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Calming effects of repetition in music for children with sensory sensitivities: Findings from two experimental studies

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ABSTRACT

Sensory sensitivity and anxiety are often experienced by neurodivergent children. Repetitive physical actions are a common way to self-regulate and reduce anxiety, yet stigma attached to these actions can discourage people with sensory sensitivities from participating in public events such as concerts. Children with sensory sensitivities therefore often miss out on the social benefits of attending live concerts. This paper reports the results of two studies (for each $N = 20$) investigating whether the predictability/level of internal repetition in classical music can be calming for Australian children aged 5–14 with sensory sensitivities. Study 1 utilized a one-on-one laboratory setting with live piano performance (two low repetition pieces, two high repetition pieces), whereas Study 2 used a group performance setting with a live cello performance (one low repetition piece, one high repetition piece). Proxy measures of anxiety and engagement were completed by parents/carers in both studies, and facial expressions and finger oximeter measures were also captured in Study 1. Across the two studies both music types had a calming effect compared to baseline, with Study 2 also indicating significantly higher interest, involvement, and enjoyment levels for high repetition music. These findings have implications for the use of music for children with sensory sensitivities in arts programming and therapeutic contexts.

A recent report estimated that between 15 % and 20 % of the world's population are neurodivergent (Doyle, 2020). This includes conditions such as Autism Spectrum Disorder (ASD), Attention Deficit Hyperactivity Disorder (ADHD), Tourette Syndrome, and Dyslexia.[1] Specifically within Australia, it was estimated that in 2015, 1 in every 150 Australians had a diagnosis of ASD (Australian Institute of Health and Welfare, 2017), with the fastest growing group being children aged 5 to 14. These figures seem to be increasing worldwide (Zeidan et al., 2022) although it is not yet clear if these increases are primarily due to a growth in the prevalence of ASD, or rather due to increased reporting and application of diagnosis (Russell et al., 2022, pp. 13505). Regardless of the reasons for these reported increases, it is clear that ASD is a larger part our lives than was thought only a few years ago.

Sensory sensitivity is common in children diagnosed with ASD and other conditions such as ADHD (Dellapiazza et al., 2021; Llanes et al., 2020). Sensory sensitivity can impact neurodivergent children in their everyday functioning, in part by limiting social participation in activities that may enhance their quality of life (Boldsen, 2022). This paper will use "sensory sensitivities" as an umbrella term for children experiencing hypersensitivity in a broader context, including both self-recognized and medical diagnoses. This research aims to investigate if live music performances—and specifically music containing higher levels of internal repetition, defined here as recurring patterns or structures within the music—can have a calming effect and facilitate positive engagement for children with sensory sensitivities.

For children with sensory sensitivities, social outings can be a great challenge (Broady et al., 2017; Lovell & Wetherell, 2019). To cope with sensory overwhelm, many children with sensory sensitivities rely on repetitive and/or restrictive actions and routines (Black et al., 2017; Brooks et al., 2016). This so-called stimming is a stereotypical feature of ASD and can be displayed in many ways, such as rocking, flicking, spinning, rubbing, or repeating a certain word or phrase (Kapp et al., 2019; McLaughlin & Fleury, 2020). The sensory overwhelm, associated anxiety, and stigma (Liao et al., 2019; Ng et al., 2020) attached to the

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[1] See Section 1.1 of the Supplementary Material for definitions of many terms used within this work, as well as Section 1.2 for discussion on our use of terms such as "children with ASD" rather than "autistic children". This Section also contains an extended definition of internal repetition, and discussion on our use of the term "calming".

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child's noticeable behaviors—that are often regarded as socially inappropriate—can contribute to avoidance of outings altogether (Broady et al., 2017; Kinnear et al., 2016). Such avoidance of social activities can limit opportunities for families to be able to spend quality time together outside the home, as well as restrict exposure and learning opportunities for children with sensory sensitivities to expand their social skills (Spain et al., 2018; Tint & Weiss, 2016). Stimming is used to help control sensory overload, whether that be from the internal (i.e., noisy thoughts or uncontainable emotions) or external environment (Kapp et al., 2019). The concept of examining internal music repetition in this study takes inspiration from these repetitive actions.

This study explores whether music containing higher repetition of predictable patterns will reduce anxiety, thereby providing a calming effect. Our aim for this work was not to study whether music replaces the need to stim, or to reduce any physical responses to the music to meet the neuronormative expectation of sitting and being quiet during a concert (Pickard et al., 2020). Rather, this study aimed to normalize natural responses to music regardless of how they are manifested and what they entail. The hope of this work is to assist with the inclusive design of sensory-friendly music programming, including but not limited to informed choices around repertoire and environment.

Along with sensory sensitivities, anxiety is a common occurrence in both ASD and ADHD. Across multiple surveys anxiety ranked as the second most common disorder or co-existing disorder (with ADHD ranked first) among school-aged children (Llanes et al., 2020; Simonoff et al., 2008). Moreover, a comprehensive Australian study (Sciberras et al., 2014) found the presence of anxiety disorder in 64 % of participating children (aged 5–13 years) diagnosed with ADHD, with other work indicating that upwards of 90 % of participating high functioning youths (aged 7–15) diagnosed with ASD qualified for two or more anxiety disorders (Ung et al., 2013). Given that youths who are living with both ASD and anxiety as coexisting conditions have higher occurrences of self-injury, depression, and parental stress in comparison to youths living solely with ASD (Kerns et al., 2015), it is critical that further work examines possible means to offset these impacting factors.

Music therapy is used to support children with ASD to increase social and emotional skills (Brancatisano et al., 2020; Foran, 2021; Haering, 2018). Yet whereas music therapy is often tailored for the individual's needs and clinical goals, real life group activities such as attending professional live concerts—and in particular classical music concerts—are not widely available to children with sensory sensitivities. With increasing awareness of autism, a new concept of 'relaxed' events is beginning to emerge (Fletcher-Watson & May, 2018; Kempe, 2014), and this extends to musical concerts (Shiloh & LaGasse, 2014). These events aim to make the environment sensory-friendly by introducing reduced levels of lighting and sound, and providing early entry hours for people with sensory sensitivities to avoid crowding. Importantly, sensory-friendly concerts can directly benefit these families by providing a genuine opportunity to engage in social and cultural activities together (Shiloh & LaGasse, 2014).

In addition to the well-documented benefits of music engagement in our daily lives (Croom, 2012; Ferreri & Verga, 2016; Jiang et al., 2016), music has been shown to positively impact children with ASD in emotional regulation, social connection, and neurological development (Blauth & Oldfield, 2022; Dănciulescu & Zaharia, 2023; LaGasse et al., 2019). Engagement with music can change brain activities in children with ASD by directly influencing auditory-motor connections (Sharda et al., 2018), and can also increase their facial and emotional recognition (Wagener et al., 2021), thereby leading to better social interactions. Children with ASD can often be musically gifted (Baron-Cohen et al., 2009; Masataka, 2017; Sharda et al., 2018), and display a strong processing ability in music (Jamey et al., 2019; Sharda et al., 2018).

According to Baron-Cohen (2009), there is an association between sensory hypersensitivity and the hyper-systemizing nature of individuals with ASD and their musical talent. Another noticeable autistic trait is a strong preference for routine, structure, and predictability (Honey et al., 2007; Leekam et al., 2011), in addition to systemizing and organizing patterns (Baron-Cohen, 2017; pp. 3, 1270; van der Zee & Derksen, 2021). Individuals with ASD sometimes display a preference for classical music (Bhatara et al., 2013; Levasseur et al., 2020), which may be due to the systematic nature of the classical musical form.

Despite the existing literature clearly linking people with ASD to preferences for structure or being drawn to processes of systemizing and organizing patterns, little empirical research has examined how this might relate to music preference and engagement in a live setting. Given that people with ASD are often reported to receive calming effects by repetition in both stimming and predictability (Goris et al., 2020; Kapp et al., 2019), the impetus of this work is to examine whether highly repetitive music might be able to provide a similar regulatory effect. This work therefore examines responses to music with either high levels of internal repetition or low levels of internal repetition. Hypotheses were designed, although we note that due to the lack of directly related empirical literature, this work can also be considered exploratory in some senses.

Aims and hypotheses

Across two studies, this work examined whether increased internal repetitive elements in classical music leads to reduced anxiety for children with sensory sensitivities attending a live performance. To supplement this investigation, levels of engagement for the children were also measured. In an attempt to record the most robust data available, the decision was made to also collect objective measurements.

It was hypothesized that

H1: Children with sensory sensitivities demonstrate significantly lower anxiety when listening to highly repetitive music, in comparison to music with less internal repetition.

H2: Children with sensory sensitivities demonstrate significantly higher engagement when listening to highly repetitive music, in comparison to music with less internal repetition.

Study 1

Method

Participants

Given that sensory sensitivity is a common feature in ASD and ADHD, our recruitment strategy targeted children who had sensory sensitivities with or without a broader diagnosis of ASD, ADHD, or other neurological conditions. After completing an initial prescreening questionnaire, 20 children (6 female, 14 male) aged 5–13 years ($M = 9.5$, $SD = 2.1$), and their parents/carers were eligible to participate. Participants consisted of ten children with diagnoses of ASD, seven children with ADHD, seven children with Sensory Processing Disorder or Sensory Modulation Disorder, two children with Oppositional Defiant Disorder, two children with anxiety, and five children with undiagnosed sensory sensitivities (identified by their parent/carer). Almost half of the children (45 %) had more than one diagnosis. Exclusions applied to children with hearing impairments, extreme sensory sensitivities that may lead to distress in the experimental setting, Down Syndrome, and Cerebral Palsy. Additionally, given that much of the procedure (detailed below) hinged upon reports provided by the parents/carers, the decision was made not to recruit parents/carers who had significant vision impairments or who did not speak English. The decision for this latter exclusion was based on the fact that translation of terms between languages may not be exact, but for future studies we encourage a more culturally diverse sample than was used here.

Procedure

Participants were recruited from a paediatric occupational therapy clinic in Australia. Printed flyers and information sheets were given by clinic staff to any interested clients. Interested parents/carers were sent a short online prescreening questionnaire link to determine their eligibility. Following this, written informed consent was obtained from legal guardians.

Experimental sessions were conducted in a private room at the paediatric occupational clinic and scheduled, where possible, to coincide with their usual therapy appointments. Children were invited to the room individually with one parent/carer accompanying the child. Sibling/s were also allowed in the room when necessary. In addition to the researcher, an assistant was present to operate the video camera (producing an objective measurement of engagement, as detailed below) and assist with oximeter readings (producing an objective measure of arousal, also detailed below). Parents/carers were asked to fill in a baseline questionnaire before commencing the study. Children were gently encouraged to wear a finger oximeter and a video camera was statically placed 1.5 m away, directly facing the child. The room was well lit to maximize clear picture quality. A *Kawai* ES 8 digital piano was placed to the left side of the child with the sound level set at the mid-way point for all children except for two children who requested a lower sound level.

Music was performed by the lead author, who is a professional concert pianist. Four solo piano pieces were performed, with two containing high levels of internal repetition, and two containing low levels of internal repetition. The presentation order of these conditions was counterbalanced, alternating the playing order of the sets of high and low repetition pieces between participants so that presentation order was not a confounding factor. The children were free to listen without movement restrictions. Parents/carers were asked to observe their child during the performances and to record their observations of the child's response to the music in a further questionnaire at the end of each condition during a short break between pieces. Oximeter measurements were manually recorded from the measurement device by the videographer at regular intervals during three measurement periods (baseline; after first experimental condition; after the second experimental condition). One child declined to wear the oximeter from the beginning of the study, and two other children requested its removal during the second experimental condition; oximeter data for these three children were not used in analyses. Each session ran for approximately 20 minutes, and concluded with a piece of popular, uplifting music selected by the lead author and not used in the experiment. Each child received a sensory-friendly gift bag for participating. An overview of the measurement time points for Study 1 is shown in Fig. 1, and an overview of the room setup is provided within the Supplementary Material.[2]

Measures and materials

The prescreening survey examined eligibility by collecting demographic information as well as requesting information about any observations or diagnoses relating to sensory sensitivity. Following the prescreening survey, parents/carers completed an online *Qualtrics* survey on a supplied tablet device (as per Fig. 1). The Multidimensional Anxiety Scale for Children (MASC) (March et al., 1997) was used to measure anxiety in children. Parents/carers rated each of the 19 statements listed on a 7-point scale (1 = Strongly disagree, 7 = Strongly agree) and an aggregate of these values was created for each time point, with higher values indicating higher ratings of observed anxiety. The Music in Dementia Assessment Scale (MiDAS) is a behavioral observation rating tool initially developed to measure the engagement of people with dementia with musical programs and often used in music therapy studies (Dowson & McDermott, 2019; McDermott et al., 2014, 2015; Ray & Götell, 2018). It was selected for use in the current study due to its usefulness in measuring behavioral indicators of musical engagement. Of the five MiDAS subscales, three were selected for use (being the most relevant subscales: Interest – measured across 3 questions; Involvement – measured across 2 questions; Enjoyment – measured across 3 questions). Wording of questions were modified as appropriate to the study context (e.g., replacing the word "therapist" with "musician"). Whereas the MiDAS scale utilizes an 11-point rating system, for ease of use for our parents/carers we utilized a smaller rating scale of "Yes" (coded as 1), "No" (coded as −1), or "Unsure" (coded as 0). This decision was made due to the fact that each parent/carer would be using these rating scales at three separate time points within the session. As per Fig. 1, an aggregate was created for each of the subscales Interest, Involvement, and Enjoyment for each music type, with higher values indicating higher observed ratings of that subscale (e.g., higher perceptions of enjoyment).

While reports from parents/carers were used to determine sensory sensitivity, the baseline survey also contained the Complementary Sensory Tool (CST) for Children with Autism (Barrios-Fernández et al., 2020) in an effort to measure the degree of sensory sensitivity present. This scale has 41 items describing three factors commonly experienced in ASD (modulation disorders; discrimination disorders; sensory-based motor disorders) but only the modulation disorders factor was utilized here (13 items). We deemed this subscale as the most relevant for answering our research questions, whereas the remaining subscales examined abilities such as perceiving danger (discrimination subscale) or fastening buttons (motor subscale). We are not aware of any other literature solely utilizing the CST modulation subscale, although Barrios-Fernández et al. (2020) reported high validity scores for this subscale. The CST items were proxy rated by parents/carers, who rated each item according to the frequency with which the symptom is experienced by their child. While CST is typically rated on a 5-point scale, as with MiDAS for ease of use for our parents/carers we utilized a smaller rating scale of "Yes" (coded as 1), "No" (coded as −1), or "Unsure" (coded as 0). An aggregate was created, with higher values equating to greater levels of sensory sensitivity.

As noted in the Aims and Hypotheses section, to minimize any potential bias from the subjective responses of proxy reports by parents/carers, two types of objective measurement were also taken. Children's facial expressions were filmed with a *Canon* EOS 5D Mark IV camera, for use in objective facial analyses (FaceReader), and a *Santa Medical* SM-1100S finger pulse oximeter was used to measure arousal levels, with increased values taken as being indicative of increased arousal levels, and higher levels of arousal being an indicator of potential anxiety. The FaceReader variables are outlined further in the section "Data analysis". The oximeter was specifically chosen because it was typically used to examine arousal/anxiety levels at the clinic at which the recruitment and experimental sessions occurred. Due to this familiarity with the device, which is a small finger clip, it was rationalized as the least intrusive method for providing an objective measure of arousal/anxiety. Similarly, we rationalized that video recording methods would be the least intrusive approach for gaining objective measurements of engagement. Given that the children were seated, no impact was expected from movement on oximeter measurements.

Musical selections

Two solo piano pieces were used in each experimental condition (Table 1). Pieces were selected with the intention of presenting audible differences in the amount of internal repetition present within the music (high repetition, low repetition). For example, Bach's *Prelude in C Major* contains continuous arpeggios and constant rhythmic patterns that are highly predictable and repetitive. Similarly, the excerpt from *Metamorphosis No.5* by Philip Glass is minimalist in style with harmonic, rhythmic, and pitch elements containing minimal variation. Although Western Art Music does not tend to contain 'pure' repetition, it is also difficult to find ecologically valid music stimuli that contains no

[2] The Supplementary Material is available at: https://osf.io/hqvp7/?view_only= 04863cb15dc843deaa82bf22a86f02ca

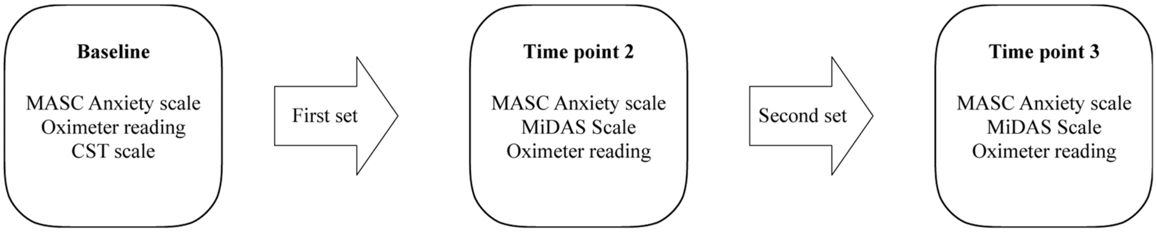

Fig. 1. Measurement time points for Study 1 (Baseline, After first set, After second set). Note that these measurements all followed the prescreening survey, and that facial expressions were filmed continuously from Baseline to the end of Study 1.

Table 1
Details of musical stimuli used in Study 1.

Selection	High repetition	Low repetition
1	Bach, J. S. (1722). *Prelude in C Major BWV 846*.	Chopin, F. (1838). *Mazurka Op.33 No.1*.
2	Glass, P. (1989). *Metamorphosis No.5*.	Debussy, C. (1915). *Élégie L.138*.

repeated elements. Therefore, the choice of low repetition pieces was based on a more narrative style in the music, such as the Chopin Mazurka, which contains less predictable patterns (Levitin et al., 2012). All four pieces were similar in performance duration (approximately two minutes each). A two-minute excerpt of *Metamorphosis No.5* (comprising the middle section) was used to match the duration of the other pieces. Excerpts of musical scores are provided in the Supplementary Material. Additionally, each piece was examined with a spectrogram to help determine the level of internal repetition that it contained (low or high). Spectrogram images and additional details are provided in the Supplementary Material.

Data analysis

Video recordings of facial expressions were analyzed using *Noldus* FaceReader software. FaceReader software calculates activation of individual Activation Units (AUs) as well as aggregate scores that can indicate overall affective states such as happiness or sadness, and data relating to head orientation. The aggregate score for FaceReader Arousal was taken as an additional indicator of anxiety in the current study (i.e., increased values indicated increased levels of arousal). FaceReader X-Head Orientation was used as an indicator of engagement, since this demonstrates a head turn to the left (in the direction of the piano) when numbers decrease. After calibration for individual participants, average scores for Arousal and X-Head Orientation were obtained for both a neutral baseline period and during the two test conditions. For further detail on assessment and scoring of FaceReader variables, see (Skiendziel et al., 2019). Recordings of facial expressions were not obtained for one child who did not sit long enough to capture the minimum duration required for analysis. All data (participant proxy ratings, Oximeter values, and FaceReader values) were successfully assessed for normality prior to analysis.

Results

Anxiety, oximeter, and arousal

To test for order effects, an initial independent samples *t*-test was performed with all aggregate MASC Anxiety scores as the dependent variable, and with participants grouped according to the order that they were presented the stimuli (high repetition first or low repetition first). Results indicated ($t(38) = -1.25$, $p = .219$) that the data had not been influenced by an order effect. Data from both conditions were therefore compared across the three Time points (baseline; high repetition; low repetition) regardless of the order in which the experimental conditions were presented. Descriptive statistics for MASC Anxiety ratings are reported in Table 2.

To test Hypothesis 1, a repeated measures ANOVA was conducted with MASC Anxiety as the dependent variable and Time (baseline, high repetition, low repetition) as the independent variable. Significant results were obtained ($F(2,38) = 11.10, p < .001, \eta^2 = .369$), as plotted in Fig. 2. Šidák post hoc tests indicated significantly lower ratings of MASC Anxiety for the high repetition category compared to baseline ($p = .002$, $d = 0.53$), as well as significantly lower ratings of MASC Anxiety for the low repetition category compared to baseline ($p = .004$, $d = 0.57$). However, no significant differences were observed between the high repetition and low repetition categories ($p = .936$, $d = 0.07$). Therefore, H1 was not supported, but a significant reduction in MASC Anxiety across both musical conditions was observed.

As a further test of H1, two separate repeated measures ANOVAs were conducted with Oximeter Arousal scores and FaceReader Arousal measures as the dependent variables and Time (baseline, high repetition, low repetition) as the independent variable. Across the three-time points Oximeter Arousal scores ranged from 53 to 121, and were measured at each time point as: baseline ($M = 92.6$; $SD = 17.7$; $Median = 96.5$); low repetition condition ($M = 95.2$; $SD = 10.7$; $Median = 95$); high repetition condition ($M = 95.4$; $SD = 12.3$; $Median = 97$). Overall, the FaceReader Arousal Measures ranged from -0.16 to 0.81. No significant differences between conditions were obtained for Oximeter Arousal scores ($F(1.46, 23.29) = 1.38$, $p = .266$, $\eta^2 = .079$) or FaceReader Arousal measures ($F(1.2, 15.56) = 2.57$, p = .123, $\eta^2 = .17$); both of these ANOVAs used Greenhouse-Geisser correction as the assumption of sphericity was not met. Thus, results did not support the first hypothesis, although a non-significant trend in the expected direction was obtained with FaceReader Arousal levels being lowest in the high repetition condition ($M = 0.30$, $SD = 0.06$, $Median = 0.30$), compared to baseline ($M = 0.42$, $SD = 0.24$, $Median = 0.46$), and the low repetition condition ($M = 0.34$, $SD = 0.06$, $Median = 0.34$).

Engagement

Descriptive statistics for the three MiDAS subscales are reported in Table 3. MiDAS scores (H2) were examined with a paired samples *t*-test on each MiDAS subscale, (Interest, Involvement, and Enjoyment), to compare low repetition and high repetition conditions. Sequential Holm-Bonferroni corrections (Holm, 1979) were applied, with reported *p* values adjusted according to this correction. Results were non-

Table 2
Descriptive statistics of MASC anxiety scale within Study 1. Ratings ranged from 1 ("Strongly disagree") to 7 ("Strongly agree"), and an aggregate of these values was created at each time point. A higher value equates to increased perception of anxiety by the parent/carer.

Anxiety	*M*	*SD*	*N*
Baseline	59.7	23.1	20
High repetition	48.1	20.6	20
Low repetition	46.6	22.3	20

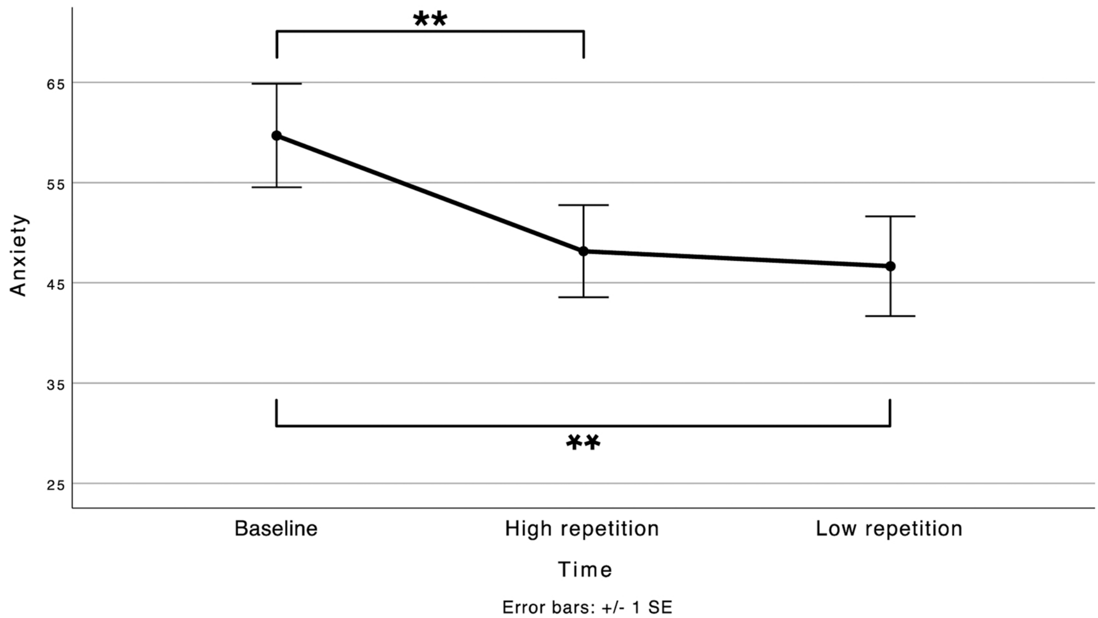

Fig. 2. Anxiety scores at baseline and the two experimental conditions for Study 1. A higher value equates to increased perception of anxiety by the parent/carer. Note: * p < .05; ** p < .01; *** p < .001.

Table 3
Descriptive statistics of MiDAS for Study 1. The rating scale consisted of 1 ("Yes"), 0 ("Unsure"), or − 1 ("No"). For each subscale an aggregate was created from values of the relevant MiDAS questions. A higher value equates to the parent/carer reporting more engagement in these subscale areas.

MiDAS subscale	Stimulus type	*M*	*N*	*SD*	*SE*
Interest	High repetition	0.7	20	1.9	0.4
	Low repetition	0.1	20	2.0	0.4
Involvement	High repetition	-0.3	20	1.5	0.3
	Low repetition	-0.9	20	1.0	0.2
Enjoyment	High repetition	0.5	20	2.3	0.5
	Low repetition	0.8	20	1.9	0.4

significant (Interest: ($t(19) = 1.82$, $p = .170$, $d = 0.36$); Involvement ($t(19) = 1.18$, $p = .126$, $d = 0.46$); Enjoyment ($t(19) = -.88$, $p = .390$, $d = 0.14$)), and so H2 was not supported.

To further test H2 a paired samples *t*-test was conducted with FaceReader X-Head Orientation as the dependent variable and Condition (high repetition, low repetition) as the independent variable. Results showed significant differences by Condition ($t(15) = -1.91$, $p = .038$, $d = 0.41$), with the high repetition condition returning lower scores (indicating more head turns to the left, towards the piano) ($M = -8.22$, $SD = 7.74$) than the low repetition condition ($M = -4.92$, $SD = 8.73$), in support of H2.

Sensory modulation difficulties (CST)

As a supplementary follow-up analysis unrelated to H1 and H2, we examined whether the degree of sensory modulation difficulties (as measured by CST) impacted changes to MASC Anxiety scores across conditions. Aggregate CST scores ranged from − 9 to 6, $M = 0.65$, $SD = 4.4$. To do this, CST scores were split at the Median (value of 1) into Low and High categories; 12 participants were grouped into the low category and 8 into the high category. The above repeated measures ANOVA concerning MASC Anxiety (dependent variable) and Time (independent variable) was re-run, with the two CST categories added as a between-subjects variable. Results indicated no significant interaction for Time and CST category ($F(2, 36) = 0.22$, $p = .804$, $\eta^2 = .012$).

Study 2

The results of Study 1 suggested that music as a whole (i.e., regardless of internal repetition level) had a calming effect on children with sensory sensitivities, although no differences were observed between high and low repetition stimuli. FaceReader X-Head Orientation scores suggested increased engagement for high repetition music, although engagement comparisons based on MiDAS values were non-significant. Additionally, FaceReader Arousal values produced a non-significant trend in which the High repetition condition produced lower values than both the Low repetition condition and baseline, as per H2. The non-significant outcomes for MiDAS and CST may be attributed (at least in part) to methodological issues such as the relatively small sample size used here, and our decision to utilize a 3-point rating scale for both scales (Yes; Unsure; No). That is, despite providing ease of use for the parents/carers in Study 1, these reduced rating scales may not have allowed sufficient variance in responses for significant findings to emerge. Therefore, in Study 2 we examined similar hypotheses although with methodological changes such as an 11-point rating scale for MiDAS, a 5-point rating scale for CST, and utilization of a group performance setting to reflect the conditions of a realistic live concert. Due to the group setting, FaceReader and oximeter analyses were not possible in Study 2.

Method

Participants

Study 2 utilized the same recruitment strategy, targeting children who had sensory sensitivities with or without a broader diagnosis of ASD and/or ADHD. Participants consisted of 20 children (6 female and 14 male) aged 6–14 years ($M = 9.4$, $SD = 2.4$), and their parents/carers. There were 11 children with a diagnosis of ASD, 9 children with ADHD, one with Sensory Processing Disorder, one with anxiety, and 9 children with undiagnosed sensory sensitivities (although with these sensory sensitivities indicated by their parent/carer). Some children (40 %) had more than one diagnosis. The concert coincided with an increase of reported COVID-19 cases in the community, leading to smaller attendance than was anticipated. Due to this, an online component was added to enable additional participants to participate in the study virtually.

Four participants completed the online version of Study 2. Independent samples Mann-Whitney *U*-tests were performed to see whether significant differences existed between people who participated in-person and online. The tests examined MASC Anxiety scores at baseline, and after both test conditions, and examined ratings of the Interest, Involvement, and Enjoyment subscales from the MiDAS during the two test conditions. No significant differences were found at $p < .05$, and therefore data from the two groups were combined and analyzed as a single dataset.

Procedure

Participants were recruited via online social media advertisements and a mailing list of professional networks of the lead author. An online prescreening survey collected demographic and CST data, after which consent forms were emailed to eligible participants. Upon arrival to the performance venue, parents/carers were given a sheet with a unique participant identifier number and a QR code linked to an online *Qualtrics* survey containing all study measures. Parents/carers completed baseline measures on their personal devices after arrival but prior to the performance, although one person used a paper version and their responses were subsequently digitized by the research team.

Study 2 was intended to evoke a more ecologically realistic concert setting. The live performance was conducted in a spacious seminar room on a university campus in Australia, allowing social distancing and sufficient room for participants to sit, lie down, or move around while listening. The study was held on a Sunday, being a day with minimal public building access and traffic. Most participants arrived earlier and had a chance to acclimatize to the space and to each other. Siblings were allowed to attend along with participants. The performance space provided sensory-friendly seating options (crashmats, textured rugs, weighted toys) and had a wall-to-wall glass window allowing natural light and visual respite. Most children sat separately to their parents, with only two children sitting in chairs next to their parents. The parents/carers were instructed to sit where they could clearly observe their child. An image of the room setup is provided within the Supplementary Material.

A professional solo cellist performed the works to further reduce possible confounding effects of the musical elements; the cello was chosen given that it usually plays a single melodic line, as opposed to the broader melodic and harmonic possibilities on the piano. The high repetition musical piece was performed first, followed by the low repetition musical piece. As this was a single music performance attended by all participants in Study 2, it was not possible to counterbalance the stimuli across the participants in this study. A short break after each musical piece allowed parents to record observations of their child's response to the music. Following these two pieces, the rest of the concert consisted of popular, uplifting music played by a professional piano and cello duo for which no outcome measures were taken. The total duration of the concert was approximately twenty minutes. Children were offered a small sensory gift for participating.

The live concert was also filmed with a camera focusing on the performer, for use in the virtual version of study. The online component was run approximately three months later. Participants viewed the recording of the live performance via a *YouTube* link embedded in an online *Qualtrics* questionnaire which also contained the same baseline and outcome measures.

Measures and materials

As with Study 1, parents/carers initially completed the demographic and CST prescreening questionnaire, and on the testing date completed proxy ratings of Anxiety using MASC (March et al., 1997) and behavioral observation ratings using MiDAS (McDermott et al., 2015). MiDAS ratings for the same three subscales as Study 1 were provided on an 11-point scale ranging from 0 ("None at all") to 10 ("Highest"), whereas CST ratings were provided on a 5-point scale ranging from 1 ("Never") to 5 ("Always"). An aggregate for MASC and for each of the three MiDAS subscales was created for each time point. The session was filmed on a *Canon* EOS 5D Mark IV camera, statically placed and primarily capturing the musician performing. All data were successfully assessed for normality prior to analysis.

Musical stimuli

One piece per condition was selected to reduce variability of responses between the pieces within each condition (Table 4). Bach's *Prelude* from *Cello Suite No.1* was selected as the high repetition piece, due to the circular repetitive semiquaver pattern. Paul Stanhope's *Dawn Lament* was chosen for the low repetition piece, in that it contains an improvisatory narrative style and was deemed by the research team as less predictable. Each piece was performed on solo cello, with performance durations of three to four minutes per piece. As with Study 1, the Supplementary Material contains excerpts of music scores as well as spectrogram images that were used to help confirm the level of repetition contained in the pieces.

Results

Anxiety

To test H1, a repeated measures ANOVA was conducted with MASC Anxiety scores as measured by the MASC as the dependent variable and Time (baseline, high repetition, and low repetition) as the independent variable (Table 5 and Fig. 3). Statistically significant differences between Time points were detected ($F(1.27, 24.09) = 17.30$, $p < .001$, $\eta^2 = .477$), using Greenhouse-Geisser correction as the assumption of sphericity was not met. Šidák post hoc tests indicated significantly lower ratings of MASC Anxiety for the high repetition category compared to baseline ($p < .001$, $d = 1.23$), as well as significantly lower ratings of MASC Anxiety for the low repetition category compared to baseline ($p = .003$, $d = 1.05$). As with Study 1, no significant differences were observed between the high repetition and low repetition categories ($p = .367$, $d = 0.26$). H1 was not supported, but as with Study 1 a significant reduction in MASC Anxiety scores across both musical conditions was observed.

Engagement

To test H2, three paired-sample *t*-tests were performed to examine any differences in Interest, Involvement, and Enjoyment subscale scores between the high repetition and low repetition conditions (Table 6). Due to multiple comparisons, the *t*-tests were subjected to sequential Holm-Bonferroni correction (Holm, 1979); adjusted *p* values are reported. All three *t*-tests were significant, and indicated higher MiDAS values for the High repetition condition: (Interest: ($t(19) = 3.17$, $p = .01$, $d = 0.92$); Involvement: ($t(19) = 2.48$, $p = .022$, $d = 0.59$); Enjoyment: ($t(19) = 4.80$, $p = .003$, $d = 0.93$)). These results therefore support H2.

Sensory modulation difficulties (CST)

Aggregate CST scores ranged from 16 to 52, $M = 33.7$ and $SD = 10.0$. To test whether the degree of sensory modulation difficulties in

Table 4
Musical pieces used in Study 2. Both pieces were performed on solo cello, with one piece selected to represent each condition (High and Low repetition).

Repetition	Piece
High	Bach, J. S. (ca. 1720). *Prelude* from *Cello Suite No.1 in G major, BWV 1007.*
Low	Stanhope, P. (1999). *Dawn Lament.*

Table 5
Descriptive statistics of anxiety within Study 2. Ratings ranged from 1 (“Strongly disagree”) to 5 (“Strongly agree”), and an aggregate of these values was created at each time point. A higher value equates to increased perception of anxiety by the parent/carer.

Anxiety	*M*	*SD*	*N*
Baseline	41.1	14.7	20
High repetition	26.7	7.4	20
Low repetition	28.7	7.9	20

participants influenced the effect of music listening, CST scores were split at the median (value of 33.5) into low and high sensory modulation difficulty groups, with 10 participants in either group. The above repeated measures ANOVA concerning MASC Anxiety scores (dependent variable) and Time (independent variable) was run again with CST groups added as a between-subjects effect. Greenhouse-Geisser correction was used as the assumption of sphericity was not met. Results indicated no significant interaction between Time and CST group ($F(1.31, 23.55) = 3.11$, $p = .081$, $\eta^2 = .147$). The main effect of Time remained significant ($F(1.3, 23.55) = 19.22$, $p < .001$, $\eta^2 = 0.52$).

Discussion

This paper reported findings from two empirical studies aiming to examine whether music with high levels of repetition had a calming effect and would be more engaging for children with sensory sensitivities, in comparison to music with low levels of repetition. Despite the literature providing general insights and rationale, this was a largely exploratory approach due to the lack of similar prior empirical work in this area. Our choice of methodology accounted for understanding of the atypical behaviors and responses that are trademarks of people with ASD. To minimize potential bias associated with proxy ratings, in Study 1 we used objective measurements from the finger oximeter and FaceReader to complement the subjective observational measurements of MiDAS and MASC from the parents/carers.

The overall results from both studies did not support H1. Rather, a significant reduction in MASC Anxiety scores across both musical conditions was observed, with no significant differences emerging between high and low repetition music. It is possible that greater variation in internal repetition may have led to observable differences, and so further study is recommended. Regarding H2, this was supported by FaceReader Head Orientation results in Study 1, as well as behavioral indicators from MiDAS (Study 2). Yet the MiDAS behavioral indicators in Study 1 did not reach significance. Overall, we conclude that both music types had a calming effect on our participants, and that high repetition music led to increased interest and engagement. With this in mind, it is clear that more work is required to understand the complexities at hand, and to examine the reproducibility of these findings.

There were numerous experimental design choices and variables of interest available to us to investigate the impact of music repetition. We chose a generally reductionist approach, in which we aimed not to control every variable available to us. The reasoning behind this is due to the primary overarching aim of this work: to introduce children with sensory sensitivities to live classical music performances by professional musicians. By limiting the number of variables that were captured we were able to keep the atmosphere of the performances (particularly in Study 2) closer to that of a concert than a laboratory experiment. This was critical to enabling responses that were ecologically valid. The limitation to this approach, however, was that a number of additional variables that may have been considered were not captured. For example, individual perceptions of musical structure and components of the stimuli such as perceptions of complexity were not rated, and the degree of sensory sensitivity between participants could have been

Table 6
Descriptive statistics of MiDAS for Study 2. The rating scale ranged from 0 (“None at all”) to 10 (“Highest”). For each subscale an aggregate was created from the values of the relevant MiDAS questions. A higher value equates to the parent/carer reporting more engagement in these subscale areas.

MiDAS subscale	Stimulus type	*M*	*SD*	*SE*
Interest	High repetition	18.0	6.4	1.4
	Low repetition	12.2	6.2	1.4
Involvement	High repetition	8.5	5.8	1.3
	Low repetition	5.2	5.5	1.2
Enjoyment	High repetition	15.5	6.3	1.4
	Low repetition	8.9	7.7	1.7

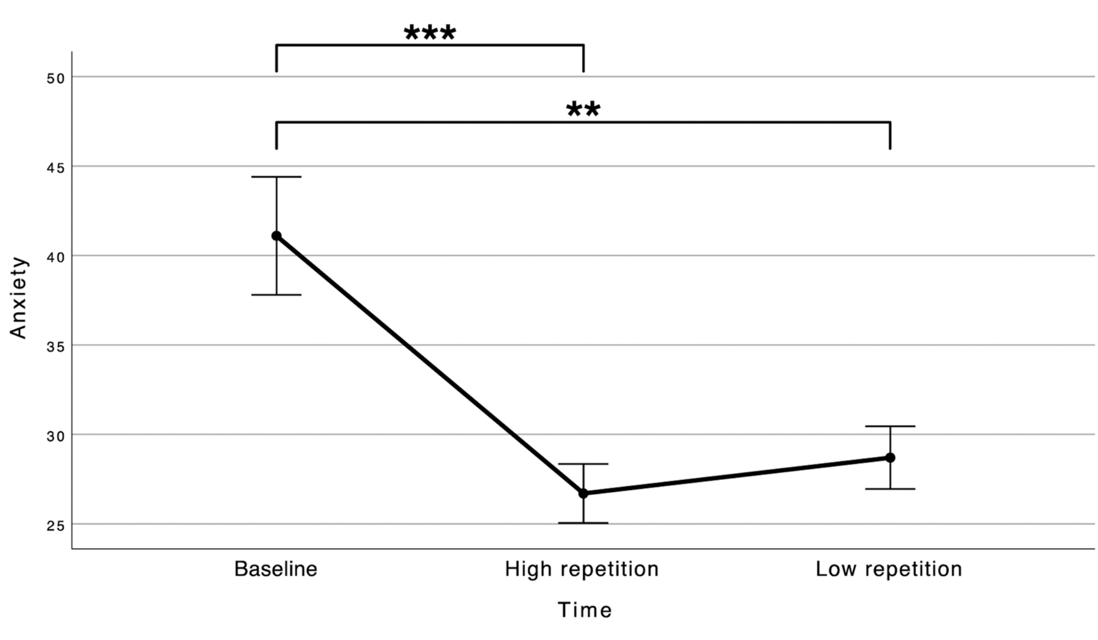

Fig. 3. Anxiety at baseline and for the two experimental conditions within Study 2. A higher value equates to increased perception of anxiety by the parent/carer. Note: * p < .05; ** p < .01; *** p < .001.

measured to greater detail. In a realistic scenario of a live concert, it is challenging to cater for individual needs, and to know exact details for audience members (such as severity levels and music perceptions or preferences) ahead of time. We therefore believe that in these early stages of empirical examination for this specific area, a somewhat reductionist approach (as used here) is the most appropriate. Our aim is to systematically expand the breadth of these examinations as more concrete and reproducible findings emerge through subsequent studies.

Overall, a number of factors may have influenced the observed results. Firstly, the small sample size of twenty participants in each study may have influenced the non-significance of some outcomes. In addition, Study 1 used two pieces in each condition. While these pieces were chosen with the intention of producing similar responses in participants, this cannot be guaranteed. In some cases, the parents indicated that responses to the two pieces within the same condition were varied, meaning that the child enjoyed one piece more than the other despite the pieces belonging to the same experimental condition. We also acknowledge that some pieces may have been more familiar to the participants—most notably the *Prelude in G Major* by Bach—which could have played a role in their preferences (Chmiel & Schubert, 2017), although familiarity ratings were not captured. To better control for differences such as individual preferences between pieces, a single piece was used per condition for Study 2, although counterbalancing of the order of the pieces was not possible as the experiment was conducted as a single performance.

It is also worth noting that in each study the MASC and MiDAS scales were presented to parents/carers three times in relatively quick succession (once prior to music being played, and once immediately following each musical condition, i.e., three times within approximately 30 minutes). As behavioral observation measures, these scales are intended to pick up changes in behavior, including over relatively short periods of time. However, in our review of the literature we were not able to identify other studies utilizing repeated measures of MASC or MiDAS in as quick succession as was used here. Future research in this area could consider more longitudinal approaches with measuring behavior. As noted above, there is also room for future work in this area to encompass a broader, more diverse population, such as including people from non-English speaking backgrounds, and using a broader age range.

Another factor to consider is the choice of music, and the difficulty in disentangling a single variable from music containing many factors. A primary purpose of this project was to introduce live classical music to families with sensory sensitivities, stemming from first-hand experiences by the lead author. Examples of Western classical music was therefore chosen to simulate realistic listening experiences, yet the compositional format of this music does not easily allow focus on a single element. Due to this, these findings may contain confounding of various factors such as pitch, tempo, mode, dynamics, and forms. One avenue for further study would be to focus on stimuli containing only a single musical component, such as using excerpts strictly containing varied drumming patterns, to examine the isolated component of rhythm. Yet conversely the stimuli used in such an approach may have limited ecological relevance to the music families would typically encounter in public performance spaces in everyday life. Regarding FaceReader measurements, we also acknowledge that conclusions for neurodivergent people based on X-Head Orientation should be approached with caution. Neurodivergent individuals may find concentration easier when not directly facing the source of auditory input, or may simply have a preference for indirect orientation, and so this finding from Study 1 is not necessarily indicative of increased engagement for all participants.

In terms of recruitment, it was difficult to recruit children based on sensory sensitivities as a standalone condition, given the time constraint and uncertainty in group gatherings during the COVID-19 lockdown periods. As sensory sensitivities can co-occur across various conditions the decision was made to cast the net wide to include sensory sensitive children with various conditions. Future studies could focus on a single diagnosis at a time, although this approach is complicated by the fact that there are usually comorbidities present, thereby potentially reducing the available sample even further for this approach. Such studies could also consider measuring and analyzing the sensory severity levels of individual participants, as well as measuring levels of stimming behaviors prior to, during, and after performances to investigate potential relationships, such as if manipulations of musical repetition or complexity led to visible changes.

The overall calming effect of live music, regardless of the use of high or low repetition, is a notable find. This calming effect could be due to the general structured nature of classical music—with repetition being the building block of musical structure (Wilson, 1989) —which aligns with the trait of systemizing and the preference for predictability being strongly prevalent in ASD. Therefore, a part of the calming effect could be attributed to the cognitive processing of patterns within a structure. Yet future work should not limit itself to classical music. Comparisons of music styles and conventions may prove fruitful, as may the inclusion of individualized music.

Methodological choices—particularly the reduction of MASC and MiDAS rating scale sizes in Study 1—undoubtedly had an impact on the outcomes of this work. The correction of this in Study 2 appears to have delivered more robust findings, and so our recommendation is for these scales to be retained, despite the ease of use for respondents afforded by the smaller scales. Additionally, while the realistic concert setting of Study 2 added to the ecological validity of this experiment, it is possible that the sensory-friendly environmental adjustments (such as cushions, toys, and the like) could have played a role in influencing the outcome compared to the one-on-one clinical setting (Study 1). Every effort was made to present the performance space in Study 2 as an inviting atmosphere, although we acknowledge that a seminar room is not a typical concert space. This may lead to broader discussion on whether moving away from traditional concert hall settings might lend well to sensory-friendly concerts on a large scale. Despite the non-traditional concert space, the children were exposed to a quality musical experience. The performances of both studies were of professional concert standard, the musicians used are industry recognized and currently active, and the pieces were written by reputable composers. Indeed, different choices regarding musical repertoire, instrumentation, the duration of the pieces, further physical modifications to the concert environment, or performances at different times of the day (morning; day; evening) may deliver different statistical outcomes.

A note of interest was that some children in Study 2 were observed imitating the movements of the cellist during the high repetition piece, and for one child, imitating these cellist movements in both the high and low repetition pieces. Several factors could have contributed to this response. Firstly, playing the cello is more visibly physical compared to the digital piano (which requires smaller movements from the performer to produce a sound, sitting at a static instrument). In contrast the cello requires larger movements, and the sound vibrations created by the cello may have been more tangibly (physically) experienced. In addition, a cellist usually faces the audience whereas a pianist usually sits with their profile to the audience, although in Study 1 the pianist was facing the profile of the child, and the child was facing the camera. These factors could have played a role in the cello being both visually and aurally stimulating.

This project focused on making quality concert experiences performed by professional musicians accessible to children with sensory sensitivities and their families. The project stems from this core idea: how to make live concerts comfortable and accessible for families with sensory sensitivities, without compromising the quality of the musical content. This work is aimed to form a basis for future research, through which we can better understand how to optimize sensory-friendly approaches.

Conclusion

The key finding of this research shows significant calming effects when listening to live music. This reiterates the benefits of music, and that live music can be used as a calming activity for children with sensory sensitivities, even when in non-familiar environments. Moreover, music with higher repetition seemed to induce higher levels of engagement (interest, involvement, and enjoyment) from the children, compared to music with low repetition.

Concert organizations are beginning to show interest in looking for inclusive ways to widen their audience participation. In addition to the existing efforts being made, such as modifying the physical environments, allowing freedom of movement and retreat, it is now time to focus on the quality of the musical content. Areas must be prioritized, such as the choice of music, the reasons behind these choices, and the evidence of these choices contributing to the positive outcome of sensory friendly concerts. Overall, this work sheds light on an under-researched area and aims to provide a reference point and pathway for further works to explore how live music can benefit children with sensory sensitivities, as well as their families. Given the relatively small sample size used, and other limitations including the unprecedented challenges of the COVID-19 pandemic at the time of research, this work can be considered preliminary. Yet the findings indicate a need for further investigation on a larger scale. This study advocates for normalizing neurodiverse-friendly approaches in professional concerts. We hope this exploratory study can create dialogues between arts organizations, creative artists, and both educational and allied health sectors in strengthening the development of programming for inclusive concerts.

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CRediT authorship contribution statement

Grace S. Kim: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing. **Anthony Chmiel:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing. **Sandra Garrido:** Data curation, Formal analysis, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Declaration of Competing Interest

Author Grace Kim is the creative director of Sensory Concerts®, a series of classical music performances aimed to be accessible to neurodivergent families. Sensory Concerts® acts under Your Music Inc., a registered not-for-profit charity in Australia. This research is motivated by a genuine quest for knowledge and improvement, rather than financial profit.

Data availability

Data will be made available in anonymized format, upon reasonable request.

References

Australian Institute of Health and Welfare, 2017. *Australian Institute of Health and Welfare: Australia's children, Children with mental illness*. Australian Institute of Health and Welfare. https://www.aihw.gov.au/reports/children-youth/australias-children/contents/health/children-mental-illness.

Baron-Cohen, S. (2017). Editorial perspective: neurodiversity - A revolutionary concept for autism and psychiatry. *Journal of Child Psychology and Psychiatry, 58*(6), 744–747. https://doi.org/10.1111/jc

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: Biological Sciences, 364*(1522), 1377–1383. ⟨https://www.jstor.org/stable/40485909⟩.

Barrios-Fernández, S., Gozalo, M., Díaz-González, B., & García-Gómez, A. (2020). A complementary sensory tool for children with autism spectrum disorders. *Children, 7*(11). https://doi.org/10.3390/children7110244

Bhatara, A., Quintin, E.-M., Fombonne, E., & Levitin, D. J. (2013). Early sensitivity to sound and musical preferences and enjoyment in adolescents with autism spectrum disorders. *Psychomusicology: Music, Mind, and Brain, 23*(2), 100–108. https://doi.org/10.1037/a0033754

Black, K. R., Stevenson, R. A., Segers, M., Ncube, B. L., Sun, S. Z., PhiliMuller, A., Bebko, J. M., Barense, M. D., & Ferber, S. (2017). Linking anxiety and insistence on sameness in autistic children: The role of sensory hypersensitivity. *Journal of Autism and Developmental Disorders, 47*(8), 2459–2470. https://doi.org/10.1007/s10803-017-3161-x

Blauth, L., & Oldfield, A. (2022). Research into increasing resilience in children with autism through music therapy: Statistical analysis of video data. *Nordic Journal of Music Therapy, 31*(5), 454–480. https://doi.org/10.1080/08098131.2022.2044893

Boldsen, S. (2022). Autism and the sensory disruption of social experience. *Frontiers in Psychology, 13*. ⟨https://www.frontiersin.org/articles/10.3389/fpsyg.2022.874268⟩.

Brancatisano, O., Baird, A., & Thompson, W. F. (2020). Why is music therapeutic for neurological disorders? The therapeutic music capacities model. *Neuroscience & Biobehavioral Reviews, 112*, 600–615. https://doi.org/10.1016/j.neubiorev.2020.02.008

Broady, T. R., Stoyles, G. J., & Morse, C. (2017). Understanding carers' lived experience of stigma: The voice of families with a child on the autism spectrum. *Health & Social Care in the Community, 25*(1), 224–233. https://doi.org/10.1111/hsc.12297

Brooks, A. W., Schroeder, J., Risen, J. L., Gino, F., Galinsky, A. D., Norton, M. I., & Schweitzer, M. E. (2016). Don't stop believing: Rituals improve performance by decreasing anxiety. *Organizational Behavior and Human Decision Processes, 137*, 71–85. https://doi.org/10.1016/j.obhdp.2016.07.004

Chmiel, A., & Schubert, E. (2017). Back to the inverted-U for music preference: A review of the literature. *Psychology of Music, 45*(6), 886–909. https://doi.org/10.1177/0305735617697507

Croom, A. M. (2012). Music, neuroscience, and the psychology of well-being: A précis. *Frontiers in Psychology, 2*. https://doi.org/10.3389/fpsyg.2011.00393

Dănciulescu, T., & Zaharia, A. (2023). Piano with a twist: A pilot study exploring the preliminary effects of a piano therapy program for children with autism spectrum disorder. *The Arts in Psychotherapy, 82*, Article 101987. https://doi.org/10.1016/j.aip.2022.101987

Dellapiazza, F., Michelon, C., Vernhet, C., Muratori, F., Blanc, N., Picot, M.-C., Baghdadli, A., Baghdadli, A., Chabaux, C., Chatel, C., Cohen, D., Damville, E., Geoffray, M.-M., Gicquel, L., Jardri, R., Maffre, T., Novo, A., Odoyer, R., Oreve, M.-J., & for ELENA study group. (2021). Sensory processing related to attention in children with ASD, ADHD, or typical development: Results from the ELENA cohort. *European Child & Adolescent Psychiatry, 30*(2), 283–291. https://doi.org/10.1007/s00787-020-01516-5

Dowson, B., & McDermott, O. (2019). Approaches to measuring the impact of music therapy and music activities on people living with dementia. In A. Baird, S. Garrido, & J. Tamplin (Eds.), *Music and Dementia: From Cognition to Therapy (p. 0)*. Oxford University Press. https://doi.org/10.1093/oso/9780190075934.003.0009.

Doyle, N. (2020). Neurodiversity at work: A biopsychosocial model and the impact on working adults. *British Medical Bulletin, 135*(1), 108–125. https://doi.org/10.1093/bmb/ldaa021

Ferreri, L., & Verga, L. (2016). Benefits of music on verbal learning and memory. *Music Perception, 34*(2), 167–182. https://doi.org/10.1525/mp.2016.34.2.167

Fletcher-Watson, B., & May, S. (2018). Enhancing relaxed performance: Evaluating the autism arts festival. *Research in Drama Education: The Journal of Applied Theatre and Performance, 23*(3), 406–420. https://doi.org/10.1080/13569783.2018.1468243

Foran, L. M. (2021). Listening to music: Helping children regulate their emotions and improve learning in the classroom. *Listening to Music, 9*.

Goris, J., Brass, M., Cambier, C., Delplanque, J., Wiersema, J. R., & Braem, S. (2020). The relation between preference for predictability and autistic traits. *Autism Research, 13*(7), 1144–1154. https://doi.org/10.1002/aur.2244

Haering, S. I. (2018). Are music-based interventions a way to improve executive function in autism? *International Journal of Learning and Teaching, 10*(1), 27–37. https://doi.org/10.18844/ijlt.v10i1.3143

Honey, E., Leekam, S., Turner, M., & McConachie, H. (2007). Repetitive behaviour and play in typically developing children and children with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 37*(6), 1107–1115. https://doi.org/10.1007/s10803-006-0253-4

Jamey, K., Foster, N. E. V., Sharda, M., Tuerk, C., Nadig, A., & Hyde, K. L. (2019). Evidence for intact melodic and rhythmic perception in children with Autism Spectrum Disorder. *Research in Autism Spectrum Disorders, 64*, 1–12. https://doi.org/10.1016/j.rasd.2018.11.013

Jiang, J., Rickson, D., & Jiang, C. (2016). The mechanism of music for reducing psychological stress: Music preference as a mediator. *The Arts in Psychotherapy, 48*, 62–68. https://doi.org/10.1016/j.aip.2016.02.002

Kapp, S. K., Steward, R., Crane, L., Elliott, D., Elphick, C., Pellicano, E., & Russell, G. (2019). People should be allowed to do what they like': Autistic adults' views and experiences of stimming. *Autism, 23*(7), 1782–1792. https://doi.org/10.1177/1362361319829628

Kempe, A. (2014). Developing social skills in autistic children through 'Relaxed Performances. *Support for Learning, 29*(3), 261–274. https://doi.org/10.1111/1467-9604.12062

Kerns, C. M., Kendall, P. C., Zickgraf, H., Franklin, M. E., Miller, J., & Herrington, J. (2015). Not to be overshadowed or overlooked: Functional impairments associated with comorbid anxiety disorders in youth with ASD. *Behavior Therapy, 46*(1), 29–39. https://doi.org/10.1016/j.beth.2014.03.005

Kinnear, S. H., Link, B. G., Ballan, M. S., & Fischbach, R. L. (2016). Understanding the experience of stigma for parents of children with autism spectrum disorder and the role stigma plays in families' lives. *Journal of Autism and Developmental Disorders, 46*(3), 942–953. https://doi.org/10.1007/s10803-015-2637-9

LaGasse, A. B., Manning, R. C. B., Crasta, J. E., Gavin, W. J., & Davies, P. L. (2019). Assessing the impact of music therapy on sensory gating and attention in children with autism: A pilot and feasibility study. *Journal of Music Therapy, 56*(3), 287–314. https://doi.org/10.1093/jmt/thz008

Leekam, S. R., Prior, M. R., & Uljarevic, M. (2011). Restricted and repetitive behaviors in autism spectrum disorders: A review of research in the last decade. *Psychological Bulletin, 137*(4), 562–593. https://doi.org/10.1037/a0023341

Levasseur, A., Jamey, K., Foster, N., Hyde, K., & Dalla Bella, S. (2020, November 14). *Musical genre preferences in Autism Spectrum Disorder. NeuroMusic Annual Conference, Hamilton, Ontario*. https://www.researchgate.net/publication/348481831.

Levitin, D. J., Chordia, P., & Menon, V. (2012). Musical rhythm spectra from Bach to Joplin obey a 1/f power law. *Proceedings of the National Academy of Sciences, 109*(10), 3716–3720. https://doi.org/10.1073/pnas.1113828109

Liao, X., Lei, X., & Li, Y. (2019). Stigma among parents of children with autism: A literature review. *Asian Journal of Psychiatry, 45*, 88–94. https://doi.org/10.1016/j.ajp.2019.09.007

Llanes, E., Blacher, J., Stavropoulos, K., & Eisenhower, A. (2020). Parent and teacher reports of comorbid anxiety and ADHD symptoms in children with ASD. *Journal of Autism and Developmental Disorders, 50*(5), 1520–1531. https://doi.org/10.1007/s10803-018-3701-z

Lovell, B., & Wetherell, M. A. (2019). Affiliate stigma, perceived social support and perceived stress in caregivers of children with autism spectrum disorder: A multiple mediation study. *Archives of Psychiatric Nursing, 33*(5), 31–35. https://doi.org/10.1016/j.apnu.2019.08.012

March, J. S., Parker, J. D. A., Sullivan, K., Stallings, P., & Conners, C. K. (1997). The multidimensional anxiety scale for children (MASC): Factor structure, reliability, and validity. *Journal of the American Academy of Child & Adolescent Psychiatry, 36*(4), 554–565. https://doi.org/10.1097/00004583-199704000-00019

Masataka, N. (2017). Neurodiversity, giftedness, and aesthetic perceptual judgment of music in children with autism. *Frontiers in Psychology, 8*. ⟨https://www.frontiersin.org/articles/10.3389/fpsyg.2017.01595⟩.

McDermott, O., Orgeta, V., Ridder, H. M., & Orrell, M. (2014). A preliminary psychometric evaluation of Music in Dementia Assessment Scales (MiDAS). *International Psychogeriatrics, 26*(6), 1011–1019. https://doi.org/10.1017/S1041610214000180

McDermott, O., Orrell, M., & Ridder, H. M. (2015). The development of music in dementia assessment scales (MiDAS). *Nordic Journal of Music Therapy, 24*(3), 232–251. https://doi.org/10.1080/08098131.2014.907333

McLaughlin, A., & Fleury, V. P. (2020). Flapping, spinning, rocking, and other repetitive behaviors: Intervening with young children who engage in stereotypy. *Young Exceptional Children, 23*(2), 63–75. https://doi.org/10.1177/1096250618798338

Ng, C. K. M., Lam, S. H. F., Tsang, S. T. K., Yuen, C. M. C., & Chien, C.-W. (2020). The relationship between affiliate stigma in parents of children with autism spectrum disorder and their children's activity participation. *International Journal of Environmental Research and Public Health, 17*(5), 1799. https://doi.org/10.3390/ijerph17051799

Pickard, B., Thompson, G., Metell, M., Roginsky, E., & Elefant, C. (2020). "It's not what's done, but why it's done": Music therapists' understanding of normalisation, maximisation and the neurodiversity movement. *Voices: A World Forum for Music Therapy, 20*(3). https://doi.org/10.15845/voices.v20i3.3110. Article 3.

Ray, K. D., & Götell, E. (2018). The use of music and music therapy in ameliorating depression symptoms and improving well-being in nursing home residents with dementia. *Frontiers in Medicine, 5*. ⟨https://www.frontiersin.org/articles/10.3389/fmed.2018.00287⟩.

Russell, G., Stapley, S., Newlove-Delgado, T., Salmon, A., White, R., Warren, F., Pearson, A., & Ford, T. (2022). Time trends in autism diagnosis over 20 years: A UK population-based cohort study. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 63*(6), 674–682. https://doi.org/10.1111/jc

Sciberras, E., Lycett, K., Efron, D., Mensah, F., Gerner, B., & Hiscock, H. (2014). Anxiety in children with attention-deficit/hyperactivity disorder. *Pediatrics, 133*(5), 801–808. https://doi.org/10.1542/peds.2013-3686

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

Shiloh, C. J., & LaGasse, A. B. (2014). Sensory friendly concerts: A community music therapy initiative to promote Neurodiversity. *International Journal of Community Music, 7*(1), 113–128. https://doi.org/10.1386/ijcm.7.1.113_1

Simonoff, E., Pickles, A., Charman, T., Chandler, S., Loucas, T., & Baird, G. (2008). Psychiatric disorders in children with autism spectrum disorders: Prevalence, comorbidity, and associated factors in a population-derived sample. *Journal of the American Academy of Child & Adolescent Psychiatry, 47*(8), 921–929. https://doi.org/10.1097/CHI.0b013e318179964f

Skiendziel, T., Rösch, A. G., & Schultheiss, O. C. (2019). Assessing the convergent validity between the automated emotion recognition software Noldus FaceReader 7 and Facial Action Coding System Scoring. *PLoS ONE, 14*(10), Article e0223905. https://doi.org/10.1371/journal.pone.0223905

Spain, D., Sin, J., Linder, K. B., McMahon, J., & Happé, F. (2018). Social anxiety in autism spectrum disorder: A systematic review. *Research in Autism Spectrum Disorders, 52*, 51–68. https://doi.org/10.1016/j.rasd.2018.04.007

Tint, A., & Weiss, J. A. (2016). Family wellbeing of individuals with autism spectrum disorder: A scoping review. *Autism, 20*(3), 262–275. https://doi.org/10.1177/1362361315580442

Ung, D., Wood, J. J., Ehrenreich-May, J., Arnold, E. B., Fuji, C., Renno, P., Murphy, T. K., Lewin, A. B., Mutch, P. J., & Storch, E. A. (2013). Clinical characteristics of high-functioning youth with autism spectrum disorder and anxiety. *Neuropsychiatry, 3*(2), Article 10.2217/npy.13.9. https://doi.org/10.2217/npy.13.9

van der Zee, E., & Derksen, J. J. L. (2021). The power of systemizing in autism. *Child Psychiatry & Human Development, 52*(2), 321–331. https://doi.org/10.1007/s10578-020-01014-4

Wagener, G. L., Berning, M., Costa, A. P., Steffgen, G., & Melzer, A. (2021). Effects of emotional music on facial emotion recognition in children with autism spectrum disorder (ASD). *Journal of Autism and Developmental Disorders, 51*(9), 3256–3265. https://doi.org/10.1007/s10803-020-04781-0

Wilson, D. (1989). The role of patterning in music. *Leonardo, 22*(1), 101–106. https://doi.org/10.2307/1575147

Zeidan, J., Fombonne, E., Scorah, J., Ibrahim, A., Durkin, M. S., Saxena, S., Yusuf, A., Shih, A., & Elsabbagh, M. (2022). Global prevalence of autism: A systematic review update. *Autism Research: Official Journal of the International Society for Autism Research, 15*(5), 778–790. https://doi.org/10.1002/aur.2696