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Piano with a twist: A pilot study exploring the preliminary effects of a piano therapy program for children with autism spectrum disorder

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ABSTRACT

Children with autism spectrum disorder (ASD) show frequent maladaptive behaviors and difficulties in social communication and motricity. Various studies suggest that music-based interventions might help overcome these challenges. Yet, their findings are not conclusive, particularly regarding piano music. The current pilot study aims to present a new music-based intervention – the Piano Therapy program – and to explore its effects on social communication, motricity, self-care, and adaptive behavior skills in children with ASD. The program uses techniques derived from Applied Behavioral Analysis and active and receptive musical methods structured around a single instrument (i.e., piano). Sixty children with ASD were quasi-randomly assigned either to the Piano Therapy group or the control group. In the experimental group, the 4-month program was administered individually, twice a week. Using the Psychoeducational Profile - Third Edition (PEP-3) reports, the examiner and the caregivers assessed participants' skills pre- and post-intervention. The findings indicate that the children enrolled in the Piano Therapy program show significant improvements in all the developmental areas assessed with PEP-3, compared to the control group. Although further research is required, these preliminary results have clinical implications for practitioners and bring new evidence about the beneficial effects of a piano-based intervention in individuals with ASD.

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder with a prevalence of 23 per 1000 (1 in 44; Maenner et al., 2021). To detect the causes of ASD, several hypotheses have been raised. One theory is that ASD would be based on a broader autism phenotype passed down by parents, in particular by fathers (Rubenstein & Chawla, 2018). Other findings link ASD to mitochondrial dysfunction, a theory that may be an important venue for treatment and prevention of severe symptoms in individuals with ASD (Rose et al., 2018). Although there is no consensus on the unique cause of ASD, several factors like genetics, environment, and medical progress, might play a role (Huguet, Ey, & Bourgeron, 2013; Rubenstein & Chawla, 2018).

The core symptoms of ASD include social communication and social interaction impairments, and restricted and/or repetitive patterns of behavior, interests or activities (American Psychiatric Association, 2013). Approximatively one third of individuals with ASD may also have intellectual disabilities (Maenner et al., 2021). Communication and language impairments, as well as motor deficits can also co-occur (American Psychiatric Association, 2013). Problem behaviour, such as self-injury, aggression, disruption, result in a diminished quality-of-life for the individual and family, is more frequent in children with ASD compared to their typically-developing peers (Newcomb & Hagopian, 2018). However, there are considerable variations in ASD profiles leading to inter-individual differences in the manifestation of symptoms and to important fluctuations over time in the severity of symptoms (American Psychiatric Association, 2013). To alleviate the severity of symptoms and improve overall functioning, the interest in improving and developing interventions has significantly increased over time, particularly for early interventions.

Several therapies, each having a different approach, targeting relatively the same areas of development, such as communication, behavior,

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and social skills were proven successful in children with ASD. One widely-used intervention for ASD is Applied Behavior Analysis (ABA; Cooper, Heron, & Heward, 2019). ABA has brought improvements for young children with developmental disorders over the years, including those with ASD. Starting with studies by Lovaas (1987), until now, it was shown that ABA may help develop adaptive functioning in areas such as: language development, social functioning, intellectual functioning, and daily life skills (Virués-Ortega, 2010). ABA can be personalized to the child's own needs and is based on behavioral techniques and learning principles (such as reinforcements, rewards, and prompt hierarchy). It is adapted to the child's natural environment and targets a large array of developmental domains, such as cognitive, socio-emotional, behavioral or communicative (Foxx, 2008; The Council of Autism Service Providers, 2020). For non-verbal individuals, Picture Exchange Communication System (PECS; Bondy & Frost, 1994) is a widespread communication program using ABA principles. This methodology has shown significant improvements in terms of social communication skills in preschoolers with ASD (e.g., Lerna, Esposito, Conson, Russo, & Massagli, 2012), but most of the studies showing positive effects are based on single case designs (Kaduk, 2017). Despite the large evidence supporting ABA interventions (Medavarapu, Marella, Sangem, & Kairam, 2019; Virués-Ortega, 2010), the outcomes should be considered with caution. First, the strength of the evidence is debatable: stronger evidence is reported generally by studies using within-subject design rather than randomized clinical trials (Roane, Fisher, & Carr, 2016). Moreover, ABA-based interventions have given rise to criticism in recent years (Leaf et al., 2022). Leaf et al. (2022) highlight several concerns regarding the popular ABA-based interventions, such as the lack of personalization of the intervention intensity and the inadequate weekly frequency, the rigidity of the program, or the underestimation of the benefits of stereotypical behavior (Leaf et al., 2022). A slightly more flexible behavioral intervention with a developmental approach is the Early Start Denver Model (ESDM; Rogers & Dawson, 2010; Ryberg, 2015). ESDM is partially based on ABA principles and also tailored for young children. The main upgrade in ESDM is the focus on the quality of social relationships favoring dynamic interactions (including with caregivers), the positive affect and the child's initiative. ESDM is also known for improving general behavior, as well as cognitive functioning, and social interactions and communication (Rogers & Dawson, 2010). Moreover, other types of intervention programs may use some ABA principles, such as music therapy, but deviate from pure ABA interventions (Lim & Draper, 2011; Mayer-Benarous, Benarous, Vonthron, & Cohen, 2021).

In terms of dosage, there is no clear standards in terms of ABA intervention intensity or duration (Whitehouse et al., 2020). However, a recent review (Linstead et al., 2017) on ABA interventional studies focused on improving adaptive, motor and social skills shows that the monthly average number of hours ranges from six to twelve hours. Certain organizations suggest that outcomes are expected to occur around three months of treatment and recommend an evaluation of the individual's progress and a reassessment of treatment goals every three to twelve months (Blue Cross of Idaho, 2021; The Council of Autism Service Providers, 2020).

Music-based approaches and ASD

Three main types of music-based approaches, which can be applied to individuals with various diagnoses and a wide age-range, can be differentiated: music therapy, music medicine and music-based interventions (Stegemann, Geretsegger, Phan Quoc, Riedl, & Smetana, 2019; Yinger & Gooding, 2014). The American Music Therapy Association (American Music Therapy Association, 2005; Stegemann et al., 2019) defines music therapy as an art and evidence-based intervention promoting health, which uses individualized musical experiences within a context of a therapeutical relationship and is only provided by certified music therapists. Music medicine is less interactive compared to music therapy and uses passive listening to pre-recorded music provided by healthcare specialists without developing a patient-therapist relationship (Stegemann et al., 2019; Yinger & Gooding, 2014). Music-based interventions refer to the use of music activities, such as singing in a choir or playing an instrument, provided by health professionals or musicians with the intention to promote health and enrich daily life (Stegemann et al., 2019). Often, these interventions are provided along with other psychotherapeutic methods (Yinger & Gooding, 2014).

For individuals with ASD, music therapies and music-based interventions are often used. As suggested by a recent review (Geretsegger, Elefant, Mössler, & Gold, 2014), music therapy has shown promising results and may be beneficial and efficient for individuals with ASD. Most of the studies on individuals with ASD participating in music therapy show improvements in socio-emotional skills, such as social interactions and relationships (e.g., increased engagement with others, socio-emotional reciprocity, joint attention, emotional understanding), and verbal and non-verbal communication, but also in initiating behavior, play, and self-care skills (Geretsegger et al., 2014; Ghasemtabar et al., 2015; James et al., 2015; Kim, Wigram, & Gold, 2008; LaGasse, 2017; Sharda et al., 2018; Whipple, 2004). In the past decade, randomized controlled and comparative studies have started to arise in music therapy applied to individuals with ASD, although the first evidence came from mainly case studies (see Geretsegger et al., 2014; James et al., 2015; Reschke-Hernández, 2011; Sharda et al., 2018). However, reviews suggest that music therapy needs more rigorous methodology in research studies (e.g.: outcome measures, comparison group), as well as a reinforced bridge between clinical practice and clinical research (Applewhite, Cankaya, Heiderscheit, & Himmerich, 2022; Reschke-Hernández, 2011). Small sample size, the large heterogeneity of music therapies, and the lack of treatment standardization hinder the replicability and the generalization of results at a larger scale (Applewhite et al., 2022; Brondino et al., 2015). Despite promising outcomes, research in this field is limited (Sharda et al., 2018).

Regarding music-based interventions delivered to individuals with ASD, several studies showed benefits in reducing vocal stereotypes and improving speech and attention skills (Lanovaz, Rapp, & Ferguson, 2012; Sandiford, Mainess, & Daher, 2013; Thompson & Abel, 2018). A large array of different musical stimuli and various application techniques have been used across these types of interventions, limiting the possibility of drawing irrefutable conclusions regarding their benefits within the ASD context (Robb, Carpenter, & Burns, 2011).

In general, some characteristics that are commonly found in individuals with ASD might explain their sensitivity and responsiveness to music-based interventions: the ability to identify or produce musical tones without an external reference (i.e., perfect pitch), the hypersensitivity to sounds, and the capacity to recognize repetitive patterns and to analyze systems based on rules (such as, in this case, the musical notation), which are all three supported by the great attention to details (Baron-Cohen, Ashwin, Ashwin, Tavassoli, & Chakrabarti, 2009; Brondino et al., 2015; Happé & Vital, 2009). The particular sensory perception of individuals with ASD may therefore explain the emergence of their musical talent (Jimenez, 2012). Musical abilities represent a strength in individuals with ASD and, consequently, they may play an important role as a motivational factor in such interventions (Sharda et al., 2018). Studies have also shown that musical understanding and appreciation is intact in individuals with ASD, which could explain the efficacy of music therapies with such groups (Molnar-Szakacs & Heaton, 2012). In addition, the research findings suggest that the social deficits characteristic in individuals with ASD may increase the importance of music in supporting their social interactions (Heaton & Allen, 2009). However, it is not clear whether the effects that music has on individuals with ASD are linked specifically to a particular instrument or musical exercise. Only recently, it was suggested that piano music can represent a promising instrument in interventions in ASD and may have particular benefits due to its specific features (Silarat, 2022). Piano is described as a pitch-percussion instrument providing a wide range of pitch

combinations and possessing a high visual quality which facilitates learning (Silarat, 2022). Only three studies using piano or a keyboard with individuals with ASD were mentioned in a recent review in music therapy (James et al., 2015). One of their cited studies (Boso, Emanuele, Minazzi, Abbamonte, & Politi, 2007) aimed at developing social engagement, improving problem behavior, and at enhancing creative music-making for young adults with severe ASD. The intervention included several different musical activities, such as drumming, singing and piano playing. Gattino, dos Santos Riesgo, Longob, Leite, and Faccini (2011) used a keyboard among other musical instruments to improve communication skills in children with ASD. In other studies (Katagiri, 2009; Whipple, 2004), piano music was used passively in the background of the tasks or activities. In general, Silarat (2022) argues that the use of piano in therapy can support the awareness, concentration and imitation skills of individuals with ASD. The author states that these benefits may be due to certain characteristics that are commonly observed in individuals with ASD: the particular sensitivity to pitch, accurate sound memory, and precision in imitating actions and physical hand movements. Silarat (2022) also suggests that their preference for patterns and interest in musical sounds, makes piano a favorable candidate due to its structured keyboard and related sounds. Also, the turn-taking and the constant social interaction between the teacher and the student can support interactive communication (Silarat, 2022). Lastly, the stimulation of the motor cortex during piano training programs is expected to further support the motor skills in individuals with ASD (Eldor, 2019).

However, the use of piano in music-based programs for individuals with ASD might be under-represented as most of the evidence comes more broadly from music therapy (Applewhite et al., 2022). Moreover, many studies on music-based interventions lack a detailed description of the material used, which prevents researchers not only from replicating the studies but also from drawing clear conclusions about the spread of piano use (Robb et al., 2011). Certain studies do not mention the type of professional who delivers the program, which may lead to a misidentification and confusion between music therapy versus music-based intervention studies and, consequently, to an exclusion of these studies from such reviews (Applewhite et al., 2022; Stegemann et al., 2019).

Finally, there is no unique general standard regarding the length and frequency of music-based approaches needed to obtain visible outcomes that can be identified in literature. For instance, the duration of interventions for individuals with ASD using music (including piano music) can vary between one week to 52 weeks (Eldor, 2019; James et al., 2015; Mayer-Benarous et al., 2021), or, in specific programs of music therapy, it can vary between one to seven months (Geretsegger et al., 2014). The weekly frequency of number of hours found in music therapy interventions varies from one up to five sessions (Geretsegger et al., 2014).

The current study

Although music-based approaches may be a promising avenue in the field of support programs for individuals with ASD, there is still limited evidence regarding their outcomes and the undelying mechanisms involved and the relevance for ASD. Moreover, the specific effects of the use of piano as a single instrument in a music-based intervention on communication, motricity, and behavior were not yet studied, although predictions of positive outcomes are anticipated and expected on account of children with ASD's particularities (Eldor, 2019; Silarat, 2022).

Therefore, the present pilot study aims at contributing to the literature refering to music-based approaches for children with ASD. We therefore suggest a new approach to better understand the instrument-related specificities and outcomes within a music-based intervention centered on piano use which was officially labeled as *Piano Therapy* (recognized trademark in the country of the study).

The main goal of the current study was to narrow a music-based intervention to a specific instrument (i.e., piano) and to explore the effects of the Piano Therapy program in children with ASD. Therefore, we examined whether the participants in the experimental group who would undertake the Piano Therapy program would benefit from such an intervention in areas such as communication, behavior and motricity skills.

Method

Participants

In two months, ninety-five participants were recruited via announcements distributed on social media and in parents' groups. The inclusion criteria were: (a) proof of an ASD diagnosis provided by a qualified psychiatrist, (b) age between 3 and 7 years, (c) no enrolment in other music programs, (d) no other comorbidities. After applying these criteria, 60 children diagnosed with ASD (age range: 3–7 years old) were selected and enrolled in the present pilot study (see Fig. 1). An overall sample of 60 participants was estimated as satisfactory based on several recommendations for clinical and/or pilot studies (Julious, 2005; Lancaster, Dodd, & Williamson, 2004; Sim & Lewis, 2012). None of the enrolled children had previous musical training. All parents signed written informed consent. Children were quasi-randomly assigned to the experimental group or the control group. At the time of enrolment, the participants were attributed to the experimental group or control group based on children and parents' availabilities during the scheduled intervention timeline: May to August 2018. The advantage of this particular timeline was that all children undertook the intervention simultaneously avoiding any other confounding effects, such as, seasonal or kindergarten semester effects. The two groups did not differ in age ($t(58) = -1.32$, $p = .19$) or gender ($\chi^2_{(1,\ 60)} = 0.13$, $p = .72$). For descriptive characteristics, see Table 1.

Throughout the study, all children continued with weekly standard care consisting of ABA therapy and speech therapy with their external healthcare providers. The standard ABA treatment delivered locally is implemented five days per week with an average number of four hours per day. As there is no national review board in Romania, the work has been conducted in accordance with the standard ethical procedures and meets all ethical guidelines, including adherence to the legal requirements of the study country. The examiner (TD) and the piano-therapist who have interacted with participants were trained psychologists recognized by the Romanian College of Psychologists at the moment of the study realization.

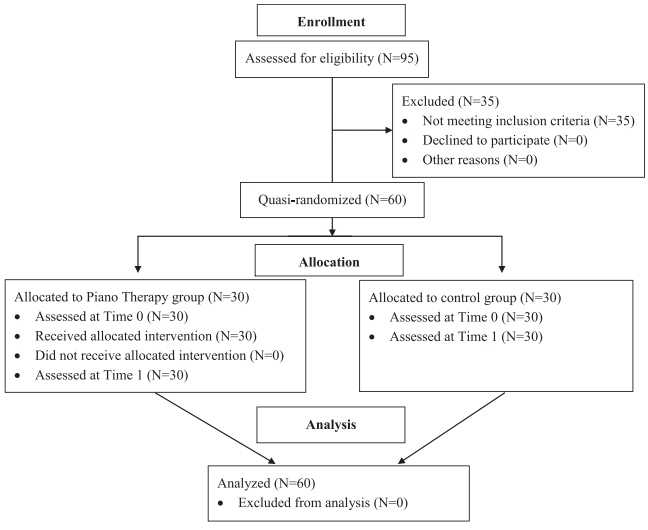

Fig. 1. Flow chart indicating the number of participants through the study stages.

Table 1
Participants' demographic characteristics.

	Experimental Group	Control Group
N	30	30
Age (years)	4.37 (1.19)	4.80 (1.35)
Gender ratio (male/female)	26/4	25/5

Intervention: the Piano Therapy program

Piano Therapy is a program, complementary to standard care, aiming at improving motricity, communication, and maladaptive behaviors of children with ASD through learning how to play piano. This new intervention was developed using techniques adapted from ABA principles and can be easily applied to the needs of children with ASD. Several differences with traditional ABA approaches are noteworthy: the piano-based intervention intensity was reduced and limited to two sessions per week, children were encouraged to express preferences which were taken into account, positive reinforcement-based contingency were used (i.e., the piano was the reward, and the motivation and pleasure to play piano were considered in the enrollment phase), the integration of stereotypes in the piano learning process and, consequently, in the reciprocal interactions with the therapist. The program has a personalized approach according to the severity of children's symptoms and needs and their progress was closely monitored. To maintain a sense of predictability, the program was built around clear objectives and a hierarchy of activities. These characteristics are in line with Leaf et al., (2022) and can help avoid any potential harm on participants and trigger better outcomes.

The exercises used in the Piano Therapy program are illustrated in Table 2. However, there are several differences between standard piano lessons and Piano Therapy sessions (see Table 3). The program exercises were built to address the three developmental domains mentioned above as they are described in the Psycho-educational Profile - Third Edition (PEP-3; Schopler, Lansing, Reichler, & Marcus, 2005).

Table 2
Description of the exercises used in the Piano Therapy program.

Name of the exercise	Description
Close fingers one by one	The pianotherapist instructs the child to close their fingers one by one.
Press each finger on the piano	The pianotherapist instructs the child to press on the piano keys with each finger.
Music scale with right hand	The child is instructed to press on the piano keys corresponding to the musical notes (C-D-E-F-G-A-H-C) by using a specific right-hand finger (1–2–3–1–2–3–4–5[a]).
Music scale with left hand	The child is instructed to press on the piano keys corresponding to the musical notes (CDEFGAHC) by using a specific left-hand finger (5–4–3–2–1–3–2–1).
Find the 2nd and 3rd black notes	The child is instructed to find the 2nd and 3rd groups of black notes.
Finger fun	Cards depicting numbers from 1 to 5 are successively presented to the child. The numbers correspond to the child's fingers. The child presses the key with the finger corresponding to the number on the card.
Arpeggio	The pianotherapist asks the child to press on the piano keys corresponding to C-E-G-C (musical notes) by using specific right-hand fingers (i.e., 1–2–3–5) and left-hand fingers (i.e., 5–3–2–1).
Vocalization	Vocalizations are chosen depending on the sounds that the child cannot yet pronounce. The pianotherapist presses the piano keys while pronouncing the vocalization. The child repeats the vocalization while focusing on their pronunciation while singing out loud.
Imaginary stories	Stories are played on the piano, helping children to associate sounds with words and follow with ease the sequence of events. The pianotherapist asks the child to repeat the right words from the story, while pressing the piano keys. Example: The story of the rain It was raining. pic, pic, pic (*Press the high piano keys*) Thunder. boom, boom (*Press low piano keys*) The puppy got scared and barked. bark, bark (*Press C and E at once*) And it rains, it rains, it rains. The rain stopped and the rainbow appeared. (*Use middle finger to press on all the piano keys*)
Creating sentences on piano	The child is asked to formulate sentences with given words while singing out loud and pressing piano keys.
Playing piano and singing songs with lyrics	The pianotherapist asks the child to sing with them a song with lyrics while playing piano together.
Piano finger twister	A board depicting different colored circles is shown to the child. The pianotherapist indicates a number and a color. The child must touch the indicated color with the finger corresponding to the number.
Playing songs with lights	A piano with lights was used. The pianotherapist selects a recorded song from the piano menu. The child observes the keys that light up and presses the key corresponding to the light.
Learning musical notes	The pianotherapist shows to the child the musical notes on the piano keys. Initially, they use a card indicating the notes. After the child has learnt to recognize the notes, the exercise continues without the cards.
Songs and emotions	The child is asked to listen to a song and name an emotion that the song transmits (e.g., cheerful, sad, melancholy).
Eye contact	All throughout the session, the child is encouraged and prompted to have eye contact with the pianotherapist.

[a] 1 =thumb, 2 =index finger, 3 =middle finger, 4 =ring finger, 5 =little finger

Table 3
Differences between Piano Therapy sessions and classical piano lessons.

	Piano Therapy sessions	Classical piano lessons
Psycho-educational assessment before and after	yes	no
Objective	Improve social and motor abilities	Learn to play the piano
Material		
Visual material (e.g., lights)	yes	no
Music sheet	yes	yes
Monitoring sheet (i.e. to evaluate the child's evolution throughout sessions)	yes	no
Exercises		
Learn musical notes	yes	yes
Practice the music scale	yes	yes
Arpeggio	yes	yes
Play songs with lyrics	yes	no
Play songs with lights	yes	no
Close fingers on by one	yes	no
Press with each finger on the piano	yes	no
Find the 2nd and 3rd black notes	yes	yes
"Finger fun"	yes	no
Play piano finger twister	yes	no
Create imaginary stories	yes	no
Produce vocalization	yes	no
Create sentences on piano	yes	no
Listen a song and find the emotion	yes	no
Sing songs	yes	no

The Piano Therapy program includes 34 one-to-one sessions distributed over 4 months, at a rate of two 50-minute sessions per week (approximatively eight hours per month) during which the therapist teaches the child different piano exercises. Throughout the sessions, the therapist uses a monitoring sheet (see Table 4), in which the objectives are set, and the structure and hierarchy of exercises are described. The sessions were tailored depending on the needs of the child and his level of development.

The Piano Therapy program was developed in 2014 by the first author of this article (TD). The objectives of the Piano Therapy program are: (a) to create a motivational environment for children with ASD, (b) to improve various skills (e.g., motricity, language, communication, attention) and support adaptive behavior, (c) to identify the need of the child and to work on piano exercises, (d) to help children with ASD to improve according to their needs, (d) to monitor the evolution of the child.

Table 4
An overview of the pianotherapist's session monitoring sheet.

Learning objectives per domain	The date when the exercise was introduced	The date when the learning objective was attained
Motor skills		
Close fingers on by one		
Press each finger on the piano		
Music scale with right hand		
Music scale with left hand		
Find the 2nd and 3rd black notes		
Finger fun		
Arpeggio		
Communication		
Vocals		
Imaginary stories		
Creating sentences on piano		
Playing songs with lyrics		
Maladaptive behaviors		
Piano finger twister		
Playing songs with lights		
Learn musical notes		
Songs and emotions		
Eye contact		

Measure

PEP-3. The Romanian version of the PEP-3 (Schopler et al., 2005) was used to assess the developmental levels targeted by the Piano Therapy program content, as well as any potential changes at Time 0 and Time 1. PEP-3 is a standardized tool assessing the development of children's skills and behaviors. PEP-3 addresses children between 6 months and 7 years. It consists of a response booklet, and Examiner and Caregiver Report Forms. In this pilot study, the examiner's observations and caregivers' answers were assessed. All items are rated on a 3-point scale: 0 = "Fail", 1 = "Emerge", 2 = "Pass". In each domain, items were summed up and a total score was calculated. All raw scores were transformed into standard scores. A higher score obtained on any of these scales indicates a higher level of development. PEP-3 was already used and proposed as an instrument to evaluate changes in children with ASD after the implementation of programs (Chen, Chiang, Tseng, Fu, & Hsieh, 2011). The use of PEP-3 in this study has several advantages: it is an assessment widely recognized and validated in children with ASD, it fulfills the criteria of measure specificity as the wide array of items correspond to skills honed in the Piano Therapy program exercises, it is an observational assessment which takes place in an ecological setting, and the ratings are made by both experimenter and parent.

Examiner Report Form. The examiner's report consists of 172 items and is based on observations of the child during a structured assessment session. It assesses the following domains:

a. Communication: it measures the child's ability to speak, listen, read, and write. The items in this field assess verbal, preverbal cognitive development, and expressive and receptive language.
b. Motricity: it measures motor skills, hand-eye coordination, and gross motor skills. The items in this field assess fine motor skills, gross motor skills, and visual-motor imitation.
c. Maladaptive behaviors: it measures maladaptive behaviors within social interactions, particular language, repetitions, and behavioral stereotypes. The items refer to affective expression, social reciprocity, and stereotypical motor and verbal behaviors.

Caregiver Report Form. This report is a questionnaire based on the caregivers' observations about the child in natural settings. It includes the following subtests:

a. Problem behavior is a 10-item subtest measuring behaviors that occur frequently in the children with ASD, such as reduced eye contact, language delay, atypical language, and repetitive rituals.
b. Self-care skills is a 13-item subtest assessing the level of the following skills: personal care, eating, drinking, dressing, and sleeping.
c. Adaptive behavior – is a 15-item subtest assessing the child's management of interactions during activities with peers, adults, and with objects.

Procedure

After obtaining parents' written consent and assigning children to groups (i.e., experimental group, control group), participants were individually assessed with PEP-3 by a psychologist at Time 0. After the evaluation, the children in the experimental group followed the Piano Therapy program consisting of 2 sessions per week. Children in the control group continued their usual treatment (standard care) without any other further instructions. Four months later (Time 1), all children were invited to a new PEP-3 assessment. The PEP-3 certified examiner is

a psychologist and the first author of the paper (TD). It is important to note that, due to the lack of resources and having found only one certified examiner (i.e., the first author) the PEP-3 assessments were not blind. The Piano Therapy program was administered by a pianotherapist, who is a psychologist who completed musical studies and is trained in ABA. PEP-3 assessments and Piano Therapy sessions took place in an outpatient therapy center, in a one-to-one setting.

Statistical analyses

Analyses were performed using IBM SPSS Statistics 26. To test the effect of the Piano Therapy program on the dependent variables, we used a MANOVA repeated measures analyses to examine the interaction between Group (i.e., experimental and control groups) and Time (i.e., Time 0 as baseline – pre-intervention and Time 1 as post-intervention). For post-hoc comparisons, we have conducted independent-sample *t* tests for between-group differences and paired-sample *t* tests to examine within-group differences. Bonferroni correction was applied to the *p*-values (the standard p-value was divided by the number of hypothesized post-hoc contrasts) in order to decrease the probability of false-positives. GraphPad Prism 8 software was used to create the nested scattered plots.

Results

Adherence and acceptability

Fig. 1 shows the number of participants per study stage. Thirty-five participants were excluded because they did not meet the study criteria presented previously. All 60 participants selected and enrolled in the study have completed all the study sessions to which they have been assigned. No dropouts nor other adverse effects were reported.

Examiner reported scores

A repeated measure 2 × 2 MANOVA (with Time as within-subject variable and Group between-subject variable) revealed a significant interaction between Time and Group F (1, 58) = 36.78, $p < .001$, $\eta_p^2 = .39$. Post-hoc independent *t* tests have shown a significant difference between the two groups on Motricity scores at Time 1 (t(58) = 2.48, $p = .016$, $d = 0.64$). Post-hoc paired sample *t* tests also showed significant differences between Time 0 and Time 1 in the Experimental group, showing a significant increase suggesting improvements in all three score domains (see Fig. 2). In the control group, the paired sample *t* tests showed a significant increase in the Communication ($p = .037$) and Maladaptive Scores ($p = .025$). However, after applying the Bonferroni correction ($p = .005$) to the nine contrasts expected to have driven the significant interaction, only the results obtained within the experimental group remained significant. Post-hoc values obtained after conducting the paired sample *t* tests, Cohen's *d* effect sizes, and the significant differences maintained after Bonferroni correction are depicted in Table 5.

Caregiver reported scores

A second repeated measure 2 × 2 MANOVA (with Time as within-subject variable and Group between-subject variable) was run, revealing a significant interaction between Time and Group: F(1, 58) = 38.99, $p < .001$, $\eta_p^2 = .40$. The control group obtained scores significantly higher than the experimental group at Time 0 in all three domains (Problem Behavior: t(58) = −2.95, $p = .005$, $d = 0.76$; Personal Self Care: t(58) = −4.87, $p < .001$, $d = 1.26$; Adaptive Behavior: t(58) = −2.42, $p = .019$, $d = 0.62$). Therefore, although the post-hoc independent *t* tests at Time 1 have showed a significant difference maintained only in Personal Self Care scores (t(58) = −4.37, $p < .001$, $d = 1.13$), it could not be interpreted in regard to intervention effects. Further, only the six

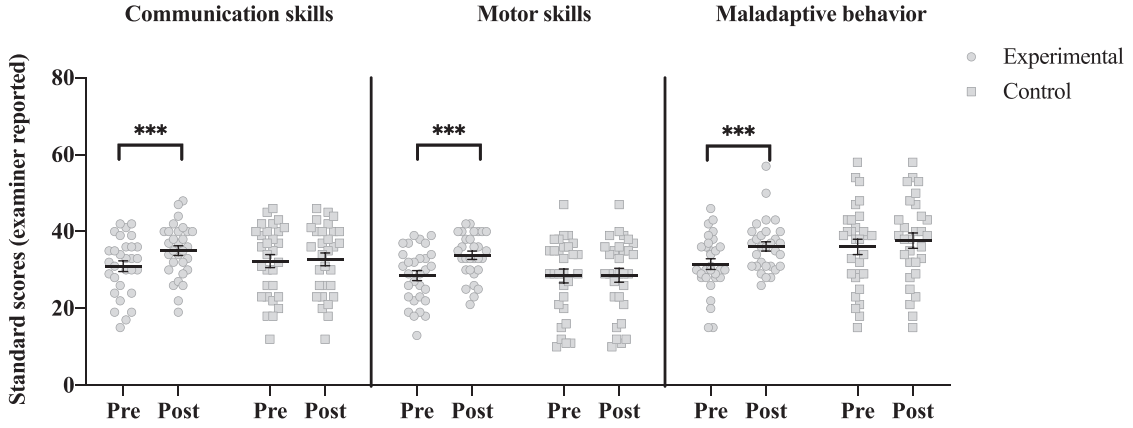

Fig. 2. Mean standard scores of the PEP-3 domains of development as observed by the examiner in experimental versus control group. The plot indicates only the contrasts of interest of which significance was maintained after the Bonferroni correction ($p = .005$). ***$p < .001$. Error bars represent standard errors.

Table 5
Within-group differences between Time 0 (pre-intervention) and Time 1 (post-intervention) on examiner reported scores as obtained using paired sample *t* tests.

	Experimental group (N = 30)			Control Group (N = 30)		
	M (SD)		*t-value* (Cohen's *d*)	*M (SD)*		*t-value* (Cohen's *d*)
	Time 0	Time 1		Time 0	Time 1	
PEP-3 score domains						
Communication	31.00 (7.52)	35.07 (6.93)	-7.02 *** (*d* =0.56)	32.30 (9.25)	32.77 (9.10)	-2.19 (*d* =0.05)
Motricity	28.53 (7.15)	33.84 (5.83)	-7.37 *** (*d* =0.82)	28.43 (9.95)	28.63 (9.89)	-1.65 (*d* =0.02)
Maladaptive Behavior	31.53 (7.46)	36.13 (6.70)	-4.75 *** (*d* =0.65)	36.00 (10.84)	37.63 (10.91)	-2.37 (*d* =0.15)

***significant at $p < .001$.

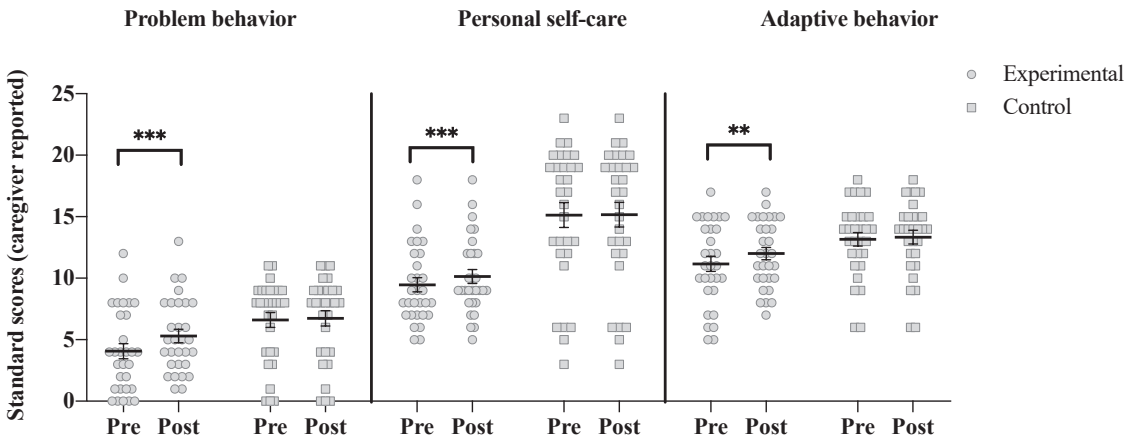

Fig. 3. Mean standard scores of the PEP-3 domains of development as reported by caregivers in the experimental versus control group. The plot indicates only the contrasts of interest of which significance wasmaintained after the Bonferroni correction ($p = .008$). **$p = .002$, ***p<.001. Error bars represent standard errors.

Table 6
Within-group differences between Time 0 (pre-intervention) and Time 1 (post-intervention) on caregiver reported scores as obtained using paired sample *t* tests.

	Experimental group (N = 30)			Control Group (N = 30)		
	M (SD)		*t-value* (Cohen's *d*)	*M (SD)*		*t-value* (Cohen's *d*)
	Time 0	Time 1		Time 0	Time 1	
PEP-3 score domains						
Problem Behavior	4.07 (3.35)	5.30 (3.00)	-6.50*** (*d* =0.43)	6.60 (3.30)	6.73 (3.41)	-1.44 (*d* =0.04)
Personal Self Care	9.47 (3.20)	10.13 (3.09)	-4.33*** (*d* =0.21)	15.13 (5.51)	15.17 (5.50)	-1.00 (*d* =0.01)
Adaptive Behavior	11.17 (3.38)	12.00 (2.75)	-3.34** (*d* =0.27)	13.17 (3.02)	13.33 (3.06)	-1.98 (*d* =0.05)

**significant at $p = .002$, ***significant at $p < .001$.

contrasts within-group were examined as they were expected to drive the interaction, while applying the Bonferroni correction of $p = .008$. Post-hoc paired sample *t* tests indicated a significant increase in the scores between Time 0 and Time 1 in the Experimental group, suggesting improvements in all three score domains (see Fig. 3). In the control group, the paired sample t-test did not show any significant changes. Post-hoc values obtained after conducting the paired sample t-tests, Cohen's *d* effect sizes, and significant differences maintained after Bonferroni correction are depicted in Table 6.

Discussion

The present pilot study intended to present a new music-based intervention using piano exclusively and several ABA techniques, which was meant to help children with ASD to improve functioning in three specific areas of development (i.e., communication, motricity, and adaptive behavior). The exploratory analyses have shown a significant change in all three developmental domains in the experimental group compared to control group. All three domains investigated and measured by the examiner have benefited from the intervention, while having moderate to high effect sizes. Moreover, parents in the experimental group reported improvements in all three domains (problem behavior, self-care skills, adaptive behavior) after the intervention, with effect sizes ranging from small to moderate. No significant changes were found between Time 0 and Time 1 in the control group that continued treatment as usual. Worthy to note: children in the control group obtained better PEP scores based on parent reports at Time 0. This could suggest that the effects we observed in the experimental group might be due to their higher severity of symptoms: these participants could be more sensitive to the intervention and the improvements could be more noticeable.

Although not yet conclusive, these preliminary outcomes are still encouraging and can be explained by several reasons. First, the increase in motor skills could be due to the program characteristics: children are actively engaged in music-making, pressing the piano keys with their fingers during the exercises. This particular outcome suggests that the Piano Therapy program can help children with ASD to overcome motor sequencing and coordination difficulties, which could have transferred to the improvements observed by parents in the self-care skills (Srinivasan & Bhat, 2013). The stimulation of the motor cortex while playing piano could have also contributed to these results (Eldor, 2019). Second, the increased communication skills found in the group who benefited from Piano Therapy can be explained by the fact that the exercises used are based on activities such as singing, oral production, and imaginative stories. These activities require constant communication between the therapist and the child, while using language, contributing in this way to the enhancement of receptive and expressive language (Srinivasan & Bhat, 2013). Finally, the improvements in behavior, reported by both experimenter and parents, could firstly be explained by the training of joint attention, social engagement and theory of mind that occur during the musical experience with a therapist (LaGasse, 2017; Silarat, 2022). These results can partially be due to the children's familiarity with certain techniques that were derived from standard ABA interventions (e.g., reinforcements, prompting), but also to the more flexible ABA techniques used in the piano-based program. In its current form, familiarity with ABA might be necessary. Nevertheless, adaptations of the Piano Therapy program are envisioned for the future to address the criticism around ABA and improve clinicians' practice in interventions for individuals with ASD (Leaf et al., 2022): determine the dosage of the intervention at an individual level, assess the child's satisfaction with the intervention, and involve parents in the goal selection process. These new adaptations could also support the use of the piano-based

intervention with other types of populations that are sensitive to music-based approaches and partially share common symptoms with ASD (e.g., dyslexia, attention/deficit hyperactivity disorder; Mayer-Benarous et al., 2021).

Another very important factor contributing to these improvements could be due to the participants' motivation: listening to music activates neural circuits of reward and emotional response for persons with ASD (Quintin, 2019), which could support patient compliance to the therapy program and engagement with the therapist (Geretsegger et al., 2014; Srinivasan & Bhat, 2013). In this vein, Heaton and Allen (2009) hypothesize that musical activities may be highly rewarding for individuals with ASD because, while fulfilling their need for socio-emotional bonds, the interpersonal interaction is less anxiogenic. Given the affective power of music suggested by these authors' research, we could speculate that the subsequent pleasure experienced during Piano Therapy program activities supports the rewarding mechanisms in ASD. Finally, next to the stimulation of the motor cortex (Eldor, 2019), Hashimoto et al. (2006) show that piano music stimulates the frontal lobe, which is responsible for language and executive functions. Authors suggest that piano music requires the integration of operations from various areas such as motor, emotion and cognitive abilities. Hence, this could explain the observed effects of a piano-based intervention in the current study making Piano Therapy Program a good candidate to simultaneously stimulate different developmental areas.

Additionally, the sensory preferences and perfect pitch qualities that certain individuals with ASD present (Dohn, Garza-Villarreal, Heaton, & Vuust, 2012; Weitlauf, Sathe, McPheeters, & Warren, 2017) may correspond to the particularities of piano music (Silarat, 2022), and may consequently contribute to the promising outcomes in the children who followed the Piano Therapy program, as well as the participants' full adhesion to the program.

In general, we observe that the results obtained with Piano Therapy are in line with the various studies cited previously which showed beneficial effects of music therapy and music-based interventions for individuals with ASD, as well as with the expectations of the effects of piano-based trainings in individuals with ASD (Eldor, 2019; Silarat, 2022).

However, several limitations of the current pilot study are worthy of note and important to take into consideration for future research. First, the Piano Therapy program is a new music-based intervention which consisted of adapting classical piano lessons to the needs of children with ASD. More studies are required to generalize this early evidence of Piano Therapy's effects and thoroughly validate the efficacy of this new intervention method. For instance, the next step would be to replicate this study using an active control group: using intervention without music (see Redondo Pedregal & Heaton, 2021) or music-based intervention with another instrument (see Gattino et al., 2011) to control for potential effects of the therapy alliance and of the attention paid to the child. Such design could also examine whether the improvements are specific to the Piano Therapy program. A design including a comparison group exclusively undertaking only Piano Therapy without additional ABA intervention could be also another future perspective. Currently, in the country of the study, this design seems unfeasible as the children are immediately enrolled in ABA programs after establishing the diagnosis. However, in this study, all participants from both groups were carrying on with their individual ABA and speech therapy with external experts, which might have reduced the impact of such biases. Second, given the small number of participants included in the study, future studies should examine the present program outcomes in studies with larger samples. While the effect sizes are satisfying, we might expect that future replications will most likely support the current findings.

Moreover, this pilot study did not include follow-up measurements, which are important to investigate whether the improvements are maintained in the long-term (Bieleninik et al., 2017; Finnigan & Starr, 2010). It is likely that increasing the number of sessions and therefore intervening over a longer period of time would maintain improvements in participants on long-term (e.g., Bieleninik et al., 2017). Indeed, variations in the intervention dosage should be examined as they might mediate the benefits of the Piano Therapy program. Another idea that could further help in obtaining valuable outcomes would be to adapt the program to group sessions, thus creating new opportunities for social interaction with peers. The inclusion of parents in such programs can also be beneficial from a systemic point of view. One example of such an intervention is the Paediatric Autism Communication Therapy-Generalised which is a parent-mediated therapy targeting parent-child communication, parental wellbeing and child disruptive behaviours across home and school (Green et al., 2022).

Another limitation is that the participants, their parents, and the PEP-3 examiner were not blind, although the pianotherapist was blind to the integration of the sessions as part of an efficacy study (e.g., no information was given regarding pre- and post-measures of PEP-3 nor the experimental design). Although some authors suggest that the risk of obtaining biased results due to this aspect is unclear (Geretsegger et al., 2014), future experiments should be blind and use inter-judge reliability to limit the potential influence of such biases and considerably increase the rigor of such studies. In the present study, improvements in the targeted developmental areas, however, were coherent with the parents' reports, independently from examiner's observations.

Finally, the investigated areas were assessed with a single method (i.e., PEP-3). Future studies should use a multi-method approach using objective measures to have a better grasp of the generalization of improvements on other skills. In addition, other measures of verbal and social skills should be added in the screening stage to gain better insight about ASD profiles (e.g., Autism Diagnostic Observation Schedule; Lord, Rutter, DiLavore, Risi, & Bishop, 2012; Vineland-II; Volkmar, 2013).

Furthermore, as various factors may interfere with the Piano Therapy program, such as the severity of symptoms, the presence of musical abilities (e.g., talent, perfect pitch, rhythm), the environmental factors (therapy compliance, socio-economic status), further research should control for these variables. However, no adverse events nor dropouts were reported during this pilot study. Moreover, given the heterogeneity of profiles and musical abilities in individuals with ASD, we might expect differential benefits following the Piano Therapy program. The profile heterogeneity in ASD and the different levels of development the participants may have at baseline may lead to unequal acquisitions in the three domains the study investigated.

This is the first pilot study to our knowledge, as regards the clinical and practical implications, that has tested a piano-based musical intervention using ABA-derived techniques specifically adapted for children with ASD. The intervention was tested in a sample with ASD without other comorbidities and in which all children were enrolled in ABA and speech therapy programs with external specialists. The Piano Therapy program efficacy was examined using a quasi-randomized clinical trial, an approach that is rather insufficiently used in this narrow field of research (e.g., Gattino et al., 2011). For instance, it is common that the evidence showing beneficial effects of music emerges from studies with single cases (e.g., Finnigan & Starr, 2010) or experimental designs without a comparison group (e.g., Boso et al., 2007). This scarce methodology could be partially explained by the complexity of music-based approaches. For instance, in music therapy, some programs use improvisational music therapy (active methods) (e.g., Kim et al., 2008), whereas as others expose children to musical stimuli (receptive methods) (Geretsegger et al., 2014). Additionally, most of the programs are not limited to nor constructed around a single unique instrument (Gattino et al., 2011). Children enrolled in the Piano Therapy program were engaged with a therapist in the use of a single instrument (i.e., the piano), during sessions with a structured plan of exercises in which receptive and active methods were alternated. The music in the current study is used in an active and not passive manner (e.g., background music) as in other music-based interventions (Katagiri, 2009).

Finally, the program follows the special considerations of Srinivasan and Bhat^s study (2013) for music-based interventions for children with

ASD in all of the proposed domains such as: the structure of the sessions' environment, the use of instructions, prompts, and feedback, the use of repetition and reinforcement, and, finally, the nature of the interaction. Piano Therapy might be an interesting new approach to be further studied in applied and clinical practice, as it includes these specific guidelines supporting the positive outcomes of such intervention in children with ASD.

Conclusions

The present pilot study aimed at exploring the effects of a new type of music-based intervention adapted for children with ASD and using piano only and ABA techniques, that is the Piano Therapy program. The preliminary findings support previous research and the idea that clinicians and other professionals (e.g., music teachers) working with individuals with ASD might benefit from Piano Therapy. Nonetheless, despite the limitations and the need for more robust future research, this pilot study has important therapeutic and theoretical implications being the first study on piano-based intervention showing improvements in communication, motricity and adaptive behavior in children with ASD. Thus, Piano Therapy is an encouraging venue for both piano- and music-based interventions that could represent a helpful tool for practitioners in this field.

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CRediT authorship contribution statement

TD developed the study (study conception and design). TD administered the project, prepared the research material, and organized the database. Data collection was performed by TD. Statistical analyses were performed by AZ. The first draft of the manuscript was written by TD and AZ. Both authors reviewed and commented the previous versions of the manuscript. Both authors read and approved the final manuscript.

Conflicts of interest

TD is the president of the Piano Therapy Association, a non-governmental organization where she works as a volunteer. TD is the author of the Piano Therapy program which is a trademark recognized by the Romanian State Office for Inventions and Trademarks (since 2014). AZ has no conflict of interest.

Data Availability

Data will be made available on request.

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References

American Music Therapy Association. (2005). What is music therapy. ⟨http://www.musictherapy.org/about/musictherapy/⟩.

American Psychiatric Association. (2013). Diagnostic and statistical manual of mental disorders (5th ed.).

Applewhite, B., Cankaya, Z., Heiderscheit, A., & Himmerich, H. (2022). A Systematic review of scientific studies on the effects of music in people with or at risk for autism spectrum disorder. *International Journal of Environmental Research and Public Health, 19*(5150), 1–31. https://doi.org/10.24869/PSYD.2020.334

Baron-Cohen, S., Ashwin, E., Ashwin, C., Tavassoli, T., & Chakrabarti, B. (2009). Talent in autism: Hyper-systemizing, hyper-attention to detail and sensory hypersensitivity. *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*(1522), 1377–1383. https://doi.org/10.1098/rstb.2008.0337

Bieleninik, Ł., Geretsegger, M., Mössler, K., Assmus, J., Thompson, G., Gattino, G., … Gold, C. (2017). Effects of improvisational music therapy vs enhanced standard care on symptom severity among children with autism spectrum disorder: The TIME-A randomized clinical trial. *JAMA - Journal of the American Medical Association, 318*(6), 525–535. https://doi.org/10.1001/jama.2017.9478

Blue Cross of Idaho. (2021). Applied Behavior Analysis (ABA) for the Treatment of Autism Spectrum Disorder (ASD). *Medical Policy Library*. ⟨https://providers.bcidaho.com/medical-management/medical-policies/mh/mp_301504.page⟩.

Bondy, A. S., & Frost, L. A. (1994). The picture exchange communication system. *Focus on Autism and Other Developmental Disabilities, 9*(3), 1–19. https://doi.org/10.1177/108835769400900301

Boso, M., Emanuele, E., Minazzi, V., Abbamonte, M., & Politi, P. (2007). Effect of long-term interactive music therapy on behavior profile and musical skills in young adults with severe autism. *Journal of Alternative and Complementary Medicine, 13*(7), 709–712. https://doi.org/10.1089/acm.2006.6334

Brondino, N., Fusar-Poli, L., Rocchetti, M., Provenzani, U., Barale, F., & Politi, P. (2015). Complementary and alternative therapies for autism spectrum disorder. *Evidence-Based Complementary and Alternative Medicine*, 1–31. https://doi.org/10.1155/2015/258589

Chen, K. L., Chiang, F. M., Tseng, M. H., Fu, C. P., & Hsieh, C. L. (2011). Responsiveness of the psychoeducational profile-third edition for children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 41*(12), 1658–1664. https://doi.org/10.1007/s10803-011-1201-5

Cooper, J. O., Heron, T. E., & Heward, W. L. (2019). *Applied behavior analysis* (3rd ed.). Pearson Education.

Dohn, A., Garza-Villarreal, E. A., Heaton, P., & Vuust, P. (2012). Do musicians with perfect pitch have more autism traits than musicians without perfect pitch? an empirical study. *PLoS One, 7*(5). https://doi.org/10.1371/journal.pone.0037961

Eldor, J. (2019). Extensive piano practicing has regionally specific effects on white matter development. *Journal of Biomedical Research and Reviews, 2*(2), 45–54. https://doi.org/10.1038/nn1516

Finnigan, E., & Starr, E. (2010). Increasing social responsiveness in a child with autism: A comparison of music and non-music interventions. *Autism, 14*(4), 321–348. https://doi.org/10.1177/1362361309357747

Foxx, R. M. (2008). Applied behavior analysis treatment of autism: The state of the art. *Child and Adolescent Psychiatric Clinics of North America, 17*(4), 821–834. https://doi.org/10.1016/j.chc.2008.06.007

Gattino, G. S., dos Santos Riesgo, R., Longob, D., Leite, J. C. L., & Faccini, L. S. (2011). Effects of relational music therapy on communication of children with autism: A randomized controlled study. *Nordic Journal of Music Therapy, 20*(2), 142–154. https://doi.org/10.1080/08098131.2011.566933

Geretsegger, M., Elefant, C., Mössler, K. A., & Gold, C. (2014). Music therapy for people with autism spectrum disorder. *Cochrane Database of Systematic Reviews*, *6*. https://doi.org/10.1002/14651858.CD004381.pub3

Ghasemtabar, S. N., Hosseini, M., Fayyaz, I., Arab, S., Naghashian, H., & Poudineh, Z. (2015). Music therapy: An effective approach in improving social skills of children with autism. *Advanced Biomedical Research, 4*(157), 1–8. https://doi.org/10.4103/2277-9175.161584

Green, J., Leadbitter, K., Ellis, C., Taylor, L., Moore, H. L., Carruthers, S., … Pickles, A. (2022). Combined social communication therapy at home and in education for young autistic children in England (PACT-G): A parallel, single-blind, randomised controlled trial. *The Lancet Psychiatry, 9*, 307–320. https://doi.org/10.1016/S2215-0366(22)00029-3

Happé, F., & Vital, P. (2009). What aspects of autism predispose to talent? *Philosophical Transactions of the Royal Society B: Biological Sciences, 364*, 1369–1375. https://doi.org/10.1098/rstb.2008.0332

Hashimoto, K., Tategami, S., Okamoto, T., Seta, H., Abo, M., & Ohashi, M. (2006). Examination by near-infrared spectroscopy for evaluation of piano performance as a frontal lobe activation task. *European Neurology, 55*, 16–21. https://doi.org/10.1159/000091138

Heaton, P., & Allen, R. (2009). "With concord of sweet sounds…": New perspectives on the diversity of musical experience in autism and other neurodevelopmental conditions. *Annals of the New York Academy of Sciences, 1169*, 318–325. https://doi.org/10.1111/j.1749-6632.2009.04583.x

Huguet, G., Ey, E., & Bourgeron, T. (2013). The genetic landscapes of autism spectrum disorders. *Annual Review of Genomics and Human Genetics, 14*, 191–213. https://doi.org/10.1146/annurev-genom-091212-153431

James, R., Sigafoos, J., Green, V. A., Lancioni, G. E., O'Reilly, M. F., Lang, R., … Marschik, P. B. (2015). Music therapy for individuals with autism spectrum disorder: A systematic review. *Review Journal of Autism and Developmental Disorders, 2*, 39–54. https://doi.org/10.1007/s40489-014-0035-4

Jimenez, S. D. (2012). *An Exploration of Teaching Music to Individuals with Autism Spectrum Disorder. [Doctoral dissertation]*. Seattle, WA: Faculty of Antioch University Seattle.

Julious, S. A. (2005). Sample size of 12 per group rule of thumb for a pilot study. *Pharmaceutical Statistics, 4*, 287–291. https://doi.org/10.1002/pst.185

Kaduk, L. (2017). The effectiveness of the picture exchange communication system for children who have Autism. *Culminating Projects in Special Education, 40*, 2–43. ⟨https://repository.stcloudstate.edu/cgi/viewcontent.cgi?article=1047&context=sped_etds&httpsredir=1&referer=⟩.

Katagiri, J. (2009). The effect of background music and song texts on the emotional understanding of children with autism. *Journal of Music Therapy, 46*(1), 15–31. https://doi.org/10.1093/jmt/46.1.15

Kim, J., Wigram, T., & Gold, C. (2008). The effects of improvisational music therapy on joint attention behaviors in autistic children: A randomized controlled study. *Journal of Autism and Developmental Disorders, 38*, 1758–1766. https://doi.org/10.1007/s10803-008-0566-6

LaGasse, A. B. (2017). Social outcomes in children with autism spectrum disorder: A review of music therapy outcomes. *Patient Related Outcome Measures, 8*, 23–32. https://doi.org/10.2147/prom.s106267

Lancaster, G. A., Dodd, S., & Williamson, P. R. (2004). Design and analysis of pilot studies: Recommendations for good practice. *Journal of Evaluation in Clinical Practice, 10*(2), 307–312. https://doi.org/10.1111/j.2002.384.doc.x

Lanovaz, M. J., Rapp, J. T., & Ferguson, S. (2012). The utility of assessing musical preference before implementation of noncontingent music to reduce vocal stereotypy. *Journal of Applied Behavior Analysis, 45*, 845–851. https://doi.org/10.1901/jaba.2012.45-845

Leaf, J. B., Cihon, J. H., Leaf, R., McEachin, J., Liu, N., Russell, N., … Khosrowshahi, D. (2022). Concerns about ABA-Based intervention: An evaluation and recommendations. *Journal of Autism and Developmental Disorders, 52*, 2838–2853. https://doi.org/10.1007/s10803-021-05137-y

Lerna, A., Esposito, D., Conson, M., Russo, L., & Massagli, A. (2012). Social-communicative effects of the Picture Exchange Communication System (PECS) in autism spectrum disorders. *International Journal of Language and Communication Disorders, 47*(5), 609–617. https://doi.org/10.1111/j.1460-6984.2012.00172.x

Lim, H. A., & Draper, E. (2011). The effects of music therapy incorporated with applied behavior analysis verbal behavior approach for children with autism spectrum disorders. *Journal of Music Therapy, 48*(4), 532–550. https://doi.org/10.1093/jmt/48.4.532

Linstead, E., Dixon, D. R., Hong, E., Burns, C. O., French, R., Novack, M. N., & Granpeesheh, D. (2017). An evaluation of the effects of intensity and duration on outcomes across treatment domains for children with autism spectrum disorder. *Translational Psychiatry, 7*, 1–6. https://doi.org/10.1038/TP.2017.207

Lord, C., Rutter, M., DiLavore, P.C., Risi, S., & Bishop, S. (2012). Autism diagnostic observation schedule, second edition (ADOS-2) manual. Western Psychological Services.

Lovaas, O. I. (1987). Behavioral treatment and normal educational and intellectual functioning in young autistic children. *Journal of Consulting and Clinical Psychology, 55*(1), 3–9. https://doi.org/10.1037/0022-006x.55.1.3

Maenner, M. J., Shaw, K. A., Bakian, A. V., Bilder, D. A., Durkin, M. S., Esler, A., … Cogswell, M. E. (2021). Prevalence and characteristics of autism spectrum disorder among children aged 8 years - autism and developmental disabilities monitoring network, 11 Sites, United States, 2018. *MMWR Surveill Summ, 70*(11), 1–16. https://doi.org/10.15585/mmwr.ss7011a1

Mayer-Benarous, H., Benarous, X., Vonthron, F., & Cohen, D. (2021). Music therapy for children with autistic spectrum disorder and/or other neurodevelopmental disorders: A systematic review. *Frontiers in Psychiatry, 12*, 1–21. https://doi.org/10.3389/fpsyt.2021.643234

Medavarapu, S., Marella, L. L., Sangem, A., & Kairam, R. (2019). Where is the Evidence? A narrative literature review of the treatment modalities for autism spectrum disorders. *Cureus, 11*(1). https://doi.org/10.7759/cureus.3901

Molnar-Szakacs, I., & Heaton, P. (2012). Music: A unique window into the world of autism. *Annals of the New York Academy of Sciences, 1252*, 318–324. https://doi.org/10.1111/j.1749-6632.2012.06465.x

Newcomb, E. T., & Hagopian, L. P. (2018). Treatment of severe problem behaviour in children with autism spectrum disorder and intellectual disabilities. *International Review of Psychiatry*, 1–14. https://doi.org/10.1080/09540261.2018.1435513

Quintin, E. M. (2019). Music-evoked reward and emotion: relative strengths and response to intervention of people with ASD. *Frontiers in Neural Circuits, 13*(49), 1–8. https://doi.org/10.3389/fncir.2019.00049

Redondo Pedregal, C., & Heaton, P. (2021). Autism, music and Alexithymia: A musical intervention to enhance emotion recognition in adolescents with ASD. *Research in Developmental Disabilities, 116*, Article 104040. https://doi.org/10.1016/j.ridd.2021.104040

Reschke-Hernández, A. E. (2011). History of music therapy treatment interventions for children with autism. *Journal of Music Therapy, 48*(2), 169–207. https://doi.org/10.1093/jmt/48.2.169

Roane, H. S., Fisher, W. W., & Carr, J. E. (2016). Applied behavior analysis as treatment for autism spectrum disorder. *Journal of Pediatrics, 175*, 27–32. https://doi.org/10.1016/j.jpeds.2016.04.023

Robb, S. L., Carpenter, J. S., & Burns, D. S. (2011). Reporting guidelines for music-based interventions. *Journal of Health Psychology, 16*(2), 342–352. https://doi.org/10.1177/1359105310374781

Rogers, S. J., & Dawson, G. (2010). Early start denver model for young children with autism. *Promoting language, learning, and engagement*. Guilford Publications.

Rose, S., Niyazov, D. M., Rossignol, D. A., Goldenthal, M., Kahler, S. G., & Frye, R. E. (2018). Clinical and molecular characteristics of mitochondrial dysfunction in autism spectrum disorder. *Molecular Diagnosis and Therapy, 22*(5), 571–593. https://doi.org/10.1007/s40291-018-0352-x

Rubenstein, E., & Chawla, D. (2018). Broader autism phenotype in parents of children with autism: a systematic review of percentage estimates. *Journal of Child and Family Studies, 27*, 1705–1720. https://doi.org/10.1007/s10826-018-1026-3

Ryberg, K. H. (2015). Evidence for the implementation of the early start denver model for young children with autism spectrum disorder. *Journal of the American Psychiatric Nurses Association, 21*(5), 327–337. https://doi.org/10.1177/1078390315608165

Sandiford, G. A., Mainess, K. J., & Daher, N. S. (2013). A pilot study on the efficacy of melodic based communication therapy for eliciting speech in nonverbal children with autism. *Journal of Autism and Developmental Disorders, 43*, 1298–1307. https://doi.org/10.1007/s10803-012-1672-z

Schopler, E., Lansing, M. D., Reichler, R. J., & Marcus, L. M. (2005). In N. Burlacu, C. Ionescu, A. I. Ionescu, & A. Moldovan-Grunfeld (Eds.), *PEP-3 Psychoeducational Profile* (3rd ed.). Romania: O.S.

Sharda, M., Tuerk, C., Chowdhury, R., Jamey, K., Foster, N., Custo-Blanch, M., … Hyde, K. (2018). Music improves social communication and auditory–motor connectivity in children with autism. *Translational Psychiatry, 8*(231), 1–13. https://doi.org/10.1038/s41398-018-0287-3

Silarat, C. (2022). Piano lessons: Fostering theory of mind in ASD through imitation. *International Journal of Disability, Development and Education, 69*(1), 154–169. https://doi.org/10.1080/1034912X.2021.1947473

Sim, J., & Lewis, M. (2012). The size of a pilot study for a clinical trial should be calculated in relation to considerations of precision and efficiency. *Journal of Clinical Epidemiology, 65*(3), 301–308. https://doi.org/10.1016/j.jclinepi.2011.07.011

Srinivasan, S. M., & Bhat, A. N. (2013). A review of "music and movement" therapies for children with autism: Embodied interventions for multisystem development. *Frontiers in Integrative Neuroscience, 7*, 1–15. https://doi.org/10.3389/fnint.2013.00022

Stegemann, T., Geretsegger, M., Phan Quoc, E., Riedl, H., & Smetana, M. (2019). Music therapy and other music-based interventions in pediatric health care: An overview. *Medicines, 6*(1), 25. https://doi.org/10.3390/medicines6010025

The Council of Autism Service Providers. (2020). Applied behavior analysis treatment of autism spectrum disorder. *Practice Guidelines for Healthcare Funders and Managers*. https://casproviders.org/wp-content/uploads/2020/03/ABA-ASD-Practice-Guidelines.pdf.

Thompson, G. A., & Abel, L. A. (2018). Fostering spontaneous visual attention in children on the autism spectrum: A proof-of-concept study comparing singing and speech. *Autism Research, 11*(5), 732–737. https://doi.org/10.1002/aur.1930

Virués-Ortega, J. (2010). Applied behavior analytic intervention for autism in early childhood: Meta-analysis, meta-regression and dose-response meta-analysis of multiple outcomes. *Clinical Psychology Review, 30*(4), 387–399. https://doi.org/10.1016/j.cpr.2010.01.008

Volkmar, F. R. (2013). Vineland adaptive behavior scales. *Encyclopedia of autism spectrum disorders* (Second ed.). Springer. https://doi.org/10.1007/978-1-4419-1698-3_101520

Weitlauf, A. S., Sathe, N., McPheeters, M. L., & Warren, Z. E. (2017). Interventions targeting sensory challenges in autism spectrum disorder: A systematic review. *Pediatrics, 139*(6). https://doi.org/10.1542/peds.2017-0347

Whipple, J. (2004). Music in intervention for children and adolescents with autism: A meta-analysis. *Journal of Music Therapy, 41*(2), 90–106. https://doi.org/10.1093/jmt/41.2.90

Whitehouse, A., Varcin, K., Waddington, H., Sulek, R., Bent, C., Ashburner, J., , … Eapen, V., Goodall, E., Hudry, K., Roberts, J., Silove, N., & Trembath, D. (2020). Interventions for children on the autism spectrum: a synthesis of research evidence. *Autism CRC*.

Yinger, O. S., & Gooding, L. (2014). Music therapy and music medicine for children and adolescents. *Child and Adolescent Psychiatric Clinics of North America, 23*(3), 535–553. https://doi.org/10.1016/j.chc.2013.03.003