

# Sociable Robot Improves Toddler Vocabulary Skills

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## ABSTRACT

We report results of a study in which a low cost sociable robot was immersed at an Early Childhood Education Center for a period of 2 weeks. The study was designed to investigate whether the robot, which operated fully autonomously during the intervention period, could improve target vocabulary skills of 18-24 month of age toddlers. The results showed a 27 % improvement in knowledge of the target words taught by the robot when compared to a matched set of control words. The results suggest that sociable robots may be an effective and low cost technology to enrich Early Childhood Education environments.

## Categories and Subject Descriptors

J.4 Computer Applications (Social & Behavioral Sciences); B.4.2 Hardware (Input/Output & Data Communications) Input/Output Devices.

**General Terms:** Algorithms, Design, Human Factors, Performance.

**Keywords:** Algorithms, Human Factors, Robotics, Ubiquitous computing

## 1. INTRODUCTION

An unprecedented number of children in the US start public school with major deficits in basic academic skills, including vocabulary skills [1]. Scientific evidence shows that children who have early failure experiences in school are those who are most likely to become inattentive, disruptive, or withdrawn later on. These same students tend to drop out of school early; and to depend on public assistance programs for survival. Empirical research using longitudinal randomized control studies is now showing that early childhood education programs can effectively prevent academic deficits [1]. However, due to their high costs, such programs may not find widespread use.

For the past 3 years and as part of the RUBI project we have been pursuing the idea of low cost sociable robots as tools to enrich early childhood education environments. During the first two years of the project we showed that long term social behaviors could be established between sociable robots and toddlers [1]. However the robot we used in the early studies had several disadvantages: It was very high cost, it did not operate fully autonomously, and it was not designed for teaching toddlers. In later years of the project we focused on developing low cost robots that could operate autonomously in the classroom and teach age appropriate materials targeted by the California Department of Education. In this paper we present our first

formal study using our latest prototype (RUBI-4). The study was designed to evaluate whether interaction with the robot could result in significant improvement vocabulary skills.

## 2. Robot Design

The design of RUBI-4 is the result of thousands of hours of field studies in which different robot prototypes were immersed for long periods of time at the UCSD Early Childhood Education Center (ECEC) at the University of California, San Diego. The design constrains were for the robot to be low cost, to support safe physical interaction with toddlers and to be able to operate fully autonomously for periods of time in the order of weeks.

### Hardware:

RUBI-4 is a 22x24x8 inch, low cost sociable robot designed to interact safely with 18-24 month old toddlers (see Figure 1). To avoid battery issues the trunk of the robot is stationary and can be powered indefinitely using a standard AC outlet. The robot sensors include a video camera, located in the nose, a microphone, 4 infrared proximity sensors, two in the body and two in the hands, 2 accelerators located in the body, and a 12-inch touch screen. The actuators are a 1 df head, 2 arms with 3 df each, a loudspeaker and the touch screen. The processing units include a Dual Core Mac mini, a MS Windows tablet controlling the touch screen, a Bioloid CM-5 servo controller, and Phidgets IO card.



Figure 1: RUBI-4 during early prototyping.

### Software:

RUBI-4 runs the CERT perceptual software and the RUBIOS robot architecture developed at the UCSD Machine Perception Laboratory at UCSD. CERT can detect upright frontal faces (plus minus 10 degrees) and analyze the expression of the detected faces using the facial action coding system (FACS). In this experiment the faces were only automatically analyzed for

presence or absence of smiles (AU 12). In addition to CERT, two additional modules were running under RUBIOS: An Emotion module and a Game Scheduler. The Emotion module controlled the dynamics of some simple emotional dimensions, including “fear”, “loneliness”, “ticklishness”, and “sleepiness”. The emotion model was implemented as a system of coupled stochastic differential equations tuned by hand using simple heuristics. For example, if the accelerometer detected excessive shaking, it increased the activation of the “fear” module. The emotional states modulated the interaction between sensors and actuators. For example, a large state of fear increases the probability of the robot crying and inhibits other interactive behaviors. The system connecting emotions and states was set up by hand and refined using field studies at ECEC.

There were two types of material presented on the touch-screen: (1) Songs. A popular song was sung by RUBI, which physically danced while a related video clip was presented on the screen. (2) Educational Games. Flash-based educational games targeting vocabulary development. For example, in one game 4 images were presented on the screen and RUBI asked to touch one of them (e.g., touch the orange). RUBI would respond to the children’s choices using its physical actuators. There were also physical games in which RUBI would take and give back physical objects given to it, using its two arms/hands. A game scheduler was in charge of starting and stopping the different games depending on the available sensory information. This was done based on an “interest estimator” which combined the number of touches received for the past minute and the number of faces detected. The parameters of the interest estimator were based on a statistical model we have previously presented [1]. The function relating the interest estimator to the game scheduling was set by hand using simple heuristics that were refined during field studies. In addition RUBI could give and take objects from the children using its two hands.

### 3. Experimental Design

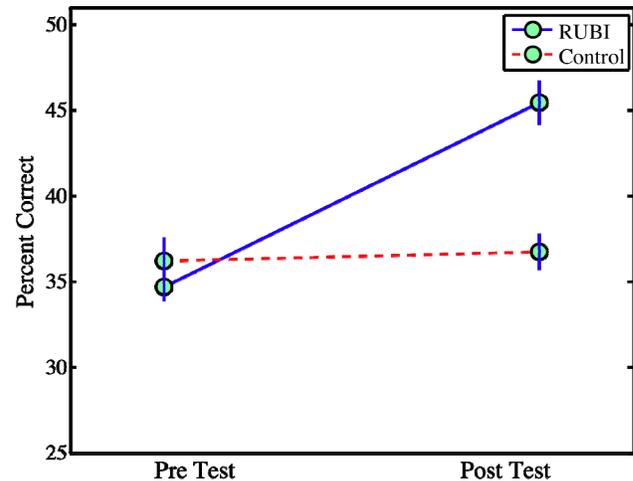
**Participants:** The 9 toddlers at room 2A of ECEC enrolled during the period of June 29 to July 17, 2008. The average age was 20.4 months the range was from 15 to 23 months.

**Materials:** 20 words from the MacArthur-Bates Communicative Development Inventory were selected and paired based on semantic similarity and frequency of use. A word from each pair was randomly assigned to either an *experimental group* of words or a *control group* of words.

**Procedure:** The study started with a *familiarization period* of 5 days over which RUBI interacted with the children but did not attempt to teach any of the words. After this period a *pre-test* was conducted to evaluate the children’s knowledge of the 10 experimental and 10 control words. The pretests were conducted one child at a time. On each trial the teacher sat close to the child, RUBI presented 4 objects in the screen and asked the child to touch one of the objects (e.g., “touch the orange”). The pretest ended when the child indicated that he/she did not want to play with RUBI anymore. The pretest was followed by a *treatment period* of 12 days (workdays from June 30 to July 15, 2008). During these 12 days RUBI was programmed to teach the 10 words in the experimental set and was left in the classroom to operate fully autonomously. After the 12 day treatment period a *post-test* was conducted to assess the children’s knowledge of the

experimental and control words. The design of the posttest was identical to the pre-test.

## 4. Results



**Figure 2: Results of the study. Vertical bars represent the margin of error (standard error of the mean).**

**Results:** Figure 2 shows the results. The dependent variable was the percentage of correct trials (chance is at 25 %). There was no significant change in the performance for the control words (36.2 % pretest vs. 36.7 % posttest). There was a statistically significant improvement ( $p < 0.01$ ) in the performance for the experimental words taught by RUBI during the treatment period (34.7 % pretest vs. 45.4 % posttest).

## 5. Discussion

The results show that RUBI had a significant effect on the average vocabulary score of the children. The effect was relatively large (a reduction of error of more than 25 %). Most significantly this was achieved using a low cost robot that operated in a fully autonomous manner using standard off-the-shelf components and software. The results are encouraging and open new scientific questions that we are currently analyzing: Did all the children benefit equally from interaction with the robot? If not, what were the predictors of improved performance? These studies may help develop new programs that would allow future sociable robots to adapt to the needs and specific characteristics of each student, the way good teachers do.

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