Assessing Musical Preferences of Children on the Autistic Spectrum: Implications for Therapy

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ABSTRACT

Music-based therapies have been yielding favorable clinical outcomes in children with Autism Spectrum Disorder (ASD). However, there is a lack of guidelines for content selection in music-based interventions. In this context, we propose a methodology for conducting experimental studies on musical preferences in children diagnosed with ASD. It consists of a generative music system with seven manipulable musical parameters where participants are encouraged to create music content according to their preferences. We conducted a preliminary transversal study with 24 children in the state of Pará, Brazil. The results suggest preferences for fast tempo, higher pitch, consonance, high event density, and timbres with smooth attacks. Intriguingly, the results revealed inconsistency in the identified preferences across therapy sessions. The critical need for personalized regulation in music-based interventions for children with ASD highlights the unique nature of individual responses, emphasizing the imperative of tailoring therapeutic approaches accordingly.

1. INTRODUCTION

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by poor communication and language skills, restricted and repetitive patterns of behaviour, and persistent deficits in initiating and maintaining reciprocal social interactions. A notable increase in diagnosed cases of ASD has been reported recently [1] – according to the World Health Organization (2023), it is estimated that currently around 1 in 100 children worldwide has autism [2].

In recent years, there has been a remarkable development in research into the disorder, leading to measures for earlier diagnosis and improving these individuals' quality of life, notably from interdisciplinary therapeutic strategies [3]. In this context, available treatments range from pharmacological treatments to behavioral interventions and alternative therapies to promote development and well-being. These interventions are typically carried out by a multidisciplinary team, which includes professionals from the fields of psychology [4], pharmacology [5], speech therapy [6], physiotherapy and psychomotricity [7], occupational therapy [8], pedagogy [9]. Commonly applied methods for teaching and improving language, psychomotor regulation, communication, socialization and adaptive behaviors include Applied Behavior Analysis [4, 10, 11], Picture Exchange Communication System [12] , TEACCH [4, 12], Early Start Denver Model [10], Relationships, Individual Differences and Development Model [4, 10], and Social Skills Training [10].

Additionally, professionals are increasingly opting for sessions using alternative therapies, which are health practices that are not part of tradition or conventional medicine. One of the alternative therapies that has shown promising results uses music as a form of therapeutic intervention [13]. Music therapy is an intervention with music in a clinical treatment context, used through a therapist-patient relationship to promote individualized goals [14]. This intervention employs a wide range of methods and techniques, which are characterized by systematic procedures that specify the particular way in which the technique is to be performed [15]. In the context of autism, common music therapy methods include Educational Music Therapy [16], Improvisational Music Therapy [15, 16], Singing/Listening to Songs [15], Audio Murotal Intervention [17], Therapeutic Listening [17] and Auditory Integration Training [17].

Although the use of music therapy has shown significant improvements in the areas of communication, social skills, attention, emotional expression, and sensorimotor regulation, there is still a lack of in-depth understanding about the most appropriate sounds for these interventions [18]. In this regard, it is becoming increasingly urgent to understand the sound and musical preferences of individuals with this disorder, to enable the development of individualized musical approaches and sound stimuli, capable of meeting their demands and specificities [18, 19].

This experimental study delves into how to prepare sound stimuli and/or music to be effectively incorporated into ASD therapies, and it was conducted as part of a larger project at the University Center of the State of Pará (CE-

SUPA) that aimed to develop a mobile application for children with ASD, focusing on their emotional and psychomotor regulation. At the same time, this study set out to investigate: 1) what the preferences are within the various musical parameters, as well as 2) whether there are any correlations between them, and also 3) whether this preference is constant or changes between therapy sessions, for children with ASD, aged between 2 and 6, of both sexes and with support levels 1 or 2, according to the DSM-5-TR [20].

We designed a methodology based on a generative computational musical engine, running on a touch screen mobile handheld device (MHD), where participants were asked to manipulate generative musical parameters.

The remainder of this paper is structured as follows. Section 2 presents related work on musical preferences in ASD. Section 3 outlines the methodology adopted in an experimental study, including participants, materials, procedures, and data analysis. Section 4 presents the results of our experiment, followed by a discussion of their implications within the context of existing literature in Section 5. Finally, Section 6 provides the main conclusions of our study and future research directions.

2. RELATED WORK ON MUSICAL PREFERENCES IN ASD

A growth literature has been reporting music interventions for individuals within the ASD. They range from reviews of the various types of music interventions [15, 16, 21], to studies comparing specific types of music interventions [16, 17], and also studies exploring music interventions for particular aspects of ASD [17, 22]. A common thread among these interventions for individuals with ASD is the need for curated music contents. Nonetheless, there remains a lack of clear guidelines for selecting appropriate musical content, particularly when initiating therapy with new patients. The sparse research exploring musical preferences among individuals with ASD examines a few parameters, concentrating mostly on higher-level genre preferences compared to lower-level structural elements such as consonance, melody, rhythm, and instrumentation. This section synthesizes findings across these parameters to provide insights into the nuanced musical preferences of individuals with ASD.

Genre preferences serve as a foundational aspect of musical preference studies among individuals with ASD. Research by Bhatara et al. [23] indicates a similar interest in music among adolescents with and without ASD, with a notable preference for classical music among those with the disorder. Levasseur et al. [19] found that rock and pop-rock were favored genres among children with ASD, while Sravanti et al. [24] uncovered a liking for culturally significant music from an early age.

Moving to more formal parameters, investigations into consonance versus dissonance perception reveal intriguing findings. Boso et al. [25] demonstrated a preference for consonant music over dissonant music among both individuals with ASD and control groups, suggesting the therapeutic potential of consonant music in communication and interaction.

Further exploration into musical structure includes preferences for melody versus rhythm. Sravanti et al. [24] reported a preference for rhythm over melody among children with ASD, with some expressing enjoyment of both aspects of music.

Additionally, preferences for instrumental music versus music with vocals have been studied. Sravanti et al. [24] found a clear preference for music with vocals over instrumental music among children with ASD, highlighting the importance of considering vocal elements in therapeutic interventions.

Finally, research into sound parameters provides information on the sensory experiences of individuals with ASD. Cibrian et al. [18] found a preference for melodic sounds, particularly those produced by the cello, as well as a preference for low notes over high notes, suggesting potential applications for the regulation of attention and emotion in therapeutic contexts.

Overall, these studies underscore the complexity of musical preferences among individuals with ASD, encompassing both higher-level genre preferences and more formal structural parameters. While providing valuable insights, further research is needed to fully understand the intricacies of musical preferences in ASD and to inform tailored interventions in therapeutic settings.

3. METHODS

We conducted an experimental study to unveil musical preferences of children with ASD regarding the parameterization of an instrumental only musical structure. We adopted a differentiated approach, contrary to existing studies that primarily employ third-person observations and perceptual surveys reflecting on the musical experience. These may fail to provide insightful or valid results due to the subjective nature of the task and heavy reliance on working memory, as individuals with ASD may have deficits in short-term (working) memory, impacting their ability to, for example, follow multi-step instructions and maintain focus on tasks requiring mental manipulation of information [26].

In this context, we propose a novel methodology for inferring musical preferences in ASD individuals by assessing trends in the parameterization of a generative music engine intuitively controlled on a MHD. The playful nature of the generative application aims to attract ASD children, the target population of our study, while allowing inferring preferences of the following seven musical parameters: tempo, pitch height, consonance, (vertical) note density, timbre, percussivity, and loudness.

3.1 Participants

The study was carried out from January 2023 to May 2023, and took place at the Physiotherapy School Clinic of CESUPA (Pará State University Center). We recruited 24 children (8% female), aged between 3 and 6 years old (mean 5 ± 3.19), who had a proven diagnosis of ASD, with support level 1 or 2 (29%), according to the DSM-5-TR classification [20] and with psycho-motor repercussions. The participants were voluntarily enrolled in the study, and all the parents consented to the study on behalf of their children.

3.2 Materials

Figure 1 shows the generative music application created for the study. The basic code for the application was created in Pure Data [27] and was based on the harmonic sequence generation algorithms Conchord [28] and D'accord [29]. The algorithms were expanded to allow for a wider range of musical layers (e.g. melody and rhythm section), as well as the parameterization of musical elements.

The musical content produced by the MHD application bears resemblance to the pop-rock and electronic genres. The timbres encompass a range of sonorities reminiscent of electric guitars, electronic pianos, marimbas, among others, while the percussion is derived from samples reminiscent of rap-rock style. To facilitate a deeper understanding of the layers within the musical content generated by the application used in the experiment, we provide musical examples online at `10.6084/m9.figshare.25377460`.

Generated music results from the parameterization of seven musical parameters:

1. **Tempo**, in beats per minute (bpm) in the continuous 40 to 140 range;

2. **Pitch** in semitones, defining a transposition interval for the harmonic and melodic content, ranging [-19,19] semitones;

3. **Consonance (Cons)** of the generated harmonic content as measured by the tonal consonance indicator in the Tonal Interval Space [30] in the continuous [0.4, 0.6] range;

4. **Density (Dens)**, defining the number of notes per unit of time in harmonic and melodic layers. It adopts a 5-point scale, ranging from zero to four;

5. **Timbre** qualities of the sound attack envelope, ranging from static smooth sound attacks transients to percussive sounds or sounds with a fast attack transient on the harmonic and melodic layers. It adopts a 6-point scale, ranging from zero to five;

6. **Percussivity (Perc)** defines the number of percussive elements adopted in the rhythmic layer by swapping from no percussion to 8 percussive loops with increasing degree of event density;

7. **Loudness (Loud)** controls the sound volume of all the generated layers, in the continuous [0,1] range.

Figure 1 displays the main interface of the MHD application. The design process commenced by selecting white as the base color due to its neutral nature. Knobs, circular buttons designed for adjusting musical parameters, were

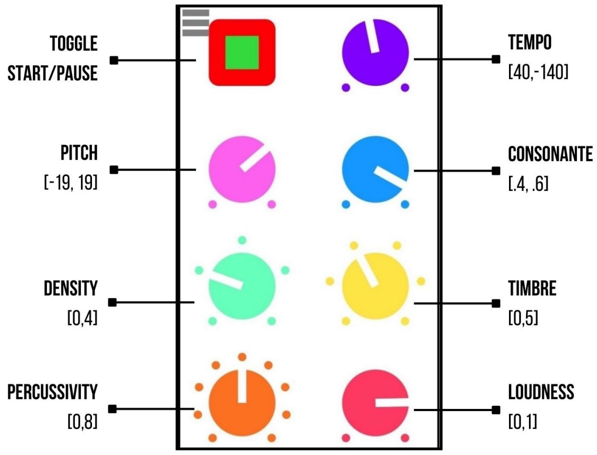

Figure 1. Interface of the mobile generative music application used in the experiment to infer the musical preferences of children with ASD.

implemented for their intuitive usability, particularly beneficial for children. Each knob was assigned a distinct color, aiding children in recognizing that each control modifies a specific musical parameter. Additionally, color selection took into account findings from prior studies suggesting colors with positive effects on children with ASD [31–33]. Furthermore, a Toggle button was incorporated to initiate or halt sound playback, featuring a red hue when paused and green when activated.

3.3 Procedures

The experience began after approval from Cesupa's Ethics Committee, and it was part of a broader project conducted the University Center of the State of Pará (CESUPA), whose objective was the development of a mobile application aimed at children with ASD, focused on their emotional and psychomotor regulation. Participants had one or two intervention sessions, with those receiving two sessions having them on different days, spaced one to two weeks apart. During the initial project phase, lasting about 1 minute per session, children were briefed on the functionality of the MHD application, including its various control parameters. They were asked to experiment only with manipulating them, without concentrating on the musical result. Subsequently, there were two phases in which the children were subjected to physiotherapy and psychology interventions. Each one lasted 14 minutes and aimed to stimulate and work on particular aspects of the child's development.

The experience of this study took place in the last phase of this larger project. The experiment was conducted by the therapist, so that there was a common link to the ASD children. After the physiotherapy and psychology interventions, the participants were asked to create music content according to their taste by manipulating the musical parameter controls of the MHD application. This phase lasted about two minutes, during which the participants experimented with the various musical parameters in the MHD application, until they produced a final music content that was based on their particular taste. This task was performed completely independently and autonomously by the participants, unless they revealed difficulties in the use of the controls, in which case they were assisted by the therapist in manipulating the parameter controls, without interfering in the final choice of the participants. Once a final parameter setting was achieved, the therapist wrote down in a specific table the values chosen by the child for each of the musical parameters, giving rise to the data for later analysis.

3.4 Data Analysis

We adopt a threefold analysis to the data to assess: 1) preferences for specific musical parameters for the participants sample; 2) infer dependencies across musical parameters; and 3) verify consistency in preferences across the two sessions. While the parameters preferences can lead to guidelines to adopt musical parameters spaces in musical stimuli for children with ASD, the second analysis infers the coupling of parameters, such as in fast tempos, typically higher pitch content is adopted. Finally, the consistency of preferences across session should inform the reliability of data across time per participant.

To infer preferences per musical parameters, we computed descriptive statistics, determining the mean, std% and skewness per parameter. The mean indicated the general trend, while the standard deviation assessed consistency between participants. Skewness identified asymmetry in the distribution and was useful in detecting tendencies in the data. Namely, parameters exhibiting low degrees of standard deviation denote greater agreements in the mean value across participants.

Skewness values closer to either negative or positive one, lead to parameters that have a certain tendency across categorized data, e.g., faster or slower tempo, and higher or lower density. Conversely, skewness value closer to zero denote symmetrical distributions. To further interpret the skewness, we computed histograms on data aggregated by fewer categories, such as a threefold categorization of slow, moderate fast tempos, to offer an intuitive and categorized distributions per parameter.

To explore possible relationships between musical parameters, the Pearson's correlation coefficient r was computed between all parameter pairs. This coefficient, in the $[-1, 1]$ range, can offer insights into the dependencies between parameters. Pearson correlation results near positive or negative unity indicate linear or inverse relationships between the parameters data, thus denoting some dependency across parameters. The closer to zero the less of a relationship exist between parameter pairs. Results can inform in the design of musical stimuli for ASD therapies.

To assess the consistency in preferences across different sessions per participant, Pearson's correlation coefficient r and its significance level p as well as the coefficient of determination R^2 were applied. The coefficient of determination, ranging from zero to one, quantifies the degree of relationship between the dependent and independent variables, allowing us to determine whether preferences are consistent over time. Values close to one indicate a strong relationship, while values close to zeo suggest a lack of significance. Prior to the correlation computation, we applied the L_1 norm to the data per parameter, scaling all values to the same range, thus avoiding erroneous linear correlations from outlier data.

4. RESULTS

The data collected from the 24 participating children underwent pre-processing to filter out unreliable interactions with the MHD application, based on feedback provided by the therapists. Initially, we excluded data from children who did not engage with MHD application. Subsequently, following a brief analysis of the remaining data, we further eliminated instances exhibiting a consistent visual pattern, such as consistently reaching maximum or minimum values. This exclusion criterion was based on the observation that these patterns tended to disregard the musical feedback, focusing solely on visual cues. Finally, data from 18 participants were considered for analysis. The first session had 15 participants and the second session had 12 participants. Nine participants attended both sessions.

4.1 Musical Parameters Preferences

Table 1 presents the descriptive statistics for the filtered data. Participants are represented by the symbol P, followed by a unique numerical identifier. For instance, participant one is denoted as P.ID01. The table is divided into two sections, the above results are from session 1 and the bottom results from session 2.

Based on the analysis that parameters exhibiting lower standard deviation values across all participants indicate more representative median parameter values, we can highlight greater alignment in the participants preferences in terms of consonance (13.5 STD%), tempo (33.6 STD%) and intensity (42.1 STD%), resulting in a preference for consonance sounds, faster tempos around 102 bpm and medium loudness. On the other hand, the musical parameters pitch and timbre showed greater divergence between the participants' choices, with higher percentage standard deviations (389.5% and 82.9%, respectively).

The asymmetry analysis indicated a consistent trend for most of the musical parameters, except for percussivity, which showed no trend. The categorical histogram analysis in Figure 2 highlights trends in preference for specific categories of values per musical parameter. The analysis corroborates the data in the Table 1, showing that parameters such as consonance, tempo and intensity were consistent among the participants, while pitch and timbre showed greater variation in preferences. The histograms confirm a preference for high tempos, high consonance sounds, medium intensity, high density and more sustained timbres. The pitch histogram showed no clear trend, and as with the skewness values for percussivity, the data indicated a general appreciation of percussion, but no specific preference for types of percussion was observed, which is why we chose not to include the graph.

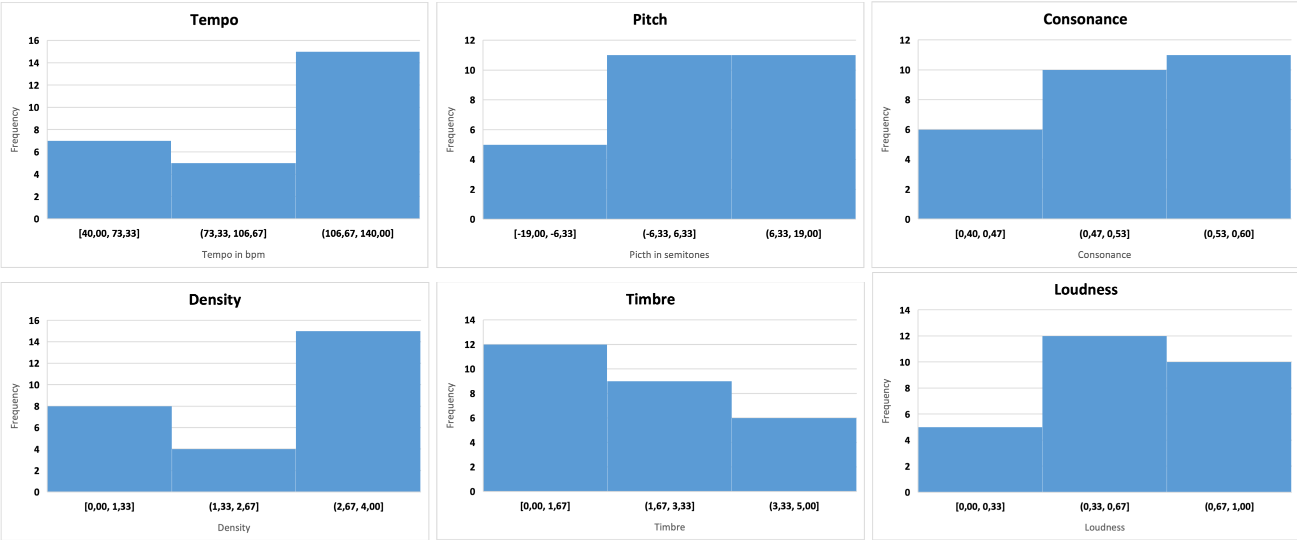

Figure 2. Histograms of musical parameter preferences from the ASD population under study to identify trends in categorical data.

ID	**Tempo** [40,-140]	**Pitch** [-19,19]	**Cons** [.4,.6]	**Dens** [0-4]	**Timbre** [0,5]	**Perc** [0,8]	**Loud** [0,1]
P.ID01	40	14	.56	3	5	0	.83
P.ID02	140	18	.4	1	0	0	.97
P.ID03	75	-4	.6	0	2	1	0
P.ID04	47	19	.6	4	3	0	.66
P.ID05	107	-19	.59	0	1	4	.45
P.ID06	140	-1	.49	2	2	4	.51
P.ID07	137	18	.53	3	0	2	.56
P.ID08	88	0	.4	4	1	2	.65
P.ID09	107	6	.53	3	3	5	.58
P.ID10	40	19	.4	4	0	5	1
P.ID11	76	-2	.48	2	3	6	1
P.ID12	107	6	.53	3	3	5	.58
P.ID13	136	17	.6	4	5	8	0
P.ID14	140	17	.6	4	5	8	1
P.ID15	47	-19	.4	0	1	8	.48
P.ID01	67	1	.49	0	1	8	.83
P.ID02	128	4	.5	0	0	8	.68
P.ID03	133	19	.47	1	1	1	.72
P.ID05	140	0	.59	3	2	3	.32
P.ID07	137	16	.4	3	5	4	.49
P.ID08	92	0	.52	2	3	4	.5
P.ID09	46	-12	.59	0	3	8	.47
P.ID11	115	-11	.6	4	5	2	.96
P.ID15	88	0	.4	4	1	2	.65
P.ID16	118	10	.56	3	4	6	.73
P.ID17	113	-9	.6	2	0	4	.16
P.ID18	44	14	.47	4	1	7	.28
Mean	101.75	2,67	.52	2.17	2.17	4.75	.57
STD%	33.6	389.5	13.5	73.3	82.9	53.9	42.1
Skew	-.39	-.41	-.39	-.47	.36	-.01	-.43

Table 1. Data resulting from our experiment compiling the parameters of each participant in two sessions from manipulating a generative music application. An horizontal line splits the data between session one (above) and session two.

4.2 Parameter dependency

To check for possible linear relationships between the parameters, we used Pearson's Correlation Coefficient r, which measures the degree of correlation between every parameter pair variables whose results are shown in Table 2. There are no linear relationships (positive or negative) between any of the parameter pairs. However, two values denote a relative relationship with a high positive trend, namely between the variables density versus pitch ($r = .5$), and timbre versus consonance ($r = .42$).

	Pitch	**Cons**	**Dens**	**Timbre**	**Perc**	**Loud**
Tempo	.18	.12	.06	.08	-.07	-.06
Pitch		-.16	.50	.13	-.20	.24
Cons			0	.42	.03	-.32
Dens				.38	-.18	.14
Timbre					.08	.06
Perc						-.09

Table 2. Pearson's correlation coefficient r across all parameter pairs assessed in the experiment for inferring linear relationships between parameters.

To further examine the parameter pairs exhibiting linear dependencies between parameters, we present scatter plots accompanied by their linear regressions for density versus pitch in Figure 3 and timbre versus consonance in Figure 4. The positive linear correlation observed between density and pitch indicates that as music density rises, pitch tends to increase as well. Consequently, denser music tends to favor higher-pitched structures. Likewise, the positive linear relationship between timbre and consonance suggests that as sharper attacks are employed in the timbre dimension, the more consonant the structures are.

4.3 Participant's consistency across sessions

Finally, to check whether each participant's preferences for specific musical parameters remained constant in both

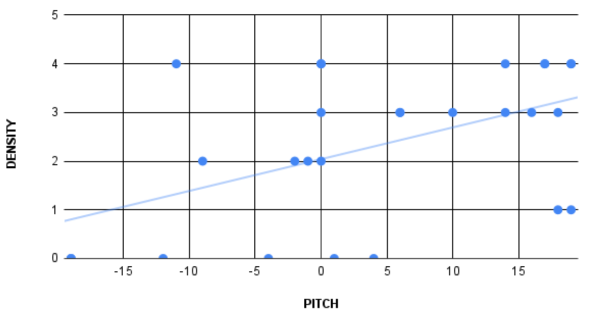

Figure 3. Scatter plot representing the relationship between the density and pitch parameters.

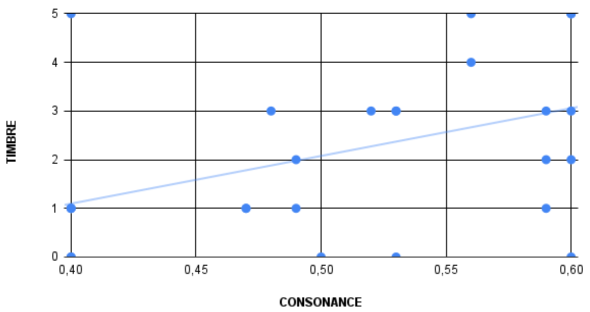

Figure 4. Scatter plot representing the relationship between the timbre and consonance parameters.

sessions, the Pearson's Correlation Coefficient and Coefficient of Determination were computed across the data collected per participants in both sessions. Only data from participants who took part in two sessions was considered. Of the 18 participants, nine were included in this analysis, and the results are shown in Table 3.

ID	r	p	R^2
P.ID01	.09	.11	.01
P.ID02	.75	.77	.56
P.ID03	-.04	.65	0
P.ID05	.75	.05	.57
P.ID07	-.05	.83	0
P.ID08	-.85	.60	.72
P.ID09	-.63	.19	.40
P.ID11	.28	.09	.08
P.ID15	-.34	.11	.11

Table 3. Pearson's correlation coefficient and Coefficient of Determination of the values chosen by the participants submitted to two sessions, to infer consistency between sessions.

Globally, results show poor agreement between the sessions with non-correlated data in r and large variability in R^2. Only one participant in Table 3, P.ID05, shows relatively consistent results between the two sessions, i.e., the parameters choice between the two session are linearly correlated.

5. DISCUSSION

This study explored musical parameter preferences in children with ASD and investigate potential linear relationships between these parameters, as well as the consistency of preferences across different sessions for the same participant. Our aim was to identify trends that could be adopted as guidelines for designing musical stimuli for ASD therapy.

In our results, it was noted that children with ASD exhibited a preference for higher pitch, diverging from Cibrian et al. [18] findings, which suggested higher attention to lower notes. The disparity can be attributed to variations in study objectives, methodologies, and session duration. Concerning consonance, children with ASD favored more consonant music, aligning with Boso et al. [25] previous findings. No specific percussivity preference was identified, but a propensity for using and preferring percussive elements emerged, consistent with Sravanti et al. [24] research.

High-density music was preferred, resonating with studies linking ASD preferences to energetic genres like rock and pop-rock [19, 23, 24]. Sustained timbres were favored over percussive ones, in line with Cibrian et al. [18] observation of heightened concentration and positive emotions with sustained sounds. Participants showed a stronger preference for faster tempos, although some preference for slower tempos was noted compared to medium tempos. Medium loudness values were preferred, potentially linked to the participants' ability to regulate music volume.

Comparing data from two sessions revealed varied individual preferences, emphasizing the complexity of sound preferences in children with ASD. The study underscores the importance of incorporating individual musical preferences into the design of interventions, offering insights for more effective therapeutic strategies. Recognizing the specific preferences of each child holds the potential to enhance the effectiveness of these strategies, create a more fitting and captivating musical environment, and contribute valuable information to the field. Despite acknowledging limitations such as sample size and population specifics, the findings highlight the need for ongoing exploration of preferences within the diverse ASD population. Additionally, a potential limitation is that the protocol could indicate preferences in a creative and generative situation, which may not necessarily correspond to the subject's musical preferences when listening to music without actively participating. Therefore, further research is needed to validate these findings in more passive listening contexts and ensure the robustness of personalized interventions. There is an imperative need to persist in expanding knowledge in this domain, considering the diverse range of preferences within the ASD population.

6. CONCLUSIONS

This study explored the musical preferences of children on the ASD and investigated the impact of different musical parameters on their therapeutic response. The results revealed that children with ASD showed specific musical preferences concerning various sound elements. The participants showed a preference for music with faster tempos, higher pitch, more consonant music, high density, more sustained timbres and percussive elements. Positive linear relationships were observed between music density and pitch, as well as between timbre and consonance. Finally, the results also showed that the consistency of musical preferences in the experimental method sessions varied greatly between sessions.

Our findings can contribute to clinical practice, offering insights for professionals working in the field of music therapy with ASD children by recognizing and understanding the need for individualized, targeted musical content for each patient. Despite the poor agreement across sessions per participant in our results, the above parameter guidelines can provide a solid starting point for content creation. In this context, arising from these experiment-derived patterns, a series of musical pieces were produced for therapy applications, which are accessible online at `10.6084/m9.figshare.25377493`. Furthermore, the experimental methodology adopted can foster creative direction for interacting with ASD children, providing a high degree of control over the generated musical structure and preferences. Longitudinal studies examining musical parameter preferences per ASD child ought to inform us about better practices in this domain.

In future work, we aim to explore the relationship between musical preferences and behavioral responses, investigating the impact of sensory sensitivity, comparing preferences across different ASD profiles and assessing the effectiveness of personalized music therapy. Additionally, we want to apply the protocol to children without ASD to infer differences to children outside of the ASD. Furthermore, the use of innovative technologies, such as applications, can be explored for evaluating and incorporating musical preferences into interventions.

7. ETHICAL STATEMENT

The research was approved by the Ethics Committee of the University Center of the State of Pará, CAAE 65135122.0.0000.5169.

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