uCue: An Interactive Musical Interface to Enhance Formative Listening Experiences for Children with ASD


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Autism Spectrum Disorder

- Autism Spectrum Disorder, or ASD, is a condition that **affects how a person communicates, interacts with others, and behaves**. People with ASD may have trouble with social skills, may not speak or use gestures like others, and often repeat actions or routines.

- The Centers for Disease Control (CDC) declared that in the United States, **1 in 54 children have Autism**. ASD is a lifelong condition and is normally diagnosed at age 2 or 3; however, signs of Autism can be detected as early as 18 months.

- Children with autism often experience sound sensitivity, making them prone to sensory overload in noisy or unpredictable environments.

Music Therapy and ASD

Evidence-based approach that uses music within a therapeutic relationship to address a patient's physical, emotional, cognitive, and social needs

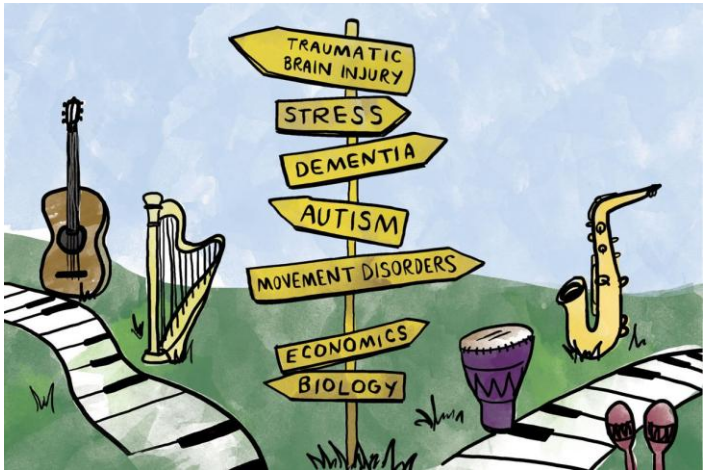


Image from Northwestern University's website: "The Power and Science of Music Therapy"

- An intervention in pediatric health care to alleviate symptoms and improve quality of life. *(Mayer-Benarous et.al.,Front. Psychiatry, April 2021)*
- Aiding communication and emotional regulation in children with ASD. *(Thompson et.al., Child Care Health Dev. Nov 2014)*
- Can improve peer interactions and provide insights into their behavioral and emotional states. *(Cibrian et. al.Pervasive Health,May 2018)*

Tangible Interfaces for Music Therapy

BendableSound (Cibrian et. al. 2016)

An interactive fabric surface that plays sound while touching a fabric to promotes self-regulation and motor control

A Do-It-Yourself (DIY) prototyping platform that allows users to create audio triggers out of existing or fabricated objects

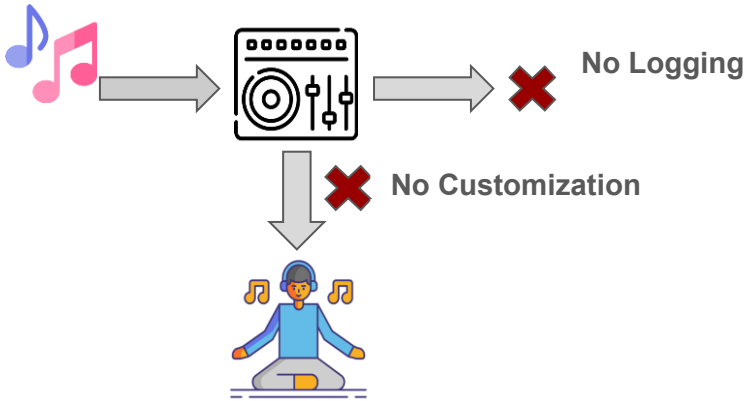
SenseBox (Hamidi et. al. 2016)

Research Gap

Existing Research

Traditional Music Therapy Framework

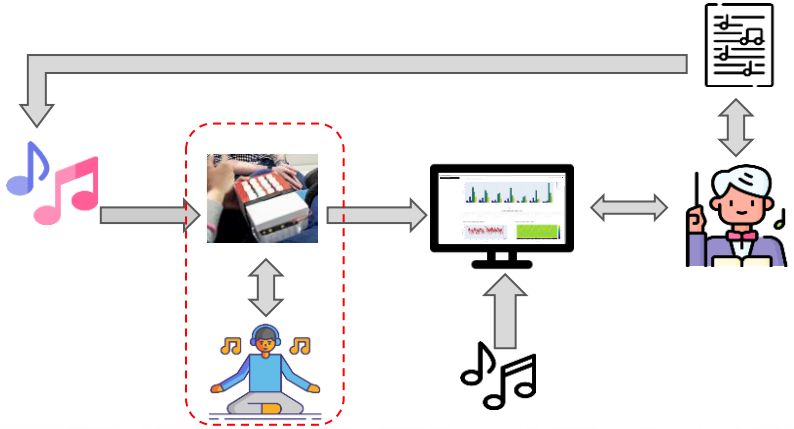
No Music Personalization options + No Logs available for improvising music therapy



Proposed Research

Proposed uCue Musical Framework

Music Personalization based on needs ⟷ Analyzing the Logs to improvise the therapy sessions



Research Questions

What if children with ASD were able to personalize their own music to enhance their listening experience?

- Does interacting with a tangible interface help children with ASD actively identify and express their musical preferences?
- Can engaging with a tangible interface to create music facilitate emotional expression and enhance these children's enjoyment of music?
- How might children with ASD benefit from having greater autonomy over their listener experience?

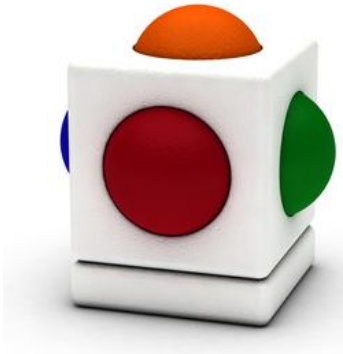
What is uCue?

- A musical interface designed to **enhance musical engagement**
- Incorporates ***modular arrangements of children's songs*** set at an accessible tempo and allows users to ***modify musical layers as needed***
- ***Collects data on listener interactions, including layer combination and timing,*** which can inform composers in creating more engaging music for this population.
- uCue was created with a vision of ***"You create, you enjoy"***

uCue: A Tangible Musical Interface

Sensory Room

Ableton Push

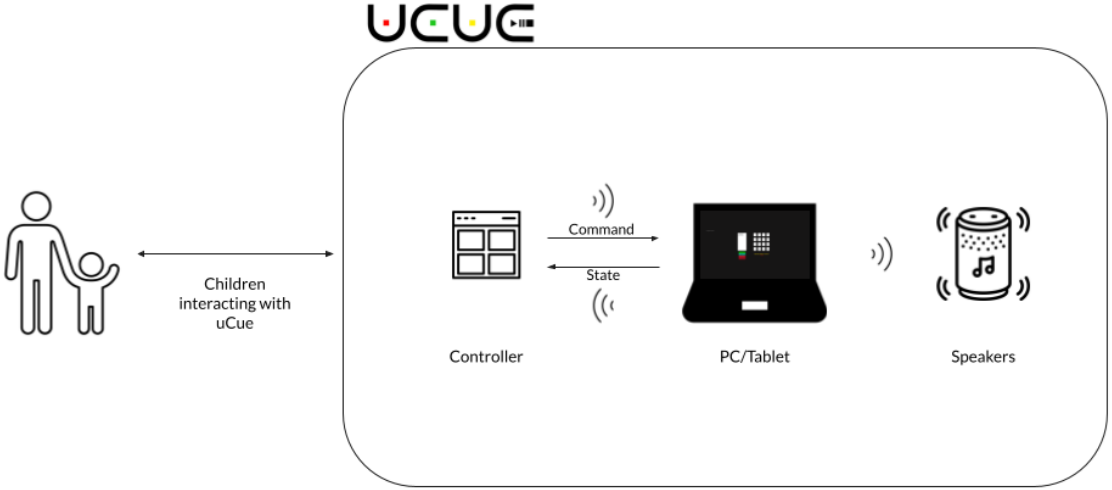


Skoog

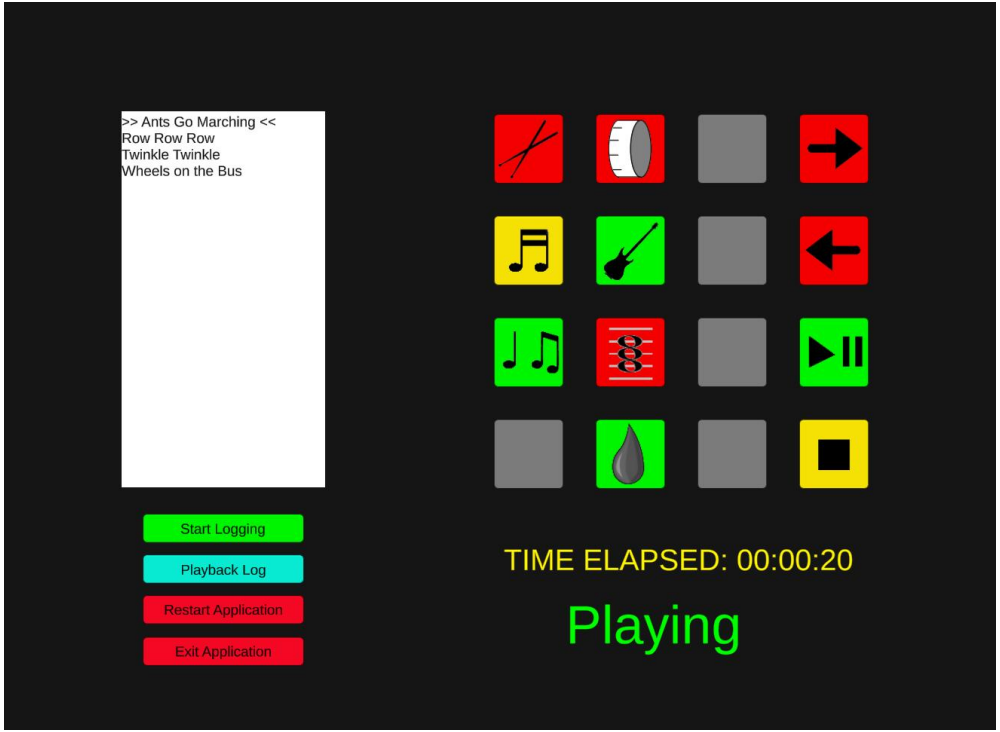
Design

- The design process included ***collaboration*** with experts from ***Autism Delaware*** and the ***Rt. 9 Library & Innovation Center***, alongside ***educators, family members, and researchers with personal ASD experience***.
- Their input shaped sensory-friendly design choices like ***soft buttons, gentle lighting, and intuitive interactions*** to reduce sensory overload.
- Although c***hildren with ASD were not directly involved*** in early design, ***trusted advisors*** informed design, study protocol, and communication strategies.

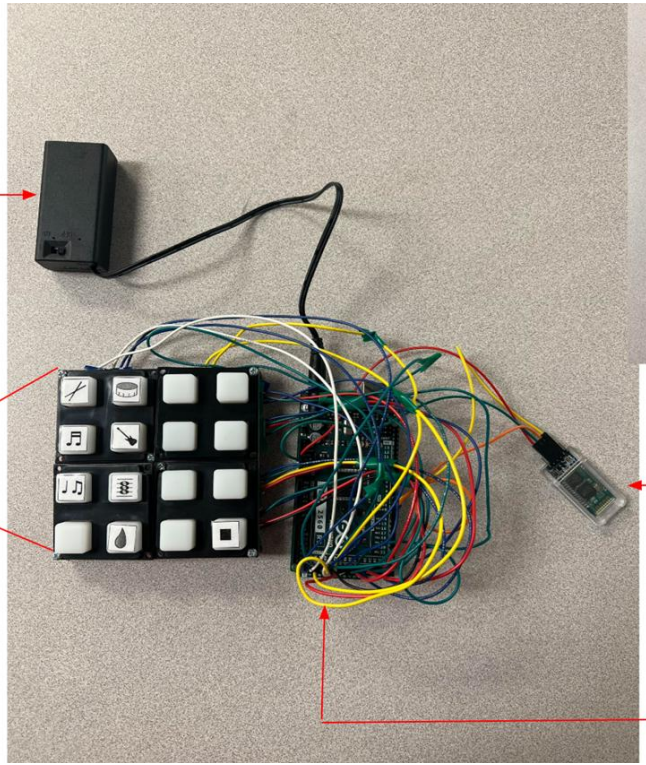
System Diagram



Software Interface

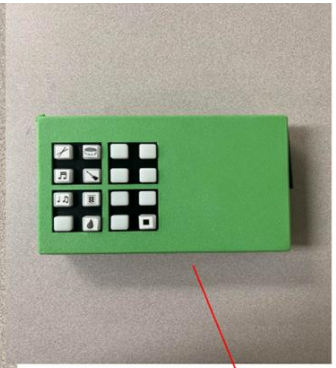


Hardware Architecture



(a)
Battery to power Arduino

(b)
16 LEDs and Diodes mounted on a 4x4 PCB covered by a 4x4 button keypad and 4 bezels

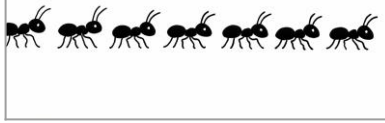
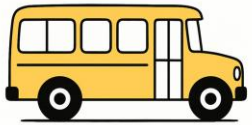


(e)
3D printed Box with button stickers pasted on the keypad

(d)
Bluetooth Module

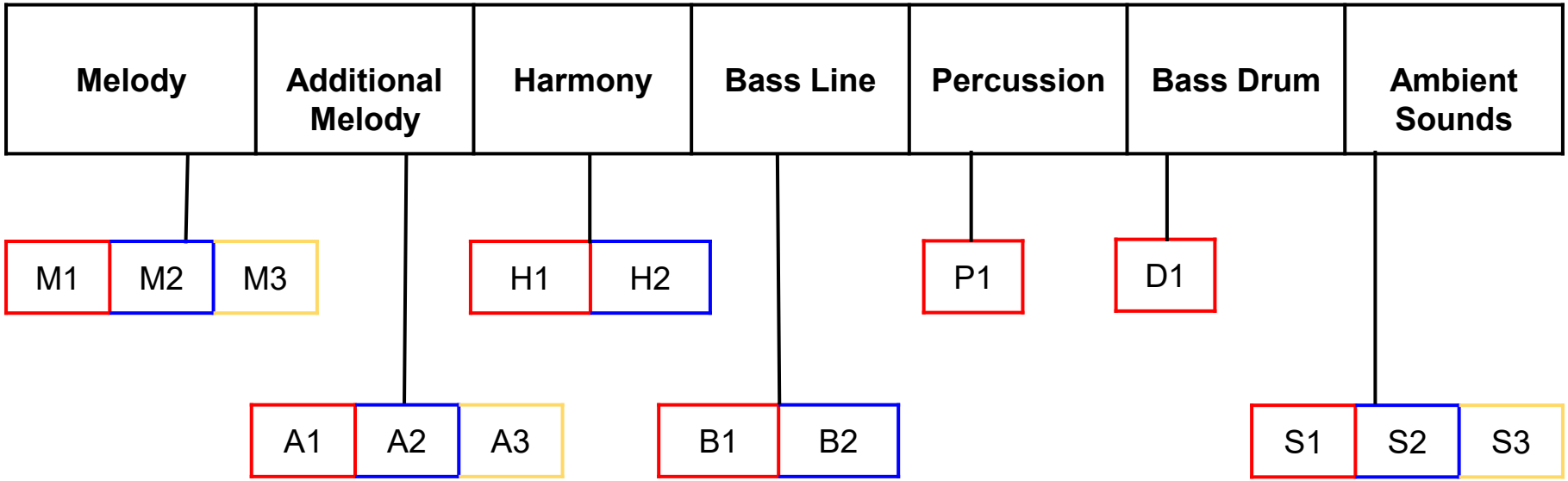
(c)
"Birds Nest" connection with Arduino Mega 2560 R3 and all other components

Musical Library

			
Ants Go Marching	**Wheels on the Bus**	**Twinkle Twinkle**	**Row Row Row Your Boat**

Musical Layers

*Over 2000 possible different combinations of sounds



Musical Composition Tools

- Nord Wave 2 Synthesizer
- Elektron Digitakt
- Arturia Polybrute

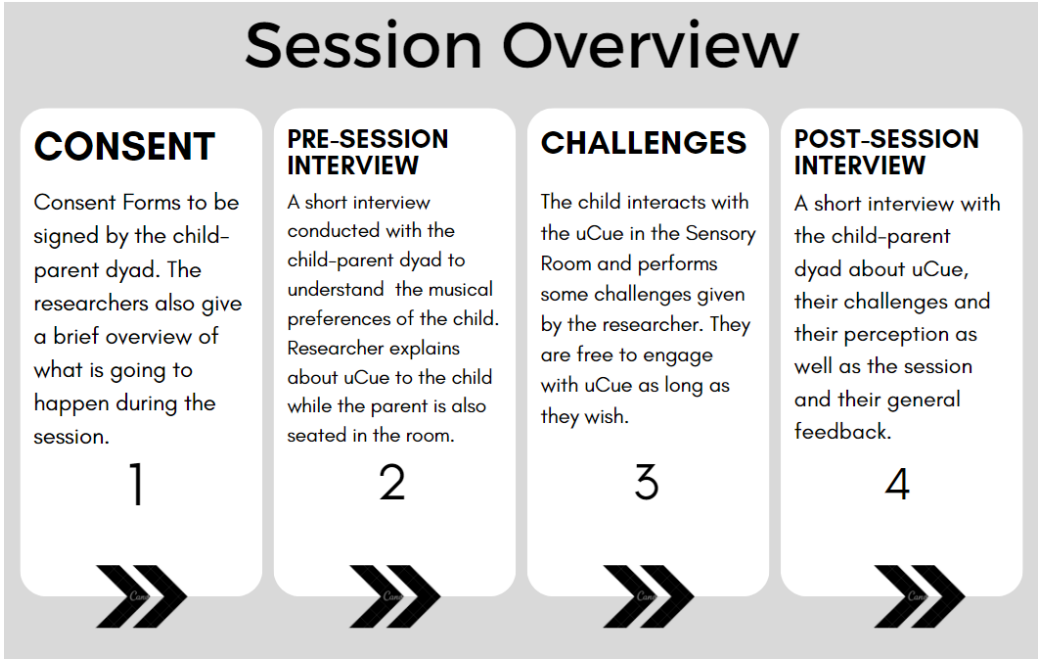
*Standard tools for music composition and production

- Notions & Composing
  - MuseScore
  - Sibelius
- Midi Manipulation & Mixing
  - ProTools

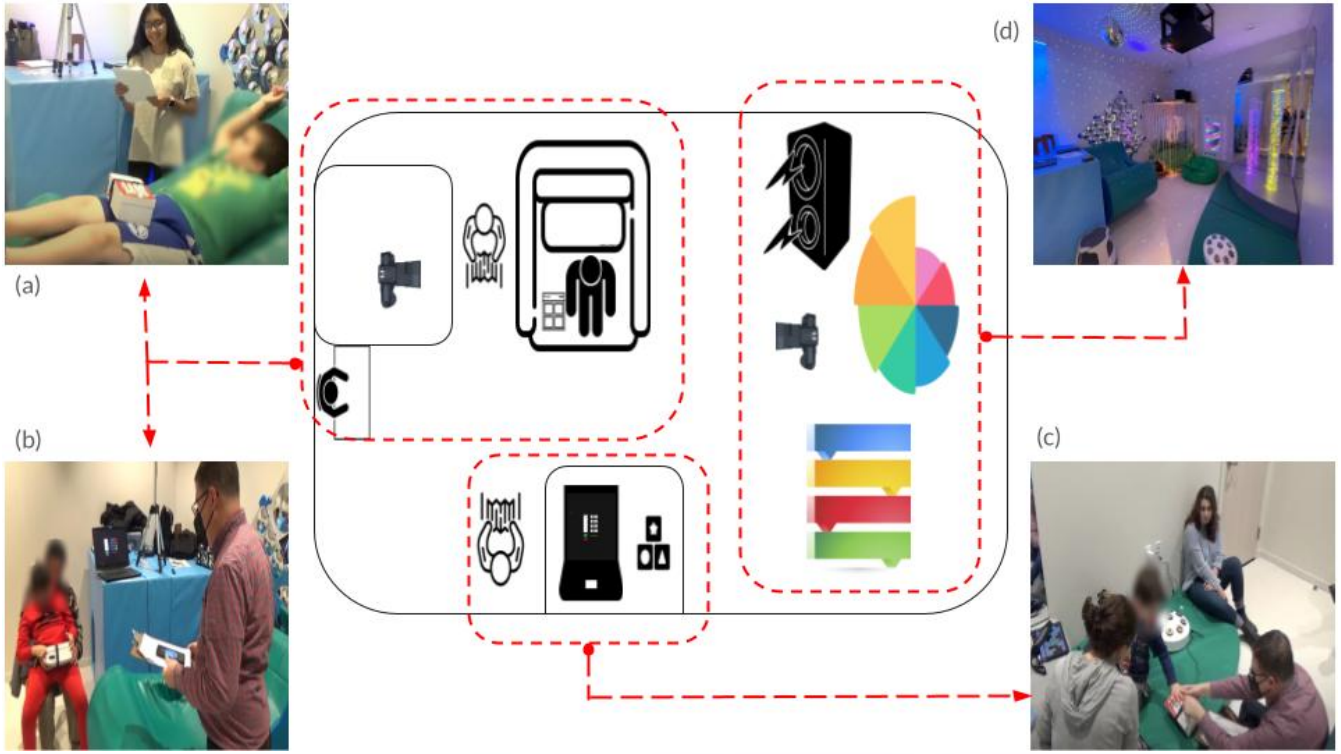
Recruitment

ID	Gender	Age	Verbal	Education	Diagnosis
C1	M	8	Yes	Elem. School	ASD
C2	M	4	No	Elem. School	ASD
C3	M	4	No	Elem. School	ASD
C4	M	4	No	Elem. School	ASD
C5	F	19	No	High School	ASD
C6	M	9	Yes	Elem. School	ASD
C7	M	10	Yes	Elem. School	ASD

Procedure


Session Overview
CONSENT
Consent Forms to be signed by the child-parent dyad. The researchers also give a brief overview of what is going to happen during the session.
1
PRE-SESSION INTERVIEW
A short interview conducted with the child-parent dyad to understand the musical preferences of the child. Researcher explains about uCue to the child while the parent is also seated in the room.
2
CHALLENGES
The child interacts with the uCue in the Sensory Room and performs some challenges given by the researcher. They are free to engage with uCue as long as they wish.
3
POST-SESSION INTERVIEW
A short interview with the child-parent dyad about uCue, their challenges and their perception as well as the session and their general feedback.
4

Sensory Room and Session Images



Results: Participant Interaction

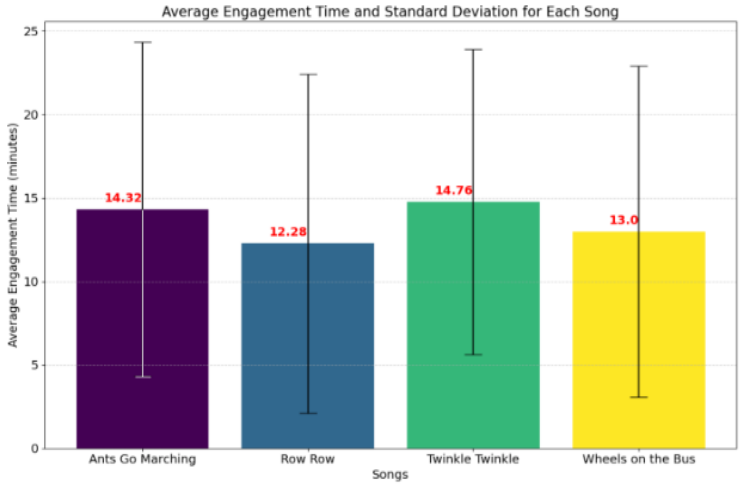


Figure 7: Cumulative Duration for Songs across Participants: "Twinkle, Twinkle" had the highest average play time at 14.76 minutes, followed by "Ants go Marching" with an average play time of 14.33 minutes. The lowest played song was "Row, Row, Row Your Boat" with an average play time of 12.28 minutes.

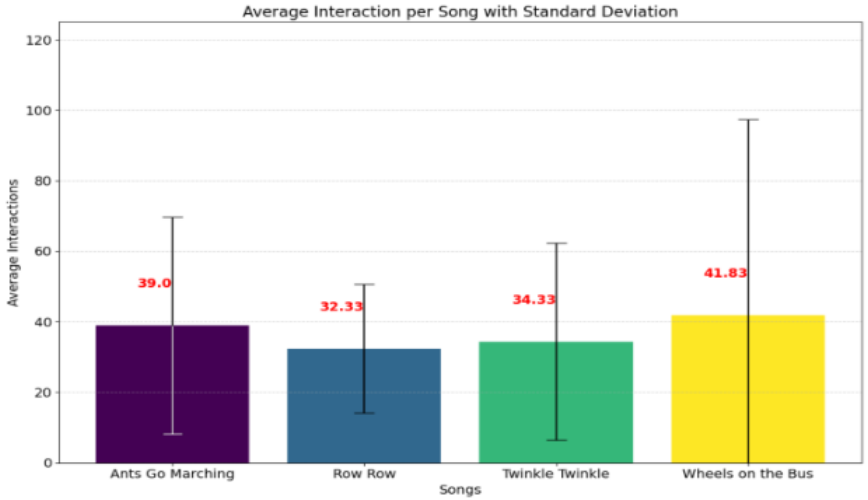
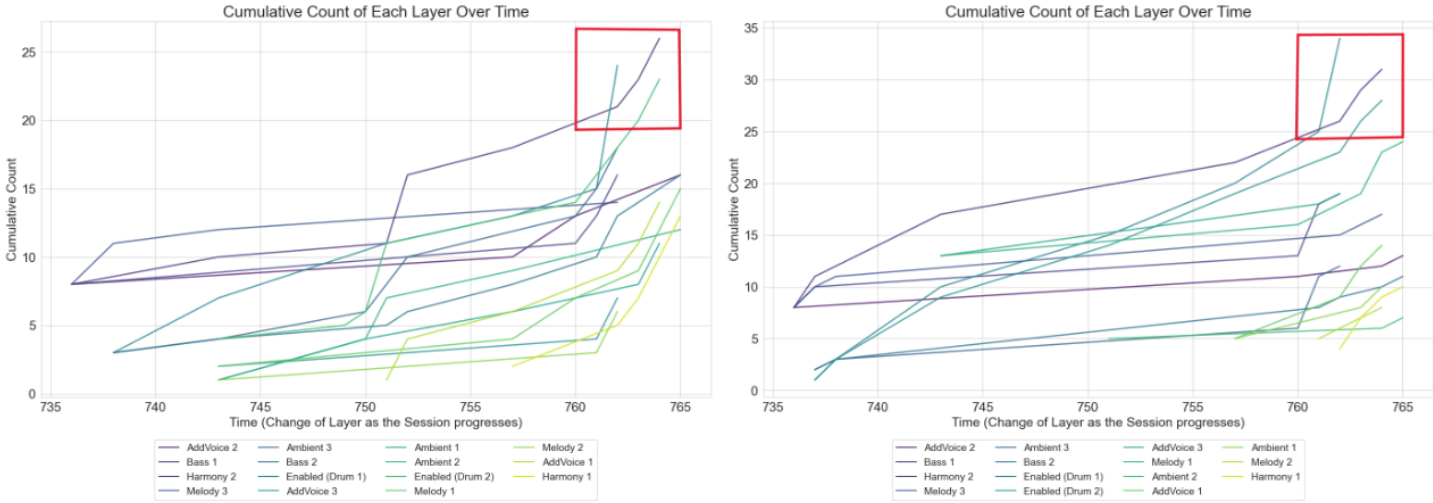


Figure 8: Cumulative Interaction for Songs across Participants: "Wheels on the Bus" had the highest average interactions at 41.83, with the greatest variability, while "Row, Row, Row Your Boat" exhibited the lowest average interactions at 32.33, with the most consistent engagement across participants.

Results: Responses to the Prompts

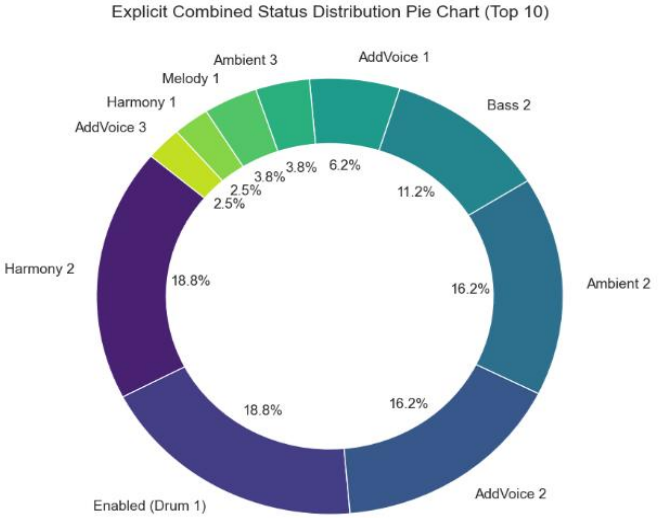


(a) Modifications to "Twinkle, Twinkle"

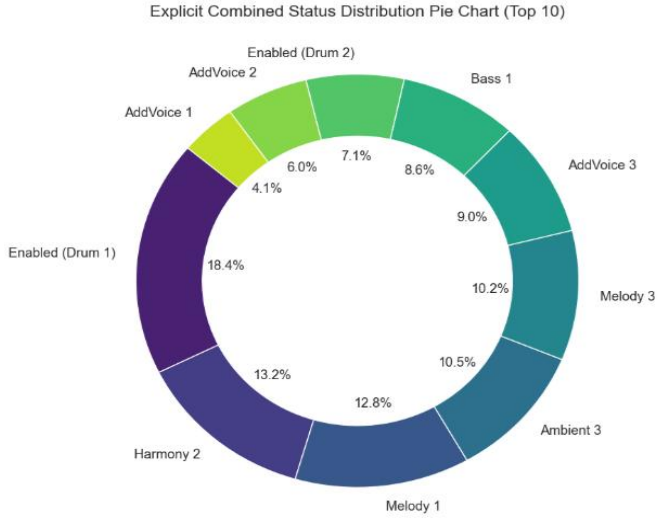
(b) Modifications to "Row, Row, Row Your Boat"

Figure 10: Time to Layer Plot The use of three layers, *Bass 1*, *Drum 1*, and *Drum 2*, keeps steadily increasing throughout the remainder of the session, highlighting the increase in energy levels towards the end.

Results: Individual Preferences



(a) *C3*'s Version of "Ants go Marching"



(b) *C5*'s version of "Ants go Marching"

Figure 11: Composition of "Ants go Marching" by two participants: C3 exhibited a preference for soft and soothing layers in their compositions. They particularly favored harmony layers, complemented by additional sound elements such as ambient noises. On the other hand, C5 leaned towards selections with upbeat layers and swift tempos. They particularly favored base layers, complemented by additional sound elements such as drums. These choices noticeably elevated the room's energy level. The contrasting preferences underscore the diverse musical inclinations of the two participants.

Results: Reactions and Engagement

	Actions/Sessions	C1	C2	C3	C4	C5	C6	C7	Total Count
★	Enthusiastically React to Music	✓	✗	✓	✗	✓	✓	✓	5/7 (71.4%)
★	Stop Button Pressing for Preferred Sounds	✓	✓	✗	✗	✓	✓	✓	5/7 (71.4%)
	Smile at Preferred Sound Combinations	✓	✗	✗	✗	✓	✓	✓	4/7 (57.14%)
	Engage with Prompts	✓	✓	✓	✗	✓	✓	✓	6/7 (85.71%)
★	Exhibit Relaxation	✓	✗	✓	✗	✓	✓	✓	5/7 (71.4%)
☆	Exhibit Energy	✓	✓	✓	✗	✓	✓	✓	6/7 (85.71%)
★	Noticeable Mood Change	✓	✓	✓	✓	✓	✓	✓	7/7 (100%)
★	Hum or Sing Along	✗	✗	✓	✗	✓	✓	✓	4/7 (57.14%)
	Interact with PECS Card	✗	✗	✗	✗	✓	✓	✓	3/7 (42.85%)
★	Dance, Rock, or Tap Along	✓	✗	✓	✗	✓	✓	✓	5/7 (71.4%)
	Total Count	8/10 (80%)	4/10 (40%)	7/10 (70%)	1/10 (10%)	10/10 (100%)	10/10 (100%)	10/10 (100%)	

Results: Parents Perception

My child was excited to explore the device and try different sounds, they smiled and laughed while using the device but also got frustrated when a song stopped abruptly

...liked changing colors and playing with the buttons. It showed they were genuinely engaged and curious. The rhythmic beats seemed to stimulate their movements and energy levels

These moments of decision-making provided insights into how children could exercise autonomy within the uCue framework.

Contributions

- Empirical evidence suggesting **uCue's potential to supports children with ASD** in accessing formative music experiences
- uCue's **logs** were able to gather **valuable interaction data** and provide insights about global musical preferences.
- The design of **a modular music template** and prototype music library

Future Work

- ***Expand Access:*** Develop web-based interfaces to reach children beyond local communities.
- ***Composer-Guided Insights:*** Leverage interaction data to help composers identify effective musical patterns and structure more engaging, personalized compositions.
- ***Refine Activities:*** Broaden uCue-supported tasks for diverse learning goals in music therapy.

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Questions?

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