Andantino: Teaching Children Piano with Projected Animated Characters

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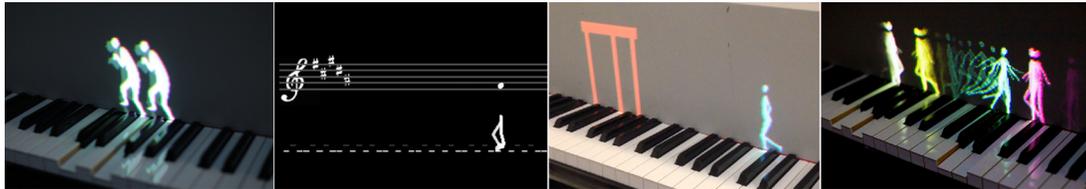Boston, MA
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Figure 1. Andantino features: (a.) Showing expression with different walks, (b.) Introducing symbolic notation, (c.) Metaphor of houses to teach harmony, (d.) Demonstrating polyphony with figures.

ABSTRACT

This paper explores how multi-modal body-syntonic interactive systems may be used to teach children to play the piano beyond the typical focus on reading musical scores and "surface correctness". Our work draws from Dalcroze Eurhythmics, a method of music pedagogy aimed at instilling an understanding of music rooted in the body. We present a Dalcrozian process of piano learning as a five-step iterative cycle of: listen, internalize, extend, analyze, and improvise. As a case study of how digital technologies may support this process, we present *Andantino*, a set of extensions of *Andante*, which projects musical lines as miniature light silhouettes that appear to walk on the keyboard of a player piano. We discuss features of Andantino based on each stage, or step, of the iterative framework and discuss directions for future research, based on two preliminary studies with children between the ages of 7 and 13.

Author Keywords
Music; Music Learning; Piano; Piano Learning; Dalcroze Eurhythmics; Progressive Education; Embodiment

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Playing a musical instrument boasts many benefits for cognition and health, and these effects are especially striking with an early start in musical training [14]. Of all the instruments, the piano is the most commonly used worldwide in initiating children [5, 15]. Most beginners start with the classical style, where the first several years of study are usually devoted to learning to read music from a score. Apart from a few notable exceptions, initial emphasis for children and other beginners is placed on finding and playing the correct notes (which we refer to as "surface correctness") [4, 24]. Expression takes a back seat, addressed only after hours of repetitive drills to cement sequences of notes into muscle memory. As a result, this initial stage is widely regarded as an unavoidably tedious and painful process. Despite the oft-cited benefits of music learning, many children quit having reached neither proficiency nor enjoyment.

Our work contributes a new approach for the design of interactive systems that help children learn to play the piano by catering their whole-body musical "intelligence". Drawing from Dalcroze Eurhythmics [2, 11], and two studies with children, we discuss how Andantino may promote an intuitive understanding of music rooted in the body, from which to scaffold the introduction of more advanced skills and concepts. In the spirit of Dalcroze, we progressively mediate but don't downplay a child's felt musical experience! Prior research introduced Andante [32], a projection-augmentation of a player piano that presents music as animated light silhouettes that appear to walk and dance on the piano keys. This paper highlights how Andantino, which expands upon Andante for the specific needs of children, can be used to both ground and lift a person's musical expressivity in learning to play the piano.

Beyond our specific system, and observations of children, the overarching goal of this paper is to help designers create more effective and enjoyable musical learning environments for children. We first summarize the primary challenges in music learning for children and discuss related work in the context of these challenges. To inform the design of novel interactive systems, we then describe a specific piano learning process adapted from Dalcroze Eurhythmics, which we distill into 5 steps, or stages—listen, internalize, extend, analyze, and improvise. Features of Andante and Andantino are detailed in light of the framework. Finally, we describe preliminary experiences of children learning to play pieces using Andantino. Based on our observations, we discuss improvements for Andantino and point to promising directions for researchers to pursue.

BACKGROUND

We frame the main challenges for children learning to play the piano as questions of *What*, *How*, and *Why*. *What* breaks down the know-hows that learning about music entails. *How* presents music learning methods from the envisioned specifically for children, supported by findings from psychology. *Why* considers the question of motivation.

What: Know-Hows of Music Learning

Jeanne Bamberger identifies 4 fields of attention in which everyday work and learning takes place for a classical musician [3]. Each area requires a distinctive understanding and a set of know-hows, which we outline below:

- **The Score** involves the understanding of symbolic notation, including the ability to read notes, rhythms, and markings for articulation, dynamics, and pedaling.

- **The Instrument** refers to the physical facility to make deliberate sounds on the instrument. This includes not only how to find notes but also the extended technique to fluidly play with a range of expression.

- **The Sound** requires the development of the ear beyond the simple identification of notes and rhythms. Understanding sound means cultivating a sensitivity to its qualities (e.g. timbre, color). This area also includes the aural imagination, where a musician gains the ability to "hear" sounds in the mind.

- **Musical Structure**: Refers to the understanding of musical building blocks such as motifs (e.g. melodic and rhythmic), harmony, polyphony, and overall form.

Experienced musicians have attained an understanding in all four realms as well as the ability to fluidly translate between them. For beginners, the simultaneous introduction of each realm and their connection poses a special challenge. Rather than delving into all four areas at once, beginner instruction for children and adults alike typically focuses on the score and actions on the instrument. Though the understanding of sound and musical structure is crucial for expressive playing, these two areas are generally left out for beginners and for children in mainstream classical pedagogy.

How: Methods to Fit Children's Cognition

An alternative view for teaching children is found in a number of learning methods from the Progressive Education movement, as developed by Dalcroze, Willems, Orff, and Kodály [2, 1, 29, 17, 13]. These methods are based on developing an intuitive sense of musicality rooted in the body and familiar songs. Sound and musical structure are taught first, made-concrete through full-body exercises, songs, and games with physical props. The symbolic score, and often even the physical instrument, are not introduced until later, after students have developed an intuitive body-based sense for patterns in sound.

These methods echo the findings of Jean Piaget, whose studies have shown that children understand the world differently from adults [1, 20]. Piaget observed a stage-like progression from purely sensory-motor to increasingly abstract, symbolic understandings in children's cognitive development from the toddler to the adolescent. In the ages where children typically begin piano lessons (toddler to 12), abstract symbolic thinking has not yet been fully developed. Cognition is rooted in concrete phenomena. Connecting music to movements of the body is thus an effective strategy to convey musical structure and expression to children. Another strategy yet underexplored is the use of enactments (or *enactive* representations as exhibited in pretend play and differed imitation) and figurations (or *iconic* re-presentations such as pictures in books or cartoons)

Why: Motivation to Practice

Motivation to practice is another major challenge for children's music learning [8]. Unlike adult beginners, who are generally self-motivated, children are often enrolled in lessons by their parents [22]. Compared to adults, they also tend to have more trouble focusing their attention for extended periods of time on activities they do not find interesting. Since music notation and traditional musical instruments are designed for adult usage, they may not have the intrinsic pull for children's attention.

RELATED WORK

Existing systems that support early stages of piano learning generally take for granted the usual priority of playing correctly according to the written score [6, 10, 12, 22, 25, 26]. They tend to avoid questions of musicality and rarely address the specific needs of children. Systems to support novices' learning to play the piano have worked on more legible ways of conveying the instructions of the score. Some bypass symbolic notation, using lights or video of a teacher's hands at the keyboard for reference [6, 10, 31]. Yet other systems use a graphical notations of falling blocks reminiscent of piano rolls to indicate which notes a student should play [22, 25, 26].

Technologies to help children learn music often introduce new toys aimed at fostering various dimensions of musicality (e.g. rhythm, melody) through playful games [28, 9]. Games have also been used to help motivate practice, where students earn points for consistent and

correct playing [12, 25]. Other approaches for motivation include social playing, such as technology that enables non-musical parents to practice alongside their children [16]. Perhaps the most effective way is to help students remain in a flow state, where the reward of overcoming challenges within the material becomes motivation to continue playing [7, 18].

RE-PRESENTING MUSIC – ENACT, EMBODY, EMBED

Based on the challenges just outlined, interactive systems to support children learning to play the piano should consider the following dimensions in their design:

- Conveying and connecting all 4 fields of attention

- Presenting music framed specifically for children's cognition and worldview

- Inspiring joy to motivate engagement with music

We argue that systems may target all three dimensions at once through how they represent, or rather, *re-present* music to the learner. The standard score is not well suited for children because its heavy reliance on symbol interpretation clashes with children's more concrete *modus operandi.* Piano roll notation as employed by several existing projects is an improvement but still ignores the structural and expressive components of music.

Prior work introduced Andante, which presents musical lines as silhouettes of miniatures figures that appear to walk and dance on the keyboard [32]. The movement of the Andante figures are concurrent to the strokes on the keyboards, which helps convey an understanding of phrasing and rhythm based on the players' intuitive understanding of "fingering" as a way of walking! This paper further explores the potential of Andantino, an extension of Andante, as a means to promote enjoyable and effective music learning that caters children's strengths. Since a child's ability to enact events (mostly through gesture and pretend play) and understand images precedes the ability for symbol interpretation, Andantino may serve as a bridge between sensory-motor and more abstract forms of musical cognition. Andantino may also help motivate practice, given children's affinity toward cartoons. And, lastly, the real fun comes from modulating the figurine's movement by fingering on the piano! We first detail the stages, or phases, of a piano learning method, as inspired by Dalcroze Eurhythmics. Features of Andantino that correspond to each stage of learning are then introduced.

Improved Piano Learning Process

Since our approach departs from the typical focus on the written score, we offer an alternative learning process that has guided the design of Andantino. This process draws from various pedagogical methods discussed in previous sections, but particularly from Dalcroze Eurhythmics [11], which has been adapted for piano pedagogy [2, 21]. Dalcroze articulated 3 successive stages of musical understanding, which closely mirror Piaget's descriptions of child development:

- **Instinctive:** The most immediate way for humans to understand music is through sensorimotor activities.

- **Conscious:** The next level is the ability to perform simple actions with a musical pattern (e.g. transposing it or scaling it in time)

- **Intellectual:** The final stage is the introduction of symbolic notation for musical phenomenon.

To understand how these ideas translate into activities for lessons and practice, we worked with a Dalcroze-certified piano instructor (co-author Pablo Puentes). Following extensive discussions and observations of three 30-minute lessons with children, we distilled our collaborator's version of the Dalcroze method for piano into a four-step iterative cycle, or framework:

1. **Listen:** The student is first exposed to a piece through the ear rather than the score. During a lesson, the teacher plays the piece for the child on the piano. An audio recording is also made available for the child to reference during the lesson and practice.

2. **Internalize:** Before going to the piano, the child must first internalize the piece through the body. The melody is introduced several measures at a time based on motifs and phrases. It is first separated into the components of pitch and rhythm, which are taught and practiced through various exercises. Exercises to train pitch include singing the tones (without a definite rhythm) and a technique known as *body solfège,* where pitches are mapped onto parts of the body. Exercises for rhythm include clapping and speaking. In the speaking exercise, the words in a phrase (ex: "mom's cooking lemon cake for tomorrow") are mapped to different subdivisions of the beat (figure 2). After the

Figure 2. Our collaborator's speaking exercise for rhythmic subdivisions

pitch and rhythm are successfully learned in isolation, they are then combined to form the full melody.

3. **Extend:** Only when students have internalized the melody (demonstrated by singing and clapping) do they go to find the notes on the piano. This ensures that natural expression from the body is extended to playing on the piano. Conscious effort is devoted not to reading notes but to the expression in the sound.

4. **Analyze:** If the child is still learning how to read, the score is introduced at this point, associated to what the student already knows how to play. Also, at this stage is when harmony is presented. In the typical learning method, harmony is generally ignored for children. In our collaborator's approach, harmonic grammar is introduced early in the process. Images and spatial (or figurative) re-presentations are privileged over

symbolic notation, as in the following "mapping game": "home stands" for *root position*, "school" stands for the *dominant*, and the "forest" is the *subdominant*. Such body-syntonic mapping technique serve as a precursor to understanding standard notation because the spatio-temporal relations at play can be understood in terms of familiar metaphors—and consolidated in action!

5. **Improvise:** Learning music should mimic the way children learn their mother tongue [11, 24]. This means not only repeating what is written but playing *with* the material in new combinations. Our collaborator plays improvisatory games with his students, for example, taking turns with the student to invent new rhythms by mixing patterns from a piece. Student should also learn to incorporate improvisation during practice to avoid mindless repetition.

Role of Technology

Beyond the now ubiquitous audio recording, neither the original Dalcroze Eurhythmics nor the piano learning method described above requires any digital interactive technologies. Here, we discuss three ways in which interactive systems may potentially support music learning.

Guiding Practice

During lessons, the teacher guides the student through each stage of the learning process, presenting the piece, introducing exercises, and correcting mistakes. However, aside from the 30-60 minutes of lessons each week, students must work alone to practice. When left by themselves, students may easily fall back into bad habits—not listening, repeating mindlessly, reinforcing mistakes. Systems may therefore improve learning by providing a structure for students to follow during practice. Helping students listen may also significantly improve the quality of practice time.

Improving Lessons

Our method and others with similar priorities have been shown to be more effective than the typical way children learn to play [21, 27]. However, these methods are not the norm because this is not how most teachers of amateurs have learned to teach. Since the boom of the piano in the 19th century among the European and American middle-class, amateur learning has proceeded with an emphasis on the written score, which was the primary way music was disseminated before the invention of recording technology [23]. The priorities of listening, embodied understanding, and creativity have historically not been emphasized for amateurs even though their early introduction significantly improves the learning experience. Thus, systems may also help teachers improve pedagogical methods by breaking down best practices and embedding them into interactive systems.

Promoting self-directed learning

Interactive systems could also serve as guidance for self-directed learning, both in children and adults Self-learning is usually promoted for motivated, mindful adult learners rather than children who are believed to need more guidance. On the other hand, Piaget and Dalcroze have taught us that children are self-directed-learners in their own right! Systems can be used to cater their own relentless urge to self-improve instead of forcing adult projections! .

ANDANTINO

We first give a brief summary of Andante's setup, and then describe Andantino's features for each stage of the learning process.

Setup

Andante is built on a Yamaha Disklavier grand piano, which controls the player piano mechanism [33]. A short-throw projector is mounted above the piano bench 7-ft from the ground, which displays imagery on the music stand and fallboard. To enable projection, a piece of plywood measuring 39" x 11" is treated with projection paint and placed on the music stand. The keyboard cover is replaced by a fallboard made from the same material.

We created two versions of the software to drive playback and animation. In the original implementation, all animations were drawn by hand to ensure a natural sense of expression in the figures' movements. Frame sequences were organized according to the type of step (e.g. whole step between white keys). A Java program controls playback by reading MIDI sequences recorded from a human player and selects the appropriate frame sequences to display for each note played on the Disklavier. Features of Andantino deployed in our user experiences were built from this implementation.

We are currently working on a new version of Andante in JavaScript that procedurally generates character animations with life-like movement from human input of musical phrases. The new program runs from the Chrome web browser, thanks to an extension of the Web MIDI specification published in June 2015 [30].

Features and Potential for Supporting Musical Training

We explain how properties of the Andante re-presentation and variations of the Andantino system may play a role in each step of the learning process.
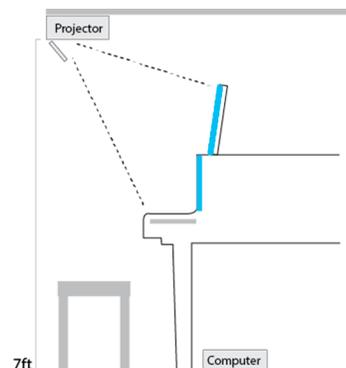

Figure 3. Andante system configuration. The main projection surfaces are colored blue. Occlusion of the main areas does not occur for an adult player's normal range of torso motion.

1. **For Listening:** Andante enacts music on the piano, enabling students to hear music as live, acoustic sound. The movement of figures may also help focus children's ears by drawing attention to qualities of the sound. For Andantino, we created a graphical user interface running on a computer adjacent to the piano where students may select portions of a piece to play as an auditory reference. The interface enables playback of hands separately and together. For students who already know how to read, projected highlights indicate which portion of the score is selected for playback

2. **For Internalizing:**. Children may —or may not—be instructed on the meaning of the figures (where the head corresponds to the pitch and the feet to rhythm, and musical lines can be understood in terms of the body) Another variation would be to use different characters with different walks to convey different moods in the music (Figure 1a). Students can then sing along or clap along with the figure to practice.

3. **For Extending:** Andante may help children transition a melody to the piano as figures to establish the connection between the sound and the instrument. Children may rest their hands on the keyboard to shadow the movement of the keys, gradually learning to play along. They may also practice the melody an octave higher or lower along with the figure. This may help students identify and correct mistakes where their playing does not blend seamlessly with the figure's playing.

4. **For Analyzing:** We prototyped new features that help children understand harmony and learn to read music. For harmony, we projected cartoons of buildings onto the piano. Each house consists of three "columns", which play the notes of the chord, and a top with an identifying shape (Figure 1c). Each house is also associated with a different color. Our prototype consisted of three houses representing the *root*, the *dominant*, and the *subdominant* harmonies. The feature to help introduce symbolic notation was prototyped with the JavaScipt version of the program. A set of staff lines were overlaid above the figure, and the position of the head was shifted up and down based on the note played by the feet (Figure 1b). We also added different stems onto the head to depict different rhythms. This feature could serve as an intermediary between the concrete world of Andante and the symbolic world of standard notation. The presence of the figure helps remind children of the continuity and the quality of musical lines.

5. **For Improvising:** Andante may be used to help students practice creatively. For example, interactions with the figure may mimic games played with the teacher during lessons. A bank of variations for each motif may be programmed into the system ahead of time, or the system may automatically generate variations based on student input. In either case, the figure would take turns playing with the student. Since improvisation is not the focus of this paper, we did not implement these features for Andantino.

PILOT EXPERIMENTS

We conducted two studies to pilot Andantino in the context of a lesson and a practice session with a total of 8 children. Current students of our collaborator were chosen for two reasons. First, the familiarity of the instructor with both our system and his students enables him to adapt his teaching using Andantino. Second, our collaborator's students are already familiar with our non-mainstream learning process, which enables us to focus on the influence of our technology. Each session was captured with two cameras, one for the student's face, the other for the hands and the piano projections. Videos were reviewed and a transcript was made of the main interactions.

Due to the small sample size of children and short duration of the sessions, our observations remain anecdotal. Still, our findings suggest promising directions for future work, both for Andantino and for the design and evaluation of other music learning systems for children. We now describe the setup of each study followed by notable results.

Study I: Lesson

ID	Age	Gender	Total years playing	Years with collaborator
1	12	F	5	1.5
2	13	F	7	0.5

Table 1. Students of Study I

ID	Age	Gender	Total years playing	Years with collaborator
A1	8	M	2.5	1.5
A2	7	M	2.5	1.5
B1	9	F	3.5	1
B2	9	F	3.5	1
C1	11	F	3.5	2
C2	11	M	2.5	2

Table 2. Students of Study II

This study compared two lessons, one where Andantino was used as a reference from the start, and another that began with only the score. Two students of comparable piano experience were selected (see table 1). As material, we chose an excerpt from a Bach canon consisting of 2 voices across 4 measures. Playing a canon is a challenge because it requires understanding the interplay between the two overlapping voices.

Both sessions began with about 5 minutes of pre-lesson exercises, where the concept of a canon was introduced via clapping exercises. The piece was then presented in a lesson planned to be about 15-minutes long. Andantino was introduced mid-way through Student-2's lesson to help alleviate visible stress. As a result, Student-2's lesson consisted of 12 minutes with only the score and 14 additional minutes using Andante. The sheet music was

kept on the music stand during both lessons, and the teacher guided each student through the piece in one to two-measure increments. An additional experimenter in the room triggered playback on Andantino based on voice commands of the instructor. Sections of the piece selected for playback were highlighted on the score using the two colors of the Andantino figures.

Study II: Practice

A second study was conducted to compare how students use different reference technologies during practice. Alongside Andantino, we implemented a version of piano roll notation commonly used by existing learning systems, where "falling blocks" were projected onto the fallboard to indicate note strikes and releases. To be comparable to Andantino, our version of Falling Blocks also appeared to play the physical piano, and voices were colored corresponding to Andantino figures.

6 students were selected for this study grouped into 3 pairs of 2 (see table 2). Pieces were chosen based on the level of the students. The youngest group learned a modified version of Allegro in G from the Suzuki curriculum, where the left hand pattern was simplified into block chords to make the harmony more explicit. The other two groups learned the same Bach canon from the first study.

A graphical user interface on a laptop computer next to the piano allowed students to select portions of each piece, 2-measures or longer, to be played back using either Andantino or Falling Blocks. Students could select whether to play back only the left hand, right hand, or both. As in the first study, the score was place on a music stand, which was highlighted to display the selected measures. Pressing the space bar starts and stops looped playback of the selection.

Sessions began with a 10-minute overview, where the teacher introduced the piece and taught the student how to use the computer interface. Students were then given 25–30 minutes to practice with Andantino and Blocks, respectively. Students decided what to play using the system and what to practice. They were also free to choose when to listen or read from the score. The teacher stayed in the room and took notes on the students' behavior. He also interjected brief instructions if a student appeared stuck. Following each practice session, the teacher conducted a small survey with each student about the technologies.

DISCUSSION

Table 3 details how students used each system to practice. We now discuss three recurring themes observed across the two studies.

Promoting Listening and Imitating

The multi-modal, enactive nature of both Andantino and blocks seems to promote deeper listening. 6 of the 8 total students (all except 2A and 2B) expressed more awareness to the structure and expression of sound when using our interactive technologies. This awareness was reflected in their body language as well as in their playing. In the second study, 5 of the 6 students (all except 2A) rarely looked at the score, relying instead on the memory of what they have heard. When listening, 1A, 3A, as well as 2B liked to put their hands on the keyboard to feel the movement of the keys. When playing, student-1 followed

| | | | Listen | | | | | Extend | | | |
| | | | Reference | | | Aural Memory | | Hands Separate | | Hands Together | |
ID	System Used	Part Practiced	Total system starts	Total repeats	Average repeats per start	Corrected mistakes by ear?	Practiced from memory?	Times RH practiced	Times LH practiced	Times HT practiced	Performance Rating
A1	Andantino	Allegro_A	7	25	3.57	Yes	Yes	8	10	16	4
	Blocks	Allegro_B	7	39	5.57			23	7	22	2
A2	Blocks	Allegro_A	7	48	6.86	Yes	Yes	8	8	12	3
	Andantino	Allegro_B	6	36	6			4	9	13	3
B1	Andantino	Canon_A	3	11	3.67	Not always	No, preferred to read score	1	1	7	5
	Andantino	Canon_B	3	15	5			6	7	4	2
	Blocks	Canon_All	3	19	6.33			8	5	16	3
B2	Blocks	Canon_A	3	14	4.67	Not always	Sometimes. Used score for hard spots.	6	5	5	3
	Blocks	Canon_B	3	9	3			3	5	2	3
	Andantino	Canon_All	3	16	5.33			3	3	22	1
C1	Andantino	Canon_A			4	Yes	Yes				4
	Andantino	Canon_B			4						
	Blocks	Canon_All			4						
C2	Blocks	Canon_A	3	3	1	Yes	Yes, except one hard spot	3	3	4	4
	Blocks	Canon_B	3	7	2.33			4	8	6	3
	Andantino	Canon_All	3	8	2.66			2	4	10	3

Figure 4: Students practicing during Study II: (top) Learning Canon with two figures, (center) learning harmony through houses. (bottom) Learning Allegro with Blocks.

Table 3: Summary of Study II sessions. Video was lost for student-C1, whose data is based on notes the collaborator took during the session. "System start" refers to when a child triggered playback on the system. RH, LH, HT denote "right hand", "left hand", and "hands together", respectively. Performances rating were given by the teacher.

closely the tempo and articulation of the Andantino figures even though none were indicated in the score. Interestingly, 1A's playing also became more detached to follow the unintentional articulation of the falling blocks. In the survey post Study 2, all students indicated that they would like to be taught with both Andantino and Blocks.

These observations suggest that the combination of audio, visuals, and haptics may help engage the attention of children when learning music. We also observe that imitation may be a good strategy to convey several dimensions of music at once (e.g. notes, timing, articulation, structure). Said otherwise, redundancy (achieved either through multi-modality or imitation) serves as an *organizing principle* that brings about new insights without conscious effort on the part of the student. Since students imitate all dimensions of what they hear, designers should be careful to avoid haphazard, non-musical choices such as the detached notes of the falling blocks.

The Score and Preoccupation with Correctness
Three students' experiences support our conjecture that playing by ear rather than reading the score is a more effective and enjoyable way to learn. When the score was first introduced in student-2's lesson, she immediately appeared nervous ("What if I mess up?"). Even though the teacher showed each segment of the piece by playing it on the piano, her attention was totally focused on the score. Later, she struggled to put the two hands together and appeared more tense with each successive mistake until the introduction of Andantino.

Similar attitudes were observed for students in Study II. For example, student-2A's attention was totally fixed on the score during the entire practice session. When attempting to put the hands together, she focused so much on reading that she did not notice the mistakes that she made. Even though student-3B generally listened carefully and learned by imitation, there was one point where he read the score to practice one transition that was not covered by Andantino and Blocks. While reading the score, 3B's playing became detached, and he lost his usual richness in tone quality, which returned after one more listen to Andantino.

These observations demonstrate how the score may become a safety line that students cling to when they encounter difficulties. However, clinging to the score may not result in easier learning. In fact, these anecdotes show how reliance on interpreting symbols inadvertently leads to prioritize surface correctness at the expense of listening and expressive playing.

Andantino and Emotional Engagement
In the first study, the introduction of Andantino visibly lightened the mood of student-2. She asked curious questions about the figures ("What are their names?", "Did they eat dinner?", "Do they need water?"). She then practiced each voice in a duet with a figure playing the other voice. Students 1, 1B, and 3A also displayed visible delight at the figures' appearance. 1B could not help laughing whenever the figures appeared. He would dance along with their movements and practiced along with the figures on a higher octave.

In Study II's post-practice survey, all except student-2B indicated that Andantino is the easiest for memorization compared to Blocks and the score. Students were also asked to close their eyes when an audio snippet was played for them. All except student-1A imagined Andantino figures. These experiences suggest that the whimsy of Andantino figures appeal to children's imagination and help motivate practice. More longitudinal studies could be beneficial to observe how an evolving narrative around Andantino figures may continue to engage children in the long-term.

FUTURE WORK
Three main features may help improve Andantino's impact as a didactic tool based on what took place during the studies.

First, we could include indication for finger usage. Because the current system lacked the information, the teacher had to intervene on several occasions to show students how to play a tricky passage. To emulate the teacher's hands, we could also combine projections of a pianist's hands on the keyboard with Andante figures [32].

Second, we may add a speed control for the playback of reference materials. We noticed that the default playback speed for both Andantino and Blocks was too fast, and all students except 3A imitated the speed of the demonstrations by default.

Finally, Andantino may be improved by including a mechanism reminding students to listen (and not reinforce incorrect playing). The head of the figure could be used to give feedback to student. For example, if students consistently make a mistake, the face could turn to them with a funny expression and proceed to show the correct phrase. Introducing an element of comedy in error correction could help ease students' frustration and motivate them to try again.

Allowing a tool to be more didactic, however, doesn't always make for better learning experiences. We all know how annoying artificial help agents can be (smiley faces, unwanted for advice), and clearly, we wouldn't want Andantino to turn into a set of miniature explainers, rather than a reflection of our play!

CONCLUSION
On one level, this paper presented designs for a system to teach children how to play the piano inspired by Dalcroze Eurhythmics. We described the musical background behind our design, prototypes of our system, as well as salient observations from experiences with children. More broadly, this paper also serves as a primer on how to design more effective and enjoyable music learning environments for children in general. We outlined the main design challenges in the context of related work, presented a design

framework based on both domain literature and actual instructor's experiences, gave the example of our own system, and described results from its deployment. We hope that this work may guide other researchers to create their own systems to help children learn music in ways that are enjoyable, playful, and personally meaningful.

To conclude, we offer a guiding intuition behind our own work: the most felicitous (and fun!) learning occurs when children are able to project themselves into imaginary micro-worlds, in which they inhabit and explore. This is the equivalent of spontaneous play that children engage in with physical objects, like blocks, for intangible concepts. Body-syntonic, enactive representations afforded by interactive systems offer a portal into these worlds. This idea was pioneered by Seymour Papert for learning math and programming with the LOGO Turtle [18]. Our work took a step to explore it for learning music. We invite designers and educators to dwell on this idea to create their own microworlds for enjoyable, playful, and personally meaningful learning.

SELECTION AND PARTICIPATION OF CHILDREN
8 children, aged 7-13, were recruited from among the students of our collaborator. Prior to the study, ethical approval was obtained from the MIT Committee on the User of Humans as Experimental Subjects (COUHES). Children as well as their parents were told about the aims of the research and signed a form giving their consent to their data being used.

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