Pianimals: Exploring Music Education with Animals

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ABSTRACT
Music is a shared language that links cultures across space and time. Historically, only a small number of individuals possessed the resources and skills to become an expert, but music is now more ubiquitous in modern lives. Online communities and platforms provide a shared environment in which anyone can view, hear, share, and create music. These advances necessitate a redefinition of musical education, one that aligns more closely with the collaborative and connected society in which we live. Within this framework, we introduce *Pianimals*, an educational app leveraging tangible interactions that engages youth ages 3-5 in fun, accessible music practices. In this paper, we explore interactions using common shared representations to promote fun, incidental learning to increase participation in music.

Video Link: https://vimeo.com/130352943

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INTRODUCTION
Music is ubiquitous in modern lives. Its influence on culture can even be traced throughout history. Music has been considered an art form and a product of human culture. As a shared language, music is arguably a necessary dimension of human development [5, 20]. In addition to being a shared language, music offers developmental benefits for children, including improvement of visual-spatial, verbal, and mathematical performance [30]. However, for much of history, music education has been largely inaccessible since only a small number of people who had the resources and skill to become an expert [18].

Figure 1: A typical setup of Pianimals with the play mat in front of the user and the computer in front of that play mat.

The modern world, the ways that people interact with and participate in music and related practices have drastically shifted. Mediated by technological gains, many people now have numerous resources to view, listen to, create, and share music within and outside of one's culture and community. Consequently, proponents argue that music education needs to shift to accommodate the new needs and practices of music learners [18]. For example, the diversification of educational practices to leverage the prior knowledge and experiences of learners so that they can acquire shared musical knowledge and values [8, 34]. Seeking to explore music education through a modern framing, we describe our contribution that leverages the knowledge and practices of early learners to create a pathway to music education.

We developed the learning application, *Pianimals*, which seeks to provide children, aged three to five, an environment in which they can explore music through common shared representations. *Pianimals* is a music-learning app for 3-5 year olds that introduces musical notation through a playful tangible interaction with animal images that correspond to notes on a musical staff (e.g. "g" is for giraffe, "b" is for bear, etc). During play, learners cover the physical animals, and the application displays the animal's face in the correct location on the musical staff with a corresponding animation. To frame this learning application within the redefined sphere of musical education, *Pianimals* pursues the following learning goals:

1) Learners will identify music as fun and relatable, and 2) learners will be introduced to notes on a musical staff.

In this paper, we begin by reflecting on the complexity of music education and the cognitive benefits of persevering in music learning. Next, we explore the learning theories that guide our redefinition of music education, suggesting the importance of common representations when introducing abstract concepts. Finally, we address the design and current implementation of *Pianimals* and highlight future directions for continued development, user testing, and research.

THEORETICAL BACKGROUND

Music Cognition

Music is complex, requiring years of training and practice to reach a level of expertise in which one can recognize, understand, and compose musical notes and tones. The functions and elements of music composition vary across culture [5]. Consequently, there are many forms of music and countless tools used to create music. Digital software with algorithmically generated sounds increase the number of musical tools to uncountable numbers.

With such complexity, how does a learner begin to understand such a complex phenomenon? The amount of effort undertaken by music professionals to master an instrument or vocal abilities is a testament to the value of music in society. People spend lifetimes coordinating and building a relationship with musical tools to unlock musical sounds while expanding their cognitive capacities for music. Additionally, listening, creating, and performing music requires a complex web of cognitive capabilities [19].

The physical training of the body to hear sounds and distinguish music, fingers and lips to manipulate objects to create music, and the dexterity and coordination to perform and replicate music is an impressive human feat. Music is a production of human biology and sociocultural interaction, and has played a central role in the evolution of the human mind both for those who enjoy and those who create [5]. Learning music is difficult for many people, but even the untrained are still able to make meaningful notes through exploration and interaction with musical interfaces [2].

Untrained exploration of music is able to produce meaningful notes because music is enjoyable to many people [3]. Many studies have shown the ability for listeners and composers to experience emotional and physical responses to music [28, 29]. Emotional responses are found in infants as young as 4 months [35, 36]. For young children, training in musical practices results in many cognitive changes. These changes correspond to more complex and intense emotional and physical responses to music [16].

Recent research has suggested that while music is complex and mastery takes many years, individuals incidentally learn about the elements of music through incidental learning [27]. These studies suggest that learners do not need to be expert musicians in order to gain the cognitive benefits of musical training. Rather, exposure to music and musical creation allows learners to pick up the shared language of music.

Redefining Music Education

Studies of music cognition highlight the benefits of musical learning, however learning occurs in social and cultural contexts. These contexts are important for the concepts that are learned and how perceptions of music are shaped [9]. The resources and tools available for budding musicians have radically changed in the 21st century compared to traditional resources. There are many new technologies that allow individuals to immediately view, hear, share, and create music across the globe. Rather than having a relatively small number of talented individuals, musical skills and knowledge can be seen as participatory cultures that appear within and across both online and in-person learning environments [10, 18]. These changes necessitate a redefinition of music expertise, education, and practices to match the growing interconnectivity.

Advocates of this redefinition argue that music education should be recontextualized to mirror everyday experiences, practices, and knowledge of learners [6, 13, 18]. Furthermore, rather than focusing on Instructionist learning, such as a typical interaction between a music teacher and a pupil, many argue that learning should be more collaborative and connected to mirror online musical environments. We situate *Pianimals* within this view, and argue that early introductions to music should include a diverse set of experiences that leverage the everyday practices and knowledge of learners.

Early introductions to music should include three components: mirror everyday practices, leverage common shared representations, and focus on fun, incidental learning. By leveraging everyday practices and shared cultural representations, we believe that music education can become more accessible for newcomers. It also provides learners the possibility of building knowledge of music and associated practices off of a web of stable pre-constructed concepts [25, 26]. We seek to reduce the complexity of music education by making abstract musical concepts more relatable.

Aligned with the notion of everyday practices, we believe that fun, incidental, and exploratory learning allows learners to construct their own understanding and conceptions of music while participating in meaningful musical practices [4, 21]. With young learners, fun is an important component since continued musical learning requires investment from the learner. Interestingly, research shows that toddlers learn better when they laugh [7]. Also, we encourage exposure to musical elements through diverse interactions in music creation since music is a shared language with some elements that can be incidentally learned [27]. We leverage these theories in the design of *Pianimals*, arguing that our application provides a fun and effective environment for learners to explore music creation.

RELATED WORK

There are many cognitive benefits of practice with music. As a result, there are many musical resources available to expose children to music and help them learn. Some resources, like the popular *Baby Einstein* products, focus heavily on the benefits of musical exposure. In the following section, we explore the landscape of educational tools and resources available for young learners with a focus on the research that requires active interaction between the user and the tool.

Educational Music Apps for Children

More often directed at youth education, these applications connect musical scales and keys through games that range from memory matching games that connect visual and written notes to games that require players to connect keys to notes on a scale. While both provide learners with a potential added motivation for learning, the game mechanics are used to encourage rote memorization. In these tools, a focus on speed and memory may disadvantage learners' deep understanding of concepts and accurate motor execution.

Noteimals

Noteimals is a music education system design for beginning piano players. They have several different products for teaching the piano and different skill levels. One product is a flash card set for each note on the Grand Staff. The flash cards are meant to be studied very frequently so that the learner can memorize the notes. To teach note reading, it provides a paper template that goes in front of the keys on the piano. The template displays animal heads on each piano key and the accompanying music sheet shows the animal heads on the music staff rather than regular music notes. The animal heads represent the keys that the learner should play [17]. This product is very similar to the developed *Pianimals* in that each animal represents a unique note, and that animal is used on the staff so that the learner can memorize the note positions.

Animal Orchestra

Animal Orchestra is an animated music game for young children to teach them the various orchestral music instruments. The application introduces children to each instrument by playing the sounds and teaching the names of that instrument. Each animal plays one of the instruments. For example, a turtle plays a harmonica, an elephant plays the trombone and a bear plays the banjo. The application offers two modes: "Play" and "Learn." "Play" involves the animals each playing a sound clip with an instrument and has the player guess which instrument, or pick which instrument based on the name the game provides. "Learn" has the players listen to each musical instrument and learn the name. *Animal Orchestra* provides 20 animals and music instruments [1]. This application is similar to our design concept in that it uses animals as a bridge to music education to keep children interested in playing the game to learn more.

BeSound

The *BeSound* musical education system incorporates physical movement with musical composition, and is intended to introduce young children to the elements of composition [33]. The child interacts with a screen, which prompts the mimicry of a character or object in order to recreate sounds created by it. This movement is recorded and analyzed to evaluate space, time, and weight. Each of these properties is used to create one aspect of the music: melody, rhythm and harmony.

The *BeSound* system is set up using a Kinect motion sensing input device, which tracks the actions of the user. Although this system has been shown to provoke some interesting and innovative creations by users, it also has some drawbacks. This system requires full physical interaction with the user, which prevents it from being easily transported or used for leisure. In addition, *BeSound* requires the direction of a teacher to be used, which means it is only usable in a supervised classroom setting [33].

BeSound also has a different goal than our proposed system. While our learning goals are more aligned with introducing children to the concept of sheet music and note intervals, the *BeSound* system looks to give users a broader and shallower introduction to musical composition. This focus is less directly applicable to users' future music learning, as the understanding of music creating is very abstracted in the *BeSound* system [33].

Touching Notes

Like the *BeSound* system, *Touching Notes* uses a Kinect motion sensor to take input from the user. The user is able to use movements to select notes in order to follow along with sheet music on the screen [38]. This results in a gamified interface which tracks correct and incorrect guesses as the user progresses through a song. Similarly to our prototype, this design aims to familiarize users with the music staff and musical notes through a more approachable interface. *Touching Notes* targets an older user group, focusing on elementary age music students who are already familiar with music (cite). This system attempts to educate users on the theoretical elements of musical notation by presenting it in a game. Although the game is effective in stimulating interest in elementary school age users, it is too advanced and abstract to appeal to a younger audience. The representation of the musical notes is abstract (do, re, mi, etc) and difficult for young users to interact with. The game does not provide enough incentive for younger users, and is visually unengaging for young children.

Zoo-phonics

Zoo-phonics is a language arts teaching system for young children in the classroom. The primary product is a system that teaches children to read by representing each letter in the alphabet as an animal that is familiar to the children [37]. For example cat resembles C, alligator resembles A, and tiger resembles T to spell CAT. *Zoo-phonics* also provides flash cards that names each animal so children can remember each animal, such as bubba bear and willie wallaby. The animals are positioned in a way so that they also closely resemble the actual letter. *Zoo-phonics* uses these animals as a way of making the letters more easily recognizable as children are typically introduced to animals at a very young age. Our design concept of using animals as a platform for recognizing the note positions is similar to *Zoo-phonics*' method of using animals to represent each note of the alphabet to transition the learner to the actual alphabet.

Interaction with Paper Interfaces

Paper is a common, yet overlooked tangible interface. There is great value in the many affordances provided to the user of paper. The relationship between a tool and the body determines the interaction [11]. Paper supports many tangible interactions: touching, writing, bending, twisting, and folding among others. Paper can be used to aid in speech transcription and speech therapy due to the ubiquitous practice people have using it in everyday life [12, 22]. Interestingly, once a paper transcription is written for an audio recording, people rarely revisit the audio recording [12]. In a technologically saturated environment, paper still holds great value. For example, paper strips are prevalent and important to air traffic control [14]. Air traffic control is an extremely high-risk and complex task where computation is essential, but controllers prefer to annotate paper strips for documentation, visibility, communication, reminders, and references. Similar to music, there is great complexity in air traffic control. It is easy to observe that, for complex tasks, the simplicity of paper interaction is desirable.

Augmenting paper interaction to enhance computer systems can be directly applied to musical interactions. Since paper allows for quick expression of diverse ideas and can be manipulated to support the intentions of the user, music is a domain of interest. The power of paper in music can be seen in the augmentation of paper as composers create musical scores in order to aid the composition process [32]. Instead of learning how to interact with a musical instrument or train the body to produce specified tones and pitches, we built a system that allowed users to interact with paper in a familiar way that they were already comfortable doing. Our research extends prior research by creating an augmented paper interface to play musical notes so that users can focus on learning the sounds of musical notes and familiarizing themselves with the placement of notes on a musical staff.

Figure 2: The mat used for playing *Pianimals*

DESIGN

In the following section, we explore the design process for *Pianimals*; an app that engages learners ages 3-5 in exploratory play with animals and music notation, through four prototype and user testing iterations.

Design Concept

Originally, our design concept was the creation of a tangible interface using a computer and piano that would allow users to view their hand position on the piano through a screen placed in front of them where sheet music is typically placed. We hypothesized that placing the screen in that location would allow the user to build the proper habits of looking forward at the music instead of glancing back and forth between the sheet music and their hands. Having to look back and forth was considered a pain point among many beginning piano players. However, after creating and testing a prototype for this problem, we realized that displaying a video feed of the user's hands in the screen in front was not a natural interaction for users.

The testing feedback from our first prototype led us to alter our design concept to one that was less complicated and with a more intuitive interface. We narrowed our learning objectives to teaching music notes and their positions on a music staff, the ability to distinguish between notes and sounds, and learning beginner music pieces. To do this, we designed an interface that would be inviting and easy to understand for all ages through the use of animals.

The current design uses computer vision and a paper mat with printed animals and fiducials that the user plays by covering different animals. By covering different animals, computer vision will detect the notes that correspond to the covered animal while other software plays the musical notes. On the computer screen, the upper half displays a musical staff where the animal notes will appear in their proper locations, and the bottom half displays a dynamic playground where the animal figures will appear. There are two modes of play that our design provides: a "free play" mode for playing any sequence of notes, and a "learn a song" mode.

With the "learn a song" mode, our design guides the user through a song by displaying the appropriate notes on the music staff, allowing them to recognize which animals should be covered on the mat. The design uses animals as a way of alleviating the intimidation many beginners feel when approaching a complicated musical instrument such as a piano, and turns the experience into a fun and interactive learning process. Below, we discuss our design process and prototype iterations in detail.

Prototype 1 and 2

Our second design prototype is a departure from Prototype 1, which used a MIDI Keyboard, laptop, webcam, commercial music software, and a monitor. The first prototype, tested with numerous users, indicated that our design did not address a salient problem for users. When using music software that provided visual feedback for corrections, people did not look at the video of their hands or feel the need to look at their hands once they saw feedback from the software on screen. They were able to identify which key on the piano to press from the software's feedback since it was able to indicate which note the user had pressed and what the note should have been pressed. However, the software's method of feedback resulted in people pressing multiple keys to test how close they were to the right one instead of actually learning the key and corresponding music note. The focus of Prototype 2 is learning music by learning how to map sounds to the positions on a musical staff through an easily identifiable learning representation for all ages: animals.

Prototype 2 explores a musical application for a younger user population that uses animals to represent musical notes. Animals are well-known concepts for young children, and we leverage their accessibility by linking easily recognizable animals with more abstract musical notations. The components for this 2nd prototype design were simpler and more accessible than Prototype 1. A computer and webcam were the only hardware components that were needed, although a stand was used for positioning the webcam above the table. We utilized computer vision through reacTIVision and Processing to design an interactive musical application to help children create a mapping between sounds and notes on a musical staff [23, 24].

The Prototype 2 we crafted uses reacTIVision as part of a larger Processing application. A simple computer interface was created containing a musical staff and a dynamic playground underneath. We designed four animal shapes that contain fiducials that reacTIVision can recognize to correspond to different musical notes. When an animal's fiducials are touched and covered, a musical note is played. A note will then show up on the musical staff, indicating that note's proper location on the music staff. A cartoon animal will also appear on the dynamic playground underneath, in this case a farm, for users to identify which animal that the note represents (Figure 5). In our prototype, "C" is for "cow," "E" is for "elephant," "F" is for "frog," and "G" is for "giraffe." In the next prototype, we expanded the number to a full octave. 8 notes were used to account for spatial relationships between notes.

The second prototype tested multiple learning objectives. First, we hoped to help users create an easily recognized mapping between musical notes on a staff to the sounds being made by touching the animals. This should also help users recognize where each note should be located on the

Figure 3: User testing Prototype 2.

musical staff. Each selected animal is related to a musical note. Second, we hoped to develop a fun and engaging application to teach users how to play notes melodically since users can easily identify the differences between notes. From the first prototype, we learned that there is value in having easy-to-use music interfaces. Some people had experience playing a piano and did not find Prototype 1 useful; other people did not have any experience with a piano and were overwhelmed by playing a piano. In all age groups from 3 years old and up, animals are easily identifiable. The goal is that by using animals as notes, users are able to more easily memorize the appropriate notes and positions on the music staff. Through testing, Prototype 2 allowed people to create simple melodies while learning to play different musical notes. Prototype 2 explored the design space for music interactions with computers and creates an interaction to encourage users to use visual feedback from a software application instead of looking at the physical music instrument. Our testing feedback from Prototype 2, led us to create a third, more thorough prototype.

Prototype 3

For our third prototype, we followed much of the same goals we had in Prototype 2, but expanded the options for users and included feedback for learning a song. The number of animals was expanded from 4 to 8, as this would allow for a full octave from "C" to "C." A full octave is a basic block for learning music, as every note is a part of an octave. Providing these eight notes for play creates an opportunity for users to build a foundation of all of the basic notes without having to learn all of the other octaves. The animals with the fiducials are printed on paper side-by-side in an arch shape so that each animal can be easily pressed without accidentally covering other animals' fiducials (Figure 2).

The third prototype provides two modes of play: "free play" and "learn a song." "Free play" is much like the second prototype, allowing users to play whatever note they like and see where the notes would appear on the musical staff as well as the dynamic playground beneath. A picture below shows the note placements on the musical staff and animal figures on the dynamic playground. The “learn a song” mode is a new concept we added after our second prototype.

In this mode, the note that a user should play is displayed on the musical staff. If the user covers the right animal and fiducial, the note sound will play, displaying the animal figure in the dynamic playground beneath and then displaying the next note that should be played. If the user presses the wrong note, the animal figure will still be displayed in the dynamic playground, but no sound will be played and the note will not be shown on the musical staff. The decision for this method of feedback and displaying the notes came from user testing feedback which indicated that playing the sounds for the wrong notes could be confusing and cause the user to learn the wrong notes. Displaying the wrong notes in the musical staff above would also confuse some users to think that was the right note that they should have played. With this method, only the appropriate notes that should be played are shown on the musical staff above, so as to clearly distinguish the right notes to be played. Sounds will only be played when the right note is pressed, allowing the user to familiarize themselves with only the song tunes and none of the wrong notes.

The components of the design are a software application developed in the Processing programming language using the reacTIVision toolkit just like in the second prototype. The reacTIVision toolkit is a computer vision framework to support tangible interaction with multi-touch surfaces. In our system, the paper play mat is the multi-touch system where users play music. In order to use both Processing and reacTIVision together, a Processing API for the TUIO protocol is used. The TUIO library is able to return which fiducial id numbers are shown [31]. Using this information, the code detects which fiducials are not being identified from the eight total fiducials. We used a camera tripod to position the camera so that it is able to cover the entire mat and adjusted to be about a foot above the mat. The camera was then angled in a way that it would look down orthogonally at the mat while being able to identify all the fiducials on the mat. See Figure 4 for the exact fiducials used for the animals.

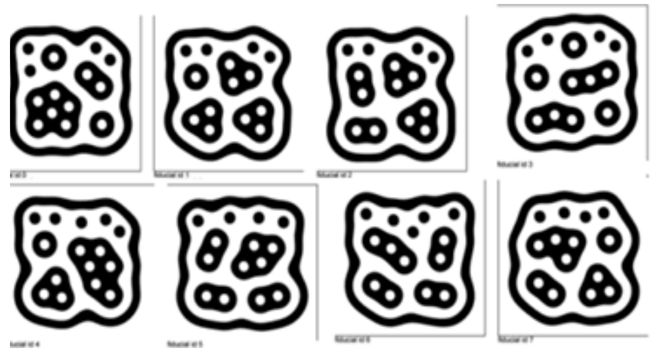

Figure 4: The fiducials used in the animals in the play mat

A HashMap for the animal notes, animal figures, note sounds, and note locations are used to display the animal notes at the proper location on the musical staff, the animal figures on the dynamic playground underneath, and play the note sound. A HashMap is the chosen data structure to reduce the amount of latency in our system. Since the interaction requires real-time audio and visual feedback, much consideration was given to efficient access of media files. The animal notes and animal figures are Portable Network Graphics (PNG) pictures that are loaded into the program when it first runs. The piano notes are Waveform

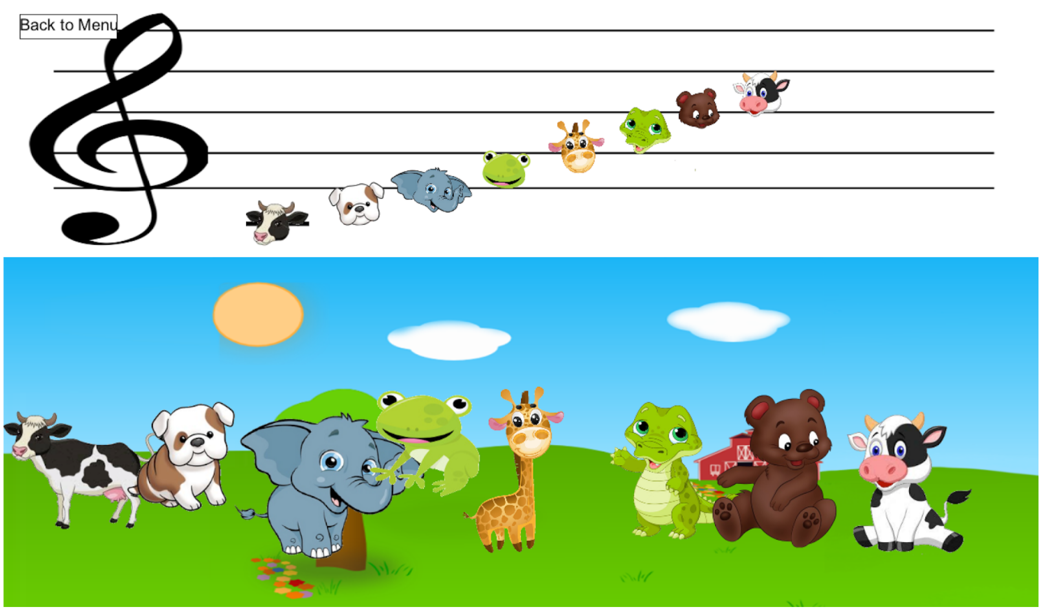

Figure 5: An image of the animal notes and animals figures that a user would see on screen.

Audio File Format (WAVE) files that are also loaded into the program when it first runs.

The code implementation for learning a song is similar. The code is programmed with the appropriate order of notes that should be played, while keeping track which note the user should be currently trying to play. Once a user covers an animal, the fiducial id for that animal is retrieved and sent to the code to check whether this fiducial matches the fiducial that should be missing i.e. the note that should be played. If the note is the correct one, the HashMap will provide the note sound that should be played and then display the next note that should be played in the list of notes. If the note is not the right one, no sound will be played. Whether the note is correct or wrong, the HashMap will provide the animal figure that will be displayed in the dynamic playground.

USER TESTING

Although we would have liked to test with more child users, we were able to test with adult users to play both modes of our Prototype 3. The testers were able to easily identify with the play mat and start interacting with it. One problem that was discovered was the response of *Pianimals* to the physical covering of animals. When a user covers a note for an extended period of time, the note is not held but played repeatedly every 2 seconds. This can be a problem for users who would expect that once the note is covered, the sound should be held and not played again from the start. Another issue that came up was that testers were not sure about how to interact with the play mat at first, and would try to press on the animals with one finger instead of covering with their hand or multiple fingers. This problem quickly went away after the testers played a couple notes.

Overall, the testers were able to easily understand the interface without much explanation. They noted that the correlation between animal and notes were very easy to understand. One tester mentioned that the game was similar to “Whack-a-Mole” because of the need to cover the animals. All mentioned that the interface was aesthetically appealing and would be very attractive to children. Having the animal notes displayed when learning a song was extremely simple for users to observe and continue with the song. One of the testers mentioned that after the age of 5 or 6, “children might just learn the actual piano instead.” Pianimals is built for all ages, but further testing in the future could determine the value for different age groups.

FUTURE WORK, & LIMITATIONS

The *Pianimals* design was developed as a means to simplify the learning of musical by creating a more approachable and understandable interface for music. With our design, users interact by touching paper, but learn about musical notes, scales, and how to begin to read sheet music. The early feedback from our initial user testing was promising. In the future, we hope to expand work on *Pianimals* to improve the learning experience, both educationally and technologically, and research its impact on learners’ knowledge and affect towards music.

For our future work, we want to be able to test with more children, more specifically in the 3-6 age range, as this is when they may find the design more as a toy than a learning tool. We would like to perform controlled user testing in order to refine the interface, and experiment with different modes of play to determine efficient and effective interactions in order to learn to play a song. There was much debate about whether only the animal notes should display or only the animal figures should display. More user testing would help us come to a better conclusion about the methods for teaching a song that would be easily understood and remembered. Furthermore, as we focused foregrounded fun and incidental learning rather than structured education with our application, future work would develop ways to make this experience more educationally rigorous for learners.

Using reacTIVision and Processing allowed for rapid iterating and quick turnarounds for prototyping, but the code still had latency issues and reacTIVision was not capable of detecting the fiducials as other computer vision software, such as Xbox Kinect or OpenCV. Setting up the system to work was a difficult task, as it required precision with positioning the camera so that all eight notes/fiducials could still be detected without leaving any notes out. Suggested solutions would be creating a stand like a tree or barn where the camera could easily fit in a slot and indicators attached to it that would show where the mat should be placed. The basic premise is to improve the setup of the system so that children can easily set it up without the guidance of their parents and not have to worry about readjusting the items when small shifts are made while playing.

We would also like to add more songs to “Learn to Play” to improve the skill range and variation in the songs that a user can learn. Adding animations would also make the design much more fun for younger users. In our current implementation, all the notes are piano notes, but we would like to expand this to more musical instruments such as a clarinet, flute, or saxophone. We would also like to improve the quality of the sound clips used in the application so that users can differentiate between a note that is touched and held, or a note that is constantly being touched.

One aspect of music that we would like to add to the design is a mode or interface for learning rhythm. Because of the latency issues with reacTIVision and Processing, rhythm is difficult to implement with this technology, as it requires fast reactions from the system. In the future, we would like to teach this through interactions such as mini-games that allow the user to play to a certain rhythm.

DISCUSSION AND CONCLUSION

Throughout the process of designing *Pianimals*, we learned much about musical education as well as education for young children. There was an emphasis on user testing our design iterations as it became apparent that preconceived notions could be proven wrong such as in our very first prototype. Being able to provide an intuitive interface is important as well, as it is much easier on the user to learn the interface and begin using the product as intended, rather than spending too much time to figure out the interface. It is essential to have a relatable system when designing an educational product as it can greatly increase the effectiveness of the teaching, as we learned in our first prototype when we provided a camera feed that turned out to be confusing because there were no similar applications in other products. Animals are extremely useful as a learning tool for younger children since many of them are introduced to them at a young age.

Pianimals provides a friendly learning system for people of all ages to learn music without the intimidation they might feel when first approaching a musical instrument such as a piano. *Pianimals* includes an animal interface for playing different animals that are shown on screen, with the animal notes on a musical staff and animal figures on a dynamic playground beneath it. Users are also able to learn a song through *Pianimals* displaying the animal note to play and only playing the note sound when the correct note is played. With *Pianimals*, users are introduced to music in a fun, interactive and engaging way.

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REFERENCES

1. *Animal Orchestra*. https://play.google.com/store/apps/details?id=air.toymiles.animalorchestra.fs.en&hl=en
2. Bamberger, J. (1996). Turning music theory on its ear Do we hear what we see; Do we see what we say? International Journal of Computers for Mathematical Learning, 1(1), 33-55.
3. Brattico, E., Jacobsen, T., 2009. Subjective appraisal of music: neuroimaging evidence. Ann. N. Y. Acad. Sci. 1169, 308–317
4. Collins, A. (1995), 'Learning communities', presentation at the annual conference for the American Educational Research Association, San Francisco CA, April, 1995.
5. Cross, I. (2001). Music, cognition, culture, and evolution. Annals of the New York Academy of sciences, 930(1), 28-42.
6. DeNora, T. (2001). Aesthetic agency and musical practice: new directions in the sociology of music and emotion. Music and emotion: Theory and research, 161-180.
7. Esseily, R., Rat-Fischer, L., Somogyi, E., O'Regan, K. J., & Fagard, J. (2015). Humour production may enhance observational learning of a new tool-use action in 18-month-old infants. Cognition and Emotion, (ahead-of-print), 1-9
8. Gee, J. P. (1992). The social mind: Language, ideology, and social practice. JF Bergin & Garvey.
9. Harwood, E. (1998). Music learning in context: A playground tale. Research Studies in Music Education, 11(1), 52-60.
10. Jenkins, H. (2009). Confronting the challenges of participatory culture: Media education for the 21st century. Mit Press.
11. Klemmer, S. R., Hartmann, B., & Takayama, L. (2006, June). How bodies matter: five themes for interaction design. In Proceedings of the 6th conference on Designing Interactive systems (pp. 140-149). ACM.
12. Klemmer, S. R., J. Graham, G. J. Wolff, and J. A. Landay. Books with Voices: Paper Transcripts as a Tangible Interface to Oral Histories. CHI: ACM Conference on Human Factors in Computing Systems, CHI Letters 5(1): ACM Press. pp. 89– 96, 2003.
13. Määttänen, P., & Westerlund, H. (2001). Travel agency of musical meanings? Discussion on music and context in Keith Swanwick's Interculturalism. British Journal of Music Education, 18(03), 261-274.
14. Mackay, W. E. Is Paper Safer? The Role of Paper Flight Strips in Air Traffic Control. ACM Transactions on Computer Human Interaction 6(4). pp. 311–40, 1999.
15. Mackay, W.E. and A.L. Fayard. Designing interactive paper: lessons from three augmented reality projects. In Proceedings of IWAR. pp. 81-90, 1999.
16. Müller, M., Höfel, L., Brattico, E., & Jacobsen, T. (2010). Aesthetic judgments of music in experts and laypersons—An ERP study. International Journal of Psychophysiology, 76(1), 40-51.
17. *Noteimals*. http://www.noteimals.com/
18. O'Neill, S. A. (2012). Becoming a music learner: Towards a theory of transformative music engagement. The Oxford handbook of music education, 1, 163-186.
19. Pearce, M., & Rohrmeier, M. (2012). Music cognition and the cognitive sciences. Topics in cognitive science, 4(4), 468-484.
20. Peretz, I. (2006). The nature of music from a biological perspective. Cognition,100(1), 1-32.
21. Piaget, J., & Inhelder, B. (1969). The psychology of the child. Basic Books.
22. Piper, A.M., Weibel, N., and Hollan, J. Introducing Multimodal Paper-Digital Interfaces for Speech-Language Therapy. Proceedings of ACM conference on computers and accessibility (ASSETS) 2010.

23. Processing Language. https://processing.org/
24. reacTIVision. http://reactivision.sourceforge.net/
25. Rogoff, B. (2003). The cultural nature of human development. Oxford: Oxford University Press. Chapter 2 (pp. 37-62).
26. Rogoff, B. (2003). The cultural nature of human development. Oxford: Oxford University Press. Chapter 7 (pp. 236-281).
27. Rohrmeier, M. and Rebuschat, P. (2012), Implicit Learning and Acquisition of Music. Topics in Cognitive Science, 4: 525–553. doi: 10.1111/j.1756-8765.2012.01223.x
28. Scherer, K. R. (2004). Which emotions can be induced by music? What are the underlying mechanisms? And how can we measure them? Journal of New Music Research, 33, 239 –251.
29. Scherer, K. R., & Zentner, M. (2001). Emotion effects of music: Production rules. In P. Juslin & J. Sloboda (Eds.), Music and emotion: Theory and research (pp. 361–392). Oxford, England: Oxford University Press.
30. Schlaug, G., Norton, A., Overy, K., & Winner, E. (2005). Effects of music training on the child's brain and cognitive development. Annals of the New York Academy of Sciences, 1060(1), 219-230.
31. TUIO. www.tuio.org
32. Tsandilas, T., Letondal, C., & Mackay, W. E. (2009, April). Mus ink: composing music through augmented drawing. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 819-828. ACM.
33. Volpe, G., Varni, G., Addessi, A. R., & Mazzarino, B. (2012). BeSound: Embodied reflexion for music education in childhood. In *Proc. IDC '12* (pp. 172-175). ACM.
34. Vygotsky, L. S. (1986). Thought and language (A. Kozulin, trans.).
35. Zentner, M. R., & Kagan, J. (1996). Perception of music by infants. Nature, 383, 29.
36. Zentner, M., & Kagan, J. (1998). Infants' perception of consonance and dissonance in music. Infant Behavior and Development, 21, 483– 492.
37. *Zoo-phonics*. http://www.zoo-phonics.com/products.html
38. Renzi, M., Vassos, S., Catarci, T., & Kimani, S. (2015). Touching Notes: A Gesture-Based Game for Teaching Music to Children. In *Proc. TEI '15* (pp. 603-606). ACM.