Cloud Rhymer: Prototype Demo and Intervention Proposal

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ABSTRACT
We present the theoretical framework and design of a technologically-mediated informal learning experience aimed at assisting students of all ages playfully engage in a language game for fun. The game's activities center around rhyming over a beat with a robotic companion. We ground the work in developmental psychology literature on the importance of early rhyming skills for children and provide technical details of a working prototype. Our work advances an informal learning intervention for children at-risk of developing reading disabilities. We propose a study using validated, evaluation measures and conclude with a detailed report on extensions to the system currently in progress.

Categories and Subject Descriptors
I.2.9 **[Artificial Intelligence]**: Robotics. K.3.1 **[Computers and Education]**: Computer uses in Education

General Terms
Design, Human Factors.

Keywords
Ludic language play, informal learning, HRI, rhyming robot, child-robot interaction, robot gaming.

1. INTRODUCTION
Most students learn in an institutional setting, such as a school. Students know what they are expected to learn and accept that learning will be controlled by the institution. Organizationally, formal education is a hierarchical system, usually with departments or ministries of education at the top and students at the bottom. Formal education implements a state-approved and regulated curriculum and hires certified teachers. Formal education commonly includes a period called 'basic education' usually ranging from six to twelve years and is made compulsory by the institution or state.

In contrast, informal learning is any activity involving the pursuit of understanding, knowledge or skill which occurs without the presence of externally imposed curricular criteria. [15]

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Figure 1. Cloud Rhymer robot

Learning theorist, Seymour Papert, whose influential theory of Constructionism (built upon Jean Piaget's Constructivist learning theories) asserted that:

"Children educate themselves best when they are free to follow their own interests."[20]

Intrinsic motivation to learn something because it is fun, is not exclusive to children but has been manifesting itself for a long time across multiple cultures. The integral role of informal learning has been reported by anthropologists describing education in early Hunter-Gatherer cultures:

"Children play to learn how to track 300 different species of birds and mammals and identify countless variety of roots, nuts and fruits. Children learn where to find these fruits and if they are edible." [14]

What's been observed is that children learn on their own through self-chosen activities, through play and exploration. A well-known example of a radically successful informal learning intervention is Sugata Mitra & Rana's (2002) minimally-invasive-education [17] and The Hole in the Wall project [18]. Another more accessible and widely recognized example of a successful informal learning intervention that has persisted (for over 40 years) in influencing positive learning outcomes by delighting millions of children throughout the world is Sesame Street [12]. When we visit museums or play a game we are engaging in informal learning.

There are several key attributes that characterize informal learning: it is voluntary, it is delivered outside formal school curriculum, it is contextual and organic, and it is activity and experience-based. Informal learning is managed by individual learners, not by teachers. Furthermore, informal learning can happen any time, anywhere and may arise in situations where learning is not the main goal.

This paper introduces Cloud Rhymer, an informal learning intervention designed as a “rhyme-on-time” child-robot interaction game. In the following Section 2, we ground our motivation to create this platform in child developmental literature with an emphasis on the importance of early rhyming skills. Section 3 summarizes the project and its goals. Section 4 gives details on the technical implementation of a working prototype of the system. In the fifth section, we discuss extensions to the system currently in progress and describe envisioned future interaction designs. The penultimate, sixth section presents the structure of the informal learning intervention and in section 7, the evaluation plan under consideration. In Section 8, we conclude and reflect on our progress through the intervention development process.

2. MOTIVATION

Rhyming is a fundamental skill for literacy development. Children are taught the alphabet using rhyme. Lullabies and songs are sung in time with a rhyme. Nursery rhymes are not just fun - they have an enormous educational value. A child’s awareness of rhyme and alliteration leads to robust development of phoneme detection [4]. Phoneme and syllable detection play a large role in learning to read [4][22]. Furthermore, children’s sensitivity to rhyme also makes a direct contribution to reading performance by helping them group words with common spelling patterns (segmentation). When we create effective assistive technologies that help bolster the age-old practice of rhyming for fun we create opportunities to affect positive change in a child’s life. Improved reading leads to academic success along with a healthier self-concept. Cook [6] classified ludic language play into two types: (a) play with language form: the sounds, the rhythm and rhyme and (b) semantic play or play with the units of meaning including the creation of new words and fictitious worlds. He states that although ludic language play is a central part of a child acquiring their first language, it does not diminish as the child matures into adulthood. In fact, the more advanced the learner, the more capable they are in participating in language play. Although the current working prototype, Cloud Rhymer, focuses on at-risk children, the framework is generalizable to a broad range of ages and can be implemented for first or second language learners.

3. PROJECT GOALS

Cloud Rhymer is a rhyming robot, connected to the Internet, that uses SMS text-messages from children to rhyme in time over a beat. The project has three core goals:

1. Develop and deploy an informal learning intervention with measurable learning outcomes using validated evaluation instruments.

2. Create a fun, rhythmically-gated child and robot interaction design for players to encounter words in an authentic yet playful way that relates to their own life.

3. Design a quality aesthetic experience that draws participants in whilst providing a content creation pipeline for expert players.

4. SYSTEM

The following section will describe the Cloud Rhymer system as implemented in the current working prototype. Although the most effective way to understand the system is to play with the robot or view a video of the interaction, this section specifies the system’s technical underpinnings in the context of a typical play sequence.

Cloud Rhymer is a simple, yet appealing, two degree-of-freedom desktop robot. Designed and fabricated by Peter Schmitt, the robot’s body is made out of CNC-milled Baltic Birch-wood. The base of the robot rests on a table and contains a power supply and an Arduino[2] microcontroller that’s been programmed to receive serial messages from an attached computer through a USB cable. The incoming serial messages are parsed by the robot’s micro-controller into motor movement commands. Two servomotors enable the robot’s head to pan (left to right) and tilt (up and down).

Cloud Rhymer’s robot control, cloud services (Internet-based searches and communication with custom server providing words to rhyme with based on incoming SMS text messages) are orchestrated in TouchDesigner[7], a powerful visual programming environment for rapid prototype development.

The robot control system acts in parallel with and in response to timing information based on the beat playing back or being actively composed and arranged in Ableton Live, a common audio production platform [1]. Cloud Rhymer’s robot voice is created with a modified version of a formant synthesizer [8] and layered atop percussion sounds synthesized in Native Instruments’ Maschine, a popular beat production instrument [19]. The robot control system is tempo-aware making it possible to adjust the periodicity of the beat and melodic phrases. Rather than analyzing the audio (a time and compute-intensive application) the robot control system receives low-bandwidth beat timing information from the audio system to keep the robot’s voice in time. Layers of music can be brought in automatically or manually as a way to develop the song or give player feedback.

5. INTERACTION DESIGN

One way to understand the current interaction design is as a series of steps in a typical play sequence.

1. Beat starts and robot’s head begins to bob in time

The robot synchronizes a low-frequency oscillator (lfo) to timing information (coming in over the network) and procedurally generates a head bobbing motion sent via serial to the robot’s servos through the embedded micro-controller.

2. Child player text messages a topic to rhyme

Cloud Rhymer provides player with a local number for text messaging, for example: (617) 4CL-RHYM. The player is instructed to send a single word and told it cannot be a proper noun.

3. Twilio API posts incoming SMS-text to private server

Upon arrival in a specific or new geographic area, the system purchases a local phone number using Twilio Cloud Communications and shares this number with players [21]. Incoming text messages are sorted, queued and posted to a custom web server that uses PHP to store and provide access to the information in a MySQL database.

4. Robot fetches topic

Cloud Rhymer contacts the web server and extracts words text messaged by players from server-side generated XML.

5. Robot creates rhymes

Cloud Rhymer robot inputs topic word sent by players to a web-based rhyming dictionary (rhymer.com’s REST API) and requests end-rhymes. Cloud Rhymer then scrapes through returned html to extract a list of rhyming words and procedurally sorts it (i.e. alphabetically)

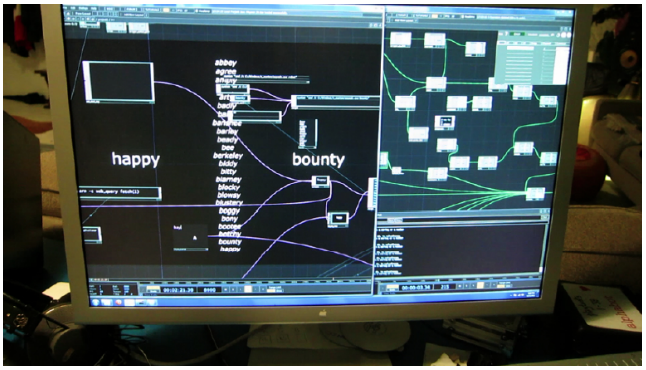

Figure 2. Cloud Rhymer's logic program

6. Robot rhymes in time and moves head

Individual rhyming words are sent to a custom robot voice synthesis program, written in C++ using the flexible and open source eSpeak speech synthesizer libraries [8]. It instantly renders an audio file of the robot speaking the requested word and queues the resulting waveform into memory. Using beat timing info, Cloud Rhymer rhymes on beat by playing back the audio file in memory as a vocal layer on top of the beat. It usually speaks at the beginning of a measure but the placement of vocal parts can be adjusted by the beat composer interactively. In this manner, the music maker has the flexibility of creating different rhyme schemas. As the robot speaks each word, Cloud Rhymer additively blends a quick but low amplitude extra head movement on top of the head bobbing. This brisk head movement overcomes the fact that the robot has no moving lips (or visual display of a mouth) and helps the player understand that the robot is currently speaking.

7. Continue rhyming and repeat from step 2

Cloud Rhymer will continue to rhyme, going down the list of words that rhyme with the messaged "seed word" until it receives a new text message and repeats the process starting again at step 2.

The aforementioned seven steps are currently implemented in the live demonstration of the working prototype. In a future version, we plan on supplanting the text-messaging action with a speech recognition interface to improve the sense of fluency. Cloud Rhymer could thus engage its audience in a dialogic turn-taking game: (a) beat begins, robot rhymes for a few bars and then says "Now its your turn…" (b) player rhymes while robot listens and (c) robot uses the last keyword player said to construct a new rhyme. By modeling the behavior, the robot teaches its audience how the game is played. Furthermore, the beat is used to gate the turn-taking and prompt player actions by letting them know when they should speak and when they should listen. Using the beat timing information to gate and segment the game flow is a useful technique, technically speaking, as most current speech recognition systems have trouble disambiguating speakers. The turn-taking provides the system with clear start/end boundaries for analysis.

6. OBSERVATIONAL STUDIES

Informal, observational studies of adults interacting and playing with Cloud Rhymer hint at its potential for being a fun and habit-forming game. Even when the robot was turned off, the authors and colleagues found themselves rhyming for no reason, rhyming for fun. Our hope is that this type of ludic language play can be really fun for children at-risk of developing reading disabilities at the same time be appealing to players of all ages.

7. PROPOSED INTERVENTION DESIGN

One of the core goals of this work is to propose and develop a structured informal learning intervention and evaluation. The following section describes the intervention book-ended by pre and post-tests to ascertain the effects and learning outcomes influenced by playing with Cloud Rhymer. Once the young participants' parents have consented to being involved and having their child participate, we plan to administer a pre-test (see Evaluation's Measures section 7.1.2) and deliver a rhyming robot to the home. A Research Assistant will train the child as well as the family on use. In order to affect change through repeated use, the parent/caretaker or close family member (i.e. older sibling) will need to agree to play together with Cloud Rhymer and the child 5 times a week for an 8 week period. At the conclusion of the intervention, we'll run the same tests administered in the pre-intervention phase along with an additional reading/word identification task.

7.1 Proposed evaluation participants

In the experimental group, 35 six to seven year old US children from families in which one of the close members has a known reading disability. In the control group: 35 six to seven year olds from same schools as children in the experimental group. In both groups, all children will be nominated for the study by parents.

7.2 Proposed evaluation measures

For the pre-test, our plan is to administer the Rhyme recognition test [5] to test phonological awareness. Additionally, we would run RICSA (Recognition of Initial Consonant Sound and Alphabet). [11]

For our post-test, following the intervention with Cloud Rhymer, we propose to run the same tests as in the pre-test phase and an additional reading/word identification task to test the child for correct word segmentation (phonemes) and spelling as in Liberman, Rubin, Duques and Carlisle (1985) or Fielding-Bamsley's measure as described in [10]: *Early intervntion in the home for children at risk of reading failure*. British Journal of Learning Support 18 (2):77-82, 2003.

8. FUTURE WORK

In addition to conducting formal experiments for collection of quantitative and qualitative data on this approach, which will help inform our continued design and development, we are also planning numerous technical and curriculum-based extensions to the current system.

Our infrastructure is set up such that, thanks to the rhymer.com integration, it can be easily extended beyond the current end rhymes (dog—log), to last syllable rhymes (hoard—keyboard), double rhymes (table—stable), beginning rhymes (star—stone), or first syllable rhymes (computer—compassion).

We also plan to exploit our existing capabilities to vary amplitude, pitch, speed (words-per-minute), inter-word pauses and different voices to provide a richer experience for speech output. This could, for example, be used to better adapt the robot's rhyming to prosodic features of the child's speech, as detected by the speech recognition engine that we plan to integrate in the next version.

In terms of content, we plan on constraining the rhyme list to categories of words (animals, body parts, etc.). Words chosen would be linked to in-class curricular goals and cognitively pre-tested for age appropriateness. Finally, integrating Cloud Rhymer with a nearby screen (computer or television) would allow us to implement a visual dictionary's display of the current word or word category.

9. CONCLUSION

Cloud Rhymer subscribes to the approach that children's input into an informal learning system should never be overshadowed by the system's capabilities (regardless of technical merits). Rather, the system should adapt to the individual players and increase the difficulty level based on the child's zone of proximal development. Our hope is that the prototype developed will be of interest to both interactive designers as well as educators looking for a novel way to use a fun and social robotic character to supplement children's critical vocabulary-building activities.

Our development efforts to date have yielded a working pipeline for a novel, robotic media platform for language play that is both extensible and potentially able to influence literacy and cognitive development in children at-risk of developing a reading disability. It employs best practices in the field of human-robot interaction, implements them in a child-centered cloud robotics framework while moving the technology into the background and focusing on the child's developmental needs, first and foremost.

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