how individual differences in sensory and dysregulation profiles impact the model's efficacy. Although formal quantitative measures of sensory profiles and ER strategies were not employed, intervention goals were collaboratively established based on participants' self-reported dysregulation issues. Musical sequences were tailored to each participant's specific profile, considering both arousal levels and modes of expression. Interestingly, these approaches yielded distinct experiences. Participants with high-arousal issues reported that music served as a source of stability, facilitating increased sensory tolerance (P1) or the safe initiation of creative expression (P2). Conversely, for the participant with low arousal and inward expression (P3), music functioned as a trigger for safe and creative emotional engagement, allowing for explicit emotional expression and joyful perception. These findings support the use of the ER Mapping Matrix. By mapping emotional issues onto specific musical characteristics, the Matrix provides a useful, individualized guide for sequentially designing musical experiences that sensitively reflect unique sensory and ER needs. However, given the importance of individual variability in this population, future studies should incorporate systematic measurement of sensory issues to further enhance this model's ecological validity. Furthermore, examining the relationship between assessments using the Matrix and previously validated dysregulation measures would further support the validity of goal-setting within this model.

In a similar context, while self-directed strategies are integral to this model, the mechanisms for their sustained use following intervention require further investigation. Based on observation from this study, successful self-implementation appears to depend less

on prior formal musical background and more on the individual's inclination and motivation to access music, as illustrated by P2's case. Given the potential gap between planning and actual implementation, the provision of concrete supportive guidelines (e.g., self-implementation tools and self-monitoring checklists) is essential to maximize the value of music as a sustainable self-strategy.

Finally, although this exploratory study prioritized qualitative depth over confirmation of intervention effects, the small sample size limits the generalizability of the findings. While subjective reports provide an authentic first-person perspective on the internal dynamics of regulation and the role of music in this process, these subjective insights may not be universally applicable, particularly given the heterogeneity and varying sensory profiles within the autistic population. Further studies with larger samples are needed to validate how the model functions across the broader spectrum, thereby enhancing its practical applicability.

In conclusion, this study offers a novel framework for understanding and supporting emotion regulation in autistic individuals through embodied musical experiences. By mapping sensory processing and emotion, the M-EER model highlights music's unique capacity to mediate regulatory change. Empirical insights from participants' lived experiences further support the value of integrative, person-centered approaches that combine structured clinical guidance with individual agency. Future research is needed to validate and expand this model to foster more inclusive and embodied therapeutic approaches for the broader neurodivergent population.

CRediT authorship contribution statement

Minzu Park: Writing – original draft, Methodology, Investigation, Conceptualization. **Ga Eul Yoo:** Writing – review & editing, Validation, Supervision, Project administration, Methodology.

Declaration of Competing Interest

The authors declare no conflict of interest.

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This article is a revised and expanded version of the first author's master's thesis submitted to Ewha Womans University. During the preparation of this work, the authors used Google Gemini to improve grammatical accuracy and readability. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the article.

Data availability

Data will be made available on request.

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