Active Listening: Encouraging Sound Awareness Through Tangible Sonic Toys

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ABSTRACT

This paper explores how sound-based tangible toys can encourage children to engage with sounds in their environment through active listening and collaboration with their peers. Twenty-eight children, aged 3 to 4.5 years old, explored sound in their environment through three toy prototypes. One toy focused on hearing sounds in the distance in relation to their environment; such as traffic, trains, and children playing. Another toy explored the recording and playback of their own sounds, being "caught" in a racket and blown out. The third toy explored a combination of shaking in sounds, stirring them to manipulate them, and pouring the mix out. Children were able to grasp the sonic and tangible metaphors of the toys and engage with them with their peers. Though they did not fully recognize the connection to sounds in different directions of their environment, children overall were more attentive to the sounds around them after the study, comprehending and engaging with both the natural and fabricated acoustic ecology.

CCS CONCEPTS

• **Human-centered computing → Sound-based input / output**.

KEYWORDS

Tangibles, Sound, Children, Active Listening

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1 INTRODUCTION

Sound is an important design feature in toys. We often see toys that include ambient sounds, background music, or directly triggered sounds through buttons. We also see many toys designed as electronic or acoustic instruments such as pianos, guitars, and drums. Yet, we rarely see toys that are specifically designed to encourage a child to actively listen to environmental sounds in different ways, outside of musical training. This paper explores children's experience of sound through the lens of active listening. We use the term active listening to mean 'listening with attention' to details within the sound, or in how sounds in the environment relate and contribute to the overall sound [20].

Children are, to an extent, naturally active listeners. Their active listening skills are engaged in playing games with their parents that involve mimicking funny sounds around them, making up new sounds, singing together, exploring their agency as they create and control sounds and other sound oriented activities. The child's ability to actively listen contributes to their understanding of their environment, as feedback from actions in their environment, an ambient background, or as a playful exploration of interaction and affordance [12]. This is because sound provides us with essential survival skills such as learning to acknowledge changes in our environment that could be consequential to us [15].

As they develop, a child learns essential skills like separating and identifying sounds to develop and improve their listening abilities. Such ability directly aligns with their perception of the affordances of sounds as information within their world. Active listening is developed through play to locate sounds, associate sounds with an object's physical attributes such as size, weight, and material and recognize the association between changes in parameters such as distance through changes in the sound. So just as physical play is part of our development in balance and coordination, sound play is an integral part of our sensorial and cultural development that serves our understanding of our environment [3]. R. Murray Schafer, while promoting the term "acoustic ecology", passionately discussed the deterioration of listening skills in children in the 1960's, and devised a set of exercises to develop "sonological competence" aimed at Canada's national curriculum.

We align ourselves with Schafer's belief of the importance of listening as inspiration to design sound-based toys [25]. We have designed three prototypes to observe how toys may support the child's process of exploring/learning the relationship between sounds and their personal agency, their experience of their environment, and their relationships to people around them. Toys and the affordances they provide for exploring sound are the child's toolkit for learning to perceive the world and expanding their reach in the world.

We are interested in bridging children's playful learning processes of listening to and engaging with sounds. We explore this through toys designed to highlight or isolate sounds from that environment. Our current work frames this interest by asking two questions: 1) Can we encourage young children's awareness of sounds in their environment? 2) Can we encourage the sharing of their experience with peers and teachers? This paper presents our design process, a mixed-methods evaluation of 3 toy prototypes, and outlines our future work.

2 THEORETICAL BACKGROUND

There is a vast amount of research on vision, motor control, and cognitive development on young children in the literature, yet information on how children engage with sound in their environment is more limited [6]. Sound seems to be approached as a tool for developmental research as it supports the connections between an infant and their parents [18] [24]. Piaget discusses sound as a mode of imitation to establish a base knowledge for infant's communication, with the discovery of new sounds assimilating into their current world view [17]. Such research supports the notion that a large part of a child's development is learning to parse sounds and actively listen to sound similarities made by themselves and others.

When looking at playful and social experiences with sound, music is often used as the platform for the experience. There are many forms of musical education for children to develop their listening skills and musical agency. By learning to hear different instruments in a piece of music, a child can develop an understanding of sound structures and how the child can contribute to the structure through their voice or instrument [23]. In this way, music provides a controlled environment for learning to separate sounds and its parameters and recognize one's own place in a sonic environment. For example, as a child learns more about sound they can break music down into identifiable components and qualities such as "high and low, fast and slow, stop (rests) and go (notes) [to] foster in toddlers the awareness of musical dynamics" [23]. Music also facilitates identifying 'my sound' and 'your sound'. These comprise one set of rudiments of critical listening and languaging that underpin analysis and discussion/sharing of their experience. They are also the start of learning cultural metaphors around sound. Listening skills include the ability to separate as well as combine sounds, developing skills of locating sound spatially as well as associating sounds with environmental or physical attributes such as distance, weight, material, and size [9]. Although these skills are often developed through music, the development of these skills in the natural environment can support a child's engagement in their sound environment [11] [25]. We are interested in how to consider sound as an active experience, and how tangible design can bridge active listening skills to create playful and social experiences.

Sound Metaphors

Metaphors and cultural associations are widely used when discussing sound. Children learn such cultural assumptions as HAPPY IS UP, SAD IS DOWN and will apply these in their exploratory play with new toys and environments [2]. Lakoff and Johnson refer to these associations as orientational metaphors [13]. Orientational metaphors are based on spatial orientations, such as up-down, in-out, front-back, on-off, deep-shallow, near-far, and then applied to more abstract concepts such as emotion or parameters of sound, such as LOUD is HIGH. In a related vein, ontological metaphors are based on our interaction with physical objects and our bodies. For example, BASS MUSIC is HEAVY, or LOUD SOUNDS GET IN THE WAY [4]. In these ways, children learn language metaphors which support and guide their understanding and experiences with sound.

These associations were explored in depth by Antle et al. when exploring interactions with sound. The SoundMaker system enables children to manipulate musical sound parameters of volume, tempo, and pitch through body movement [2][4]. Two different mappings were created between the movement and the sound: an embodied metaphor context and a non-metaphor context. The embodied version uses knowledge built into a children's intuitive understanding of the world, where the other version could be learned but was not built on existing intuitive knowledge. Findings showed that children were more accurate when using the interface with the embodied metaphor mapping compared to children using the non-metaphor mapping. Although this work focused on older children in a task to control sound, it does present an interesting exploration of children actively listening to a sound in order to assess their agency in controlling it. We are interested in considering other less direct forms of interaction between the child and their sonic environment, while maintaining an intuitive gesture for the interaction.

Agency and Affordances of Sound

One aspect of a child's interaction with sound through toys is the impact (or agency) the sound affords them in their

environment. We look to affordances of sound, as the methods of interaction that are offered by a sound, to explore opportunities for toy design [10][14] and in earlier studies we have categorized three levels of sonic affordance [8]. First, a simple button or trigger such as can be found on the side of a truck suggests being pushed, and from the child's experience, they may expect a sound to be triggered. This example highlights how affordances built into a toy's design through shape, color, texture and other qualities may suggest a use including the triggering, recording, and manipulation of sound [12]. At this level, the toy affords the engagement with sound as the handle affords the engagement with the door. The sound component is a part of the toy that is activated as any other physical part of the toy. A second level in considering sonic affordance is what the making of the sound affords. Just as the door handle affords the opening of the door by pushing the noisy toy can afford the child new agency in their environment such as the gaining of attention by repeated triggering or nuanced playing. Any object that can produce noise, or amplify their voice can be used as a toy and can help the affordance of getting attention. These affordances may not be purposefully designed into a device such as a fork or a cup but are discovered by a child through their use and the response of those around them. These first two do focus on the sound as a controlled object either as part of the toy or as part of the child's voice in the world.

The third level of affordance when considering sound focuses on the sound as it is listened to, as feedback. Gibson discusses the notion of active and passive touch. For Gibson, this is the difference between touching an object as a way to feel it and gain information or too touch as a byproduct of holding [10]. We may infer a sonic equivalent in the experience of actively attending/ listening to a sound vs. passively letting sounds fade into the background [11]. Through their experience and play the child learns that some sounds when listened to provide information about their environment, other provide a pleasant background and still, others can be ignored [6]. The sound of a pet running in a different room may entice the child to go and see what is happening, while a car passing outside is ignored. In the context of toys, a sound that is part of the toy mechanism may attract attention at first, but latter is ignored as a passive noise of little importance. This parsing of sounds in the environment is part of the child's development and experience [3]. We are most interested in this third level, to design toys that will encourage critical and selective listening that can be shared with others.

3 RELATED WORK: DESIGNING DIGITAL SOUND TOYS FOR CHILDREN

Some projects do involve active listening and social engagement through sound. One such project, Our Little Orchestra by Browall and Linquist, explores how children collaborate with sound in technology in ways that would not be screen, panel, or mouse-based [7]. They created a sound mixer in the shape of a birthday cake using the metaphor of round shapes to support togetherness. A similar work that is more recent is the Blipblox Audio Exploration Module, a kid's synthesizer for encouraging play with electronic music. Features include a low pass filter, eight oscillator modulation schemes, two envelope generators, MIDI, two Low-Frequency Oscillator, to name a few [1]. These projects encourage listening to compare sounds and assess how different parts (of the mix or of the synthesized sound) are working together. MusicPets is another toy for children that designs plush toys to store audio in a DJ-like scenario [22]. Plush toys have a slider to change pitch, and three buttons for recording, creating pauses and inserting chords. The duration of the sound created is visualized through an LED strip. Again these projects are quite music oriented, but the addition of recording does provide the opportunity for exploring sounds in the child's everyday environment.

There are a few projects that have explored sound play in toy and tangible design that focus more on sound experience rather than music. TouchSound is a bracelet that generates sounds when the wearer touches other objects and can control the pitch, volume, and tempo [16]. BuildaSound is comprised of 25 large foam blocks with images on them that can be configured, smashed, thrown and played within any way and will compose sounds through computer vision of the block organization [19]. The Moving Sounds project explored tangible prototype design concerning how children understood metaphors of sound relating to pitch, volume, and tempo [5]. They found that while children can understand multiple metaphorical mappings, they did not find any advantages to using multiple different metaphorical mappings (such as pulling, stick, and rotation) over a single mapping (such as rotation). These projects explore the isolation of sound as both a playful medium to engage with as well as using sound to understand one's perception of their environment.

4 TOY DESIGN PROCESS

Observed Child Behaviors

We began this project by observing three young children, ages 2.5 to 4 years old, playing with a variety of toys over a six month period. Toys were both traditional and digital, and we noted the elements of agency, affordance, and interaction that were explored in both motor and sound actions [8]. We found that children's behavior with their toys are more about experience and exploratory use. They engage and explore with toys as just another part of their world [21]. We saw cases of pure interest in agency, as well as explorations to

create new and unusual noises. Children then figured out that they could use this control over new noises as a way to get attention from others, and then explore play in new ways. Such actions suggest that the child experiences sound both as a part of a physical object, as an element in their environment, and as a tool they can use to their advantage.

Implemented Design Choices

Based on the literature and our findings from the preliminary observational study, we developed three prototypes of sound-based toys: a Sonascope, Butterfly Racket, and Mixing Pitcher. We observed that children tend to engage with sounds as a part of their agency on their environments. Our prototypes focused on provoking a young child's engagement with sound by encouraging them to consider sounds around them as a tangible object to explore and share with their peers. For this reason, we designed toys to be interactive, to have a leveraged engagement from other commonly existing toys, and required motor engagement beyond pushing a button.

The build of each toy used consumer-level Bluetooth speakers with microphones embedded into the toy as the onboard audio system. This base system for each toy was networked to a laptop running Max/MSP, designed to provide a range of interactions for the particular toy. These interactions included playing, recording, and manipulating sounds. The design ensured that the sound emanated from the toy object and appeared to be recorded in the moment, but actually placed the heavy audio processing on the laptop for easier development. The design allowed the toys to be remotely controlled by the authors, for a "wizard-of-oz" experience, that simulated the experience of interaction with sound for the participant.

Sonascope

The Sonascope is a short, straight tube inspired by a telescope, which incorporates the metaphor of isolating a sound and bringing it 'closer'. The toy was designed to be pointed in a different direction or at different objects to hear sounds of that particular environment/object. The interaction is analogous to a parabolic microphone; however, our 'wizard-of-oz' design avoids the limitations and inherent noise of an actual mic while affording us new abilities such as being able to point at objects through windows or beyond the child's sight, but still in their environmental awareness (eg. a playground at the end of the street). As a simple implementation of this concept, we used a hollow foam tube as the shape that was simple, with a variety of gestural affordances (including, but not limited to, pointing towards sound). The tube had the Bluetooth speaker embedded inside, with the speaker most accessible on one end of the hollow tube, and held in place with athletic tape which also provided a second bright color and an implied hand position. The Sonascope played pre-recorded sounds of the immediate sonic environment of the study. Individual sounds were played back depending on the direction in which it was pointed (see Figure 1). The motivation behind this toy was not only the concept of hearing and parsing different elements in a complex environment, but also encouraging children to consider sound objects as existing, even when they cannot hear them.

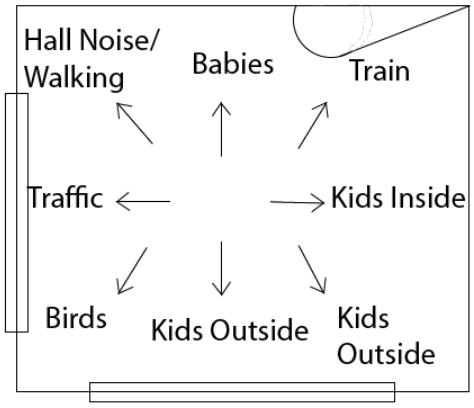

Figure 1: Sonascope Mappings

Butterfly Racket

This toy uses a badminton racket as the basis for a sonic butterfly net to catch and release sounds. Playful actions to engage with sound include waving the racket to "catch" a sound, and then blowing on it to "release" the sound. These actions leverage the metaphors of common toys such as "butterfly nets" and "bubble wands." We chose these actions to support a novel way that a young child might try to catch and remove something very light from a net. When the child waves the racket, the microphone records the nearest sounds. When the child blows on the racket, the recorded sound played back through the speaker. The microphone component was embedded at the base of the racket where it connected to the handle, and the speaker was embedded in the end of the handle. We used the racket without the strings or a net to encourage experimentation and play. The motivation for this toy is a way to "capture" sounds as though they are butterflies and to share them as they would bubbles, or provide closer examination as they would a butterfly, thus encouraging the sharing of their experience of sounds in their environment.

Mixing Pitcher

This toy is made from a typical mixing pitcher for holding liquids, and is used by speaking into the pitcher (recording sound) or "shaking in" sounds. These shakers produced a shaking sound while triggering a sound to be recorded. Once

a sound is "added" in the pitcher it may be stirred to change the tempo (fast or slow). The child may then decide to add another sound or hear the mix by pouring out the sound. Even after pouring out sound, more sounds can be added or the pitcher dumped and the process can start again. The microphone and speaker were embedded in the bottom of the pitcher to encourage the engagement with the inside of the pitcher. We chose these actions in order to play with the combination of vocal sounds of the children and pre-recorded environmental sounds, and to engage with the motor actions of filling, stirring, and pouring. The motivation for this toy is to map the existing actions of water in a pitcher to a way of listening to one's environment and allow the child to explore building up a complex sonic environment on their own. We wanted to play with sound in a way that would be fun and a bit silly while using actions that would relate to real-world metaphors of mixing-up, and putting objects in and out.

Figure 2: Racket, Pitcher, and Sonascope Toy Design

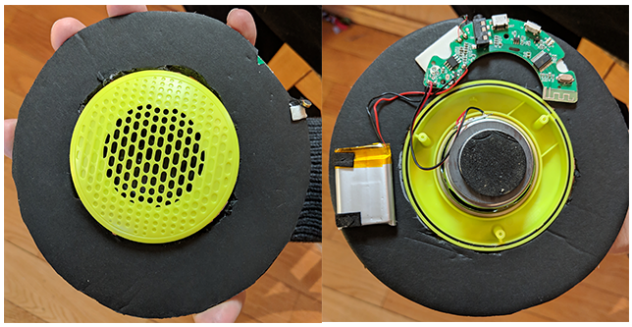

Figure 3: Pitcher Electronics

5 STUDY DESIGN

Pilot Study

We performed an exploratory pilot study with three children aged 2.5-4 years old in order to test the engagement with early prototypes of the toys. The toys included the Sonascope, the Butterfly Racket, and an Accordion for sucking up, shaking up, and squeezing out sounds. One male was four years old (S), one male was 2.5 years old (F), and the one female was also 2.5 years old (T). Toys were played with one at a time, by a child on their own and then in interaction with a parent or sibling. The oldest child was very engaged with the toys for extended periods of time and saw the metaphor and relational mappings between the physical actions and the sounds they made. However, both the younger 2.5-year-old participants had a harder time focusing on the toys for long and were more interested in the silly sounds that could be made by a quick physical action, than any real metaphoric mapping to existing physical action. We found that the Sonascope and Butterfly Racket had many successful interactions around recognizing sound and sharing it, and understanding the metaphors of gesture in the design. However, the Accordion toy was less successful. For this reason we replaced this toy in the larger study with a newly design toy Mixing Pitcher that would still address the idea of collecting and mixing sounds from the environment, but would have a more understandable interaction. A second change in moving to the larger study was the number of children playing with the toys at one time. The sharing aspect of the toys was also more of a success than we were expecting, so we designed the large study to explore more peer to peer interactions.

Full Study

In order to investigate the potential benefits and limitations of encouraging active listening in children through sound-based toys, we designed the full study to address the following objectives:

(1) How were sounds recognized? (As the actual sound it is, as a physical object, or as sound from an object in the environment?)
(2) How were the sounds associated with gestures? (Were the designed physical or spatial metaphors recognized? Were new affordances or interactions explored?)
(3) How were the sounds shared? (Solo play, small group, or large group play)

Participants

The first session had 12 participants aged 3-4 years old. Eight children were male and four were female. The second session had 16 participants aged 4-5 years old. Seven children were male and nine were female. In total we had 28 participants, 15 were male and 13 were female (54 percent male, 46 percent female). No previous music or motor activity experience was required. Consent forms were required for the child's participation, a minor's assent script was used, and children were repeatedly reminded that they did not need to participate or

could stop at any time. One child in the facility did not participate, and there was consistently a group of 2-4 children that engaged in a separate activity during the study (though each child eventually engaged with the toys). These children appeared to be the more shy ones of the group, and usually had longer solo interactions with the toys when compared to more rambunctious children that had shorter but many repeated interactions with the toys.

Figure 4: Racket, Pitcher, and Sonascope Toys in Action

Protocol

The authors performed the study as an open play session at a daycare facility in two separate classrooms. The protocol of the study was the same in each session, introducing a focus on sound to the children as a group by talking about what the children could hear in the present moment, and what they could remember hearing that morning. One toy was presented at a time until all three toys had been explored, after which we had a class debrief to talk about the experience. The Sonascope was presented first to bridge attention to the environment, then the butterfly racket was presented to give the child agency with their voice, and finally the mixing pitcher was presented to give options for layering in and mixing multiple sounds. Since we were observing interactions with the toys and not the comparison of the toys, and had a plan for how the order of the toys primed the children's hearing, we did not change the order of the toy presentation.

When a toy was first presented the children were allowed to explore without explanation. Then the researchers would prompt the child with a suggestion of what action they could try with the toy. Sometimes the researcher would show the child if they seemed confused or unsure. The child would play with the toy while engaging their peers, their teachers, and the researchers until they lost interest. At this point, a new toy was brought out to follow the same protocol until all three toys had been explored.

Open questions were used throughout the session to help the participants articulate what they were exploring, to ask them what they would do next, or what they wished the toy would do next. The data was then qualitatively analyzed through an open coding of gestures, actions, and verbalizations of the participants in interaction with the toys, their peers, and the other researchers. Through the qualitative data we discovered much about what gestures the children used to engage with sounds, how they were shared, and what metaphors of sound in toys were recognized by children. While video recording was not allowed by the daycare facility, the researchers timed the interactions with the toys as much as possible in the classroom environment. These interactions are compared between toys to better understand what types of shared engagement emerged, and how their engagement with the toys varied from expected/typical to exploratory/creative. These terms relate to actions the researchers expected when designing and actions that were less expected.

Pre vs Post Session Briefing

We began and ended the session by asking the children what kinds of sounds they could hear in the moment, and then what sounds they remembered hearing that day. We also asked what sounds the children liked. The children's responses were collected and are discussed in the qualitative analysis section. In general it was found the students were more in-tune with the sounds in their environment after the session.

Findings: Quantitative Results

We timed the length of play that children were engaged in each interaction, initially to provide the length of focus that each child had when they played with each toy (see Table 1). We also timed the length of time that the toy was available based on the interest level of the class (see Table 2). We found that on average, the length of interaction time was dependent on the size of group that was engaging. Children tended to interact in three different ways: solo with the toy, in small groups (2-4 children), or in large groups (8+ children). Although these types of interactions are not surprising in the context of a daycare, it was reassuring that the toys were engaging in all three of these play situations.

Because of the classroom environment, there were many instances of large-group interactions (see Table 3). In these interactions with the toys, many children had very short, direct interactions with the toy but passed it around or shared

Table 1: Total Time of Engaged Play with Sound Toys

Toy	Total Time in Session 1	Total Time in Session 2
Sonascope	20 min	18 min
Racket	17 min	21 min
Pitcher	23 min	18 min

Table 2: Average Time of Engaged Interactions with Sound Toys

Toy	Solo	Small Group	Large Group
Sonascope	1.5-2 min	3-5 sec	3-5 sec
Racket	1.5-2 min	3-5 sec	2-4 sec
Pitcher	30 sec-1.5 min	3-4 min	4-6 min

Table 3: Average Instances of Engaged Interactions with Sound Toys

Toy	Solo	Small Group	Large Group
Sonascope	1-2	20+	20+
Racket	1-2	20+	20+
Pitcher	5+	5+	5+

their sound with others. This process resulted in the average time each child spent with the toy as 2-3 seconds to listen to or speak into the toy, listen to its playback, and share it with another. The sharing repeatedly around the group meant the interactions could go on for up to 10 minutes of constant, short, interactions with 8+ children simultaneously. In this group situation it was observed that the gestural exploration stayed similar between each child (see qualitative data for more information) resulting in a very unified style of interaction with the toy. Small-group interactions happened between 2-4 children, where the interactions (of the one child) were about the same length of time as the large group (2-3 seconds) as the children repeatedly shared the toy. However, these groups were less stable. Individual children would join and leave the group while the overall number stayed the same. Still a small group would exist in some form 2-4 min and during this time morph the style of interaction to more creative forms (see qualitative data for more information). This means that children explored more alternative ways to engage with the toys, and did not repeat gestures as much. Solo interactions happened when a single child got the toy, and had a longer time to explore it without interruptions from others. These interactions could have the individual child engaging with the toy for minutes on their own. The mixing pitcher was a bit different, in that there were fewer and shorter solo interactions, and fewer and much longer small and large group interactions. The gestural exploration was quite similar between children, but they engaged much more as a group.

Findings: Qualitative Observations and Results

Pre vs. Post Session Briefing. Each session began and ended with a brief discussion of what sounds the students had heard or were hearing around them; either on their way to school or in the moment. Before the session some children mentioned hearing or remembering sounds of traffic, booms and bangs, wind, or annoyed parents. After the session several children mentioned hearing (in that moment) the sounds of kids playing next door, the fan in the bathroom, chairs moving, traffic outside, keys on the computer taking notes, and other more subtle sounds in the environment. These responses suggest that the sessions did encourage listening and an awareness of sound in the environment. It should be noted that the children in the study were too young for writing, so verbal responses were used. However, the researchers acknowledge issues such as peer pressure in such questioning.

After the sessions the children were also asked about sounds they remembered from the toys, including their favorite sounds or interactions. The top sounds that children mentioned included their own voice, the people and traffic outside, and the funny animal sounds (some which did not actually exist in the toys, such as werewolves and whales). When asked about the interactions and the ways they played with the sound, all the interactions had at least some children mentioning it as a favorite. In both sessions all children raised their hand when asked if playing with sound was fun, and again when asked if they wanted to listen to their environment more. Though this response can only minimally be seen as a reflection on the toys themselves, since the situation was setup by the teachers as a special fun activity, it does suggest that the children enjoyed having playful interactions with sound, regardless of how well they understood our objectives.

Themes based on observations. Three themes emerge from the analyzed data, which reflect the focus of the research objectives: actions, sharing, and sound recognition. The action themes come from observing the actions the children performed with the toy. The theme of sharing arose from observations of the children sharing their experience with the toy. The theme of sound recognition reflects the student indicating a recognition and or association with the sound. We will present how each of these themes were observed in children's interaction with each toy then discuss the full analysis of the themes in relation to the full study.

Themes reflected in the Sonascope. The Sonascope was designed as a straight stick, to be pointed in different directions to simulate the experience of hearing the distant sounds in those directions. However, the actions observed varied widely from this original design. When in large groups the gestures were more typical and would be repeated by many

children (such as yelling "hello" into the speaker while taking turns, and doing this over and over for up to 8 minutes). However, in the smaller groups the gestures varied more and there was less repetition between children (such as one child looking through the end, and the next child showing a sound to a teacher). Actions made with the pointer include those indicative of it as a toy, such as squishing the middle of the pointer and looking into it like a telescope. Actions indicative of it as a toy making sound included: dropping it when it first made sound (out of surprise), laughing at the 'funny' sounds, or yelling into it to engage with the sound. More importantly were sharing and social interactions such as: two children putting ears on either end, holding the speaker end towards a friend, or passing the device around.

The sharing that children exhibited with the Sonascope surpassed the original design. Sharing included children trying to listen simultaneously (such as one on either end), passing it around a group with turn taking, holding it for others to hear, showing it to teachers for them to hear, or pushing the toy against the glass to the other room for them to hear. These actions indicate that children were inspired by their interaction with the toy to share their experience with the sounds it was creating.

We also observed indicators that sound recognition was an active part of the child's engagement with the Sonascope. These include children yelling out what sounds they hear, noting "its a listening toy!", or defining the sounds they experienced (which was different from what the sounds actually were) such as lions, elephants, and dogs. Children were surprised at the change of the sound, though did not seem to comprehend how or why the sounds changed. Some children yelled into the device to make the sound (such as birds) go away, but they did not do this for mechanical sounds (such as cars). Still, even when the researcher explained that they were listening to the sounds that are far away; such as the street, the playground outside, the train tracks, the infant room, or grownups in the hallway, the children did not connect the sound to the spatial location/ mapping. For example, the children consistently could not make the connection between the sound and the place even though they recognized most of the sounds as what they were. These findings are different from the three children in the pilot study who, when working with the toys on their own, could comprehend the spatial locations. This suggests that the social setting created a smaller focus on the object itself and less on the environmental metaphors, but that in a one-on-one interaction could potentially be bridged.

Themes reflected in the Butterfly Racket. The Butterfly Racket was designed with a small badminton racket that had a mic where the handle and the racket met, and the speaker at the base of the handle. The racket was designed to be swooped to catch and record the sound, and blown in to play the sound back. The actions observed reflected the original design, but included new interactions as well. The new actions included blowing into the speaker, shaking the racket, holding the speaker to their ears, and putting their heads through the racket (catching their friend). Similar to the Sonascope, when in large groups the gestures were more typical and would be repeated by many children (such as blowing into the mic while taking turns, and doing this over and over for up to 6 minutes). However, in the smaller groups the gestures varied more and there was less repetition between children (such as one child telling secrets, and passing it to another child to listen).

Though the students had been told to share the toys, the children were observed engaging in sharing beyond the simple mandated sharing. Observed sharing did include taking many repeated but very short turns, which would be expected when told to share. Through the course of the session the sharing acts that were observed seemed to go beyond the mandated turn taking. Sharing developed into intentional acts of including friends, such as: showing the sounds to others, one listening simultaneously while another was singing, and one telling secrets to the racket (while their head was in the racket) and then giving it to another child.

Observations of sound recognition with the Butterfly Racket included repeatedly yelling hello, or making funny noises into the mic and telling others "that's me!". The children also started playing with how they made sounds, such as yelling with a Doppler effect (where the sound travels further away). They recognized that it was their sounds, particularly when telling the racket "secrets" meant for their friends. The children showed less surprise at hearing and recognizing the noises made by the racket then the Sonascope, probably because they recognized their voice and the priming of sound as an object of play. However, the children got excited to make funny sounds that they could use to surprise their friends. The childrenâĂŹs actions suggest that the sound from the racket toy was more predictable, creating more agency with it (which is evident through the sound capture, which the Sonascope does not have). Children's actions suggest that the sound from the racket toy was more predictable, but that they had more agency with it (which is obvious through the sound capture, which the Sonascope does not have).

Themes reflected in the Mixing Pitcher. The Mixing Pitcher was designed with a mic and speaker in the bottom of a pitcher, with paper tube shakers made with beans and a paper tube stir stick. Sounds could be recorded and "added" into it, stirred, and the mix could be poured out. As with the other toys, the actions observed included and exceeded those of the original design. For example, children tried listening to

the stir stick, stirring, shared stirring (up to 10 kids simultaneously), adding sounds with shakers, just shaking shakers, pouring it all out, asking to put more sounds in, putting the pitcher on their head, and putting other toys into the pitcher. When in large groups the gestures were attempted simultaneously by many students (such as the group of 10 children holding the stir stick and stirring for 3 minutes). In the smaller groups the gestures varied more and there was less repetition between children (one child was dropping toys in, another put the pitcher on their head, another was whispering in, all while taking turns for 5 minutes).

Based on the large variety of actions afforded by this toy, sharing was taken to a new level. As with the other toys, sharing involved taking turns, but also included working together to stir, holding the pitcher for others to hear, and asking a friend to add more sounds.

Sound recognition included noticing when there were a lot vs. a little sound, needing to add more sound, or to pour it out to hear all of it ("That is all the sounds!"), whispering into the pitcher, singing into the pitcher, listening just to the shakers, identifying the actual sounds (i.e. crickets: "I like that sound!"), dogs, water, and noting their experience of the sounds ("its a whale!", "that sounds like a werewolf!"). Children were surprised at some of the animal sounds, the sound of all the tracks being layered on the pouring out, and that the stir stick did not have any sound.

Discussion of Themes and Observations

Levels of Active Listening and Recognition. One objective of the study was to explore how toys may encourage active listening of children, to recognize and engage with their sound environment. Yet we have purposely not set a threshold of when active listening occurs: instead we contend that as a developed skill it is present at varying levels. The observations show that all the children did engage with the toys as "listening" or generally sound based toys. We see this in *Self* as the child acknowledging the sound as an object to play with, as opposed to ignoring sound while playing with other attributes of the toy. This basic level of recognition was reached by all the toys.

Similarly with *Friends*, when the children played with toys that incorporated a mic, the children were observed recognizing the sounds of their voice, the voice of friends and other sounds they recorded easily into the device. This shows active listening to the extent that they identified their own or friend's voice or sound actions.

The next level of active listening is the identifying of *Environmental* sounds that are part of the engagement with the Sonascope and shakers for the Mixing Pitcher. At this level children at times misidentified sounds. It is interesting that the misidentifying did not hamper their engagement in the toy and that they were trying to identify sounds that were difficult. Still the misidentification may have contributed to the observed inability or lack of interest in recognizing the sounds as part of a whole environment. Though the students talked about individual sounds as they added them, they did not show interest in the mixture as an environment but more as simply something they had done. This seems to suggest that they were more interested in single sounds then complex environments, the first levels of active listening. Students did seem to enjoy the sounds made by the Sonascope (as *Other sounds*, but even when prompted, did not make the connection to sounds in their environment. Their recognition (and misidentification) of sounds when using the Sonascope suggests a focus on the individual sounds over the association of the sound with objects or spaces in their environment. The children were engaging with sounds of their immediate environment and those of themselves or friends. However, sounds from more distant objects in the school environment were fun but less anchored in the immediate environment.

While the children did not fully engage with the sounds in their environment such as listening to the traffic in the street or the train that was nearby, they were actively listening to themselves, their friends, and the prerecorded sounds. The children were more attentive to what they could hear in their environment after the session, so to make them more aware of their ecology there would need to be some priming to listen.

Sharing Sound and Social Interaction. Even though the researchers were interested in how the child would share their experience with the sounds from each toy, the toys themselves were not designed directly as sharing devices. Yet, the children all easily shared their experience and often their sounds through the objects, by taking turns or passing them back and forth. There were situations where all the students tried to share the sounds synchronously (i.e. all children stirring at once, or all yelling into the Racket at the same time), or use the toys asynchronously (i.e. to transfer a sound "secret" between friends).

Surprise was another strong component to the social interaction. At a simple level, children often showed surprise that a toy made sound, that they could identify themselves or another's voice, or that they could identify an unexpected sound. At another level, the toys were often used in an attempt to surprise their friends, and prompted them to explore a variety of funny sounds. When children were playing with a toy on their own they often brought it to a teacher or researcher to share, but also spent time alone engaging with the sounds. Such observations support the idea that environmental sound toys (not just musical) can be designed to encourage individual and social experiencing of sounds.

Gestural Affordances and Metaphor. Children were very engaged with the concept that sound could be manipulated

like an object, either while they recorded it or when mixing. Each toy was designed around a set of gestures metaphorically linked to an interaction with sound as a physical object. However, children did not hold to the metaphor as much as they responded to the affordances of the toy. For example, when using the Sonascope, the children invented their own (unprompted) interactions based on the affordances of the tube: listening on both ends simultaneously, looking into it, attempting to squish the center. These were all actions which focused on listening to and sharing sound experiences but ignored the affordance and design metaphor of pointing to sounds in a extended sonic environment and favored the social affordance for sharing. Similarly with the Butterfly Racket, the affordance of passing sounds overshadowed the affordance metaphor of catching sounds on their environment. The Mixing Pitcher's affordances were quickly comprehended, based on the understanding that vessels contain something. It is interesting to note that even with this toy the children pushed the social affordances such as working together to stir while adding sounds. Overall, in the very social environment of the daycare classroom it seems that the children focused on the affordances that supported social interaction and sharing. In should be noted that this is different from the observations in the pilot study done in home situations where the social interactions, though still present, were more balanced with the designed metaphors (more attentive based interactions).

Benefits and Limitations. This study used toy designs and metaphors that were iterated from prior studies. We were able to see the strengths of each toy in group settings, though saw fewer individual interactions than we would have in a more controlled setting. For this stage of the project we believe the group data to be more valuable, and will continue to work on how toy designs can be engaging as individual toys as well. There also was less interest by the children in the full study with how the toy worked. In the pilot study the first thing the child did was figure out where the speaker is and how to turn the toy on and off. In the full study only one of the toys were turned off (by accident), and there was very little interest in "how it works", though where the speaker was located became important to hear the sound in the loud classroom.

Future Design Considerations. Many children were not able to correctly identify sounds but were still engaged with what they thought they heard. It should be noted that though the sound files used were of CD quality, several of the recordings were complex field recordings and that the quality of the speaker in the toy was not ideal. These elements could have contributed to the misidentification of the sounds. To understand this part of the child's experience and a more accurate assessment of their ability or tendency to associate sounds with their environment a more controlled study would be necessary. It is also noteworthy that in the pilot study, some participants did make associations with their environment. In that study the child was in their home environment. In this situation it may be assumed that the child was more familiar with the sounds and objects in not only the immediate but also the extended environment. Further study in a home environment may provide further information on the child's willingness to associate recorded sound objects with objects in their extended environment (far visual or out of visual field) and how this affects their awareness of these sounds.

6 CONCLUSION

Children are constantly learning new skills by experiencing and exploring their world, and toys help them reflect on their place in their world. Based on these ideas we ask the question: Can we encourage young children‘s awareness of their sonic environment and encourage social listening by designing sound toys that highlight or isolate sounds from that environment?

We presented a study using three prototype designs and evaluated them using a mixed methods approach for children ages 3 to 4-years-old. The prototypes were presented to two classes of children at a daycare center during their free-play time. We observed the children engaging with the toys spontaneously as individuals, small groups, and large groups. We did see a fascination with how the toys could provoke social interaction, and that simpler metaphors between actions and sounds were easy to comprehend. Novel actions that created surprise were very engaging, and different ages had different approaches to agency and interest in exploring the affordances of the toys. We found that many aspects of the toys' design seemed to encourage the sharing of experience with the sound and social play with the sound objects. One focus of our study was to look at the effects of isolating sounds in the child's environment to encourage active listening and social engagement. In the pilot study we observed that the isolation of sounds preconceived to be in their environment often provoked the child to engage with the toy in a different way, talk to their parents about the sound and their understanding of its meaning and even attempt to explore the sound without the toy. Such engagement was not as evident in the full study. We observed that though the children did not engage with the toys using the environmental metaphors such as pointing to locations for sounds or constructing soundscapes, the sessions did result in students reporting more awareness of the sonic environment.

7 SELECTION AND PARTICIPATION OF CHILDREN

The study was held at a daycare center with the consent of the director, where classrooms were selected to host the

study based on their age group. The parents of children in those classrooms signed consent forms, and the researchers followed a minor's assent script to ask children for their consent to engage. Researchers regularly told children that they did not need to participate and could end their engagement at anytime, and no one would be mad at them. Researchers also watched for nonverbal cues to indicate their continued consent. The study was held in an open play format so that children were allowed to play with other toys at any time or refrain from engaging by moving to a different part of the room. Even though parents consented to video recording (and were told that data would only be accessed by the researchers and kept in a secure location), no recording of the sessions was allowed by the daycare center. The only data taken were handwritten notes which used no direct identifiers.

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