Using the Baby-Babble-Blanket for Infants with Motor Problems*  
An Empirical Study

Harriet J. Fell, Ph.D.  
Hariklia Delta, M.S.  
Regina Peterson, M.S.  
College of Computer Science  
Northeastern University, Boston, MA 02115

Linda J. Ferrier, Ph.D.  
Zehra Mooraj, B.S.  
Megan Valleau, M.S.  
Dept. of Speech Language Pathology & Audiology  
Northeastern University, Boston, MA 02115

Abstract

Children with motor problems often develop to be passive, presumably because of an inability to communicate and to control the environment. The Baby-Babble-Blanket (BBB), a pad with pressure switches linked to a Macintosh computer, was developed to meet this need. Lying on the pad, infants use head-rolling, leg-lifting and kicking to produce digitized sound. Data is collected by the BBB software on the infant's switch activations. An empirical study was carried out on a five-month-old infant with club feet, hydrocephaly and poor muscle tone to determine what movements the infant could use to access the pad, whether movements would increase over a baseline in response to sound, and what level of cause and effect the infant would demonstrate. Videotapes and switch activation data suggest that the infant:

1) could activate the device by rolling his head and raising his legs.
2) increased switch activations, over a no-sound baseline, in response to the sound of his mother's voice.
3) was able to change from using his head to raising his legs in response to the reinforcer.

KEY WORDS: infants -- communication and environmental control -- sound -- motor problems -- single-case study -- pad.

1 Introduction

Infants with severe motor problems, even those with apparently normal cognitive skills, frequently develop to be passive children with limited or nonexistent speech [1]. Seligman [2] has attributed this "learned helplessness," to an inability to control the environment. Other literature [3] suggests that even severely disabled infants can learn to control their environment through the use of micro-switch technology. At later ages, these children may spend many hours on floor mats with little to engage them or any means of communicating with caregivers. While there are now many environmental and communication aids for children who can touch a screen or activate a single switch with a limb, little attention has been given so far to harnessing very early movements, such as head-rolling, to activate assistive technology. A primary goal in developing the Baby-Babble-Blanket (BBB) was to develop and test a system that would allow even the youngest infant or most severely disabled child to control the environment and communicate while in a lying position. A second goal was to include an automatic data collection system that would demonstrate that the infant was controlling the system in response to the reinforcing consequences it provided. A final goal was to use the device to improve the motor abilities of these infants.

An interdisciplinary team including a speech-language pathologist, a computer scientist, and a physical therapist, developed the BBB. It will allow severely physically disabled infants to: 1) establish cause and effect skills, 2) explore a babbling repertoire like normal infants, and 3) use early motor movements to produce digitized sounds. We are testing the BBB in the home with normal infants, infants with cerebral palsy and other motoric problems, and in a school with multiply handicapped children. Data are presented on a cognitively normal five-month-old infant with poor muscle tone, club feet and hydrocephaly who used the device to hear his mother's voice.
The BBB (patent #5260869) is a multiple micro-switch-activated pad serving as input to a Macintosh computer and our software. The software allows digitized output of speech, babbles, words, sentences, music or environmental sounds, to be accessed by the switches. The BBB includes a data collection system that uses a single-case study design to evaluate the responses of infants who are otherwise difficult to test.

2 Specification of the BBB

The "Baby Babble Blanket," a Macintosh based system (See Fig. 1.) includes the following components:

1) An input device, a blanket the infant lies on, that includes 12 switches. This is the Powerpad™, a device developed by Nintendo for computer games (but regrettably no longer produced.) It is a plastic, waterproof blanket that includes large pressure sensitive switches ten inches apart. The blanket consists of two layers of polymer plastic separated by urethane sponge material to inhibit inadvertent contact of the outer layers unless they are overtly pressed together. One inch holes in the sponge allow contact under pressure. The inner surfaces of the polymer are imprinted with a conductive material. The conductive material pads are brought together to a single location so that they can be connected to an output connector. The device is then hooked up to the computer via a standard cable connection. Pilot investigation showed that the pad can be activated by infants weighing less than twenty pounds.

2) A Macintosh computer control system that connects with the Powerpad via a Gold Brick™ interface box (Transfinite Systems Inc.), and is commercially available.

3) The Hypercard software we have developed that carries out the following functions: selection of particular switches to be activated by the infant, depending on the particular pattern of motor movement available to the infant and the positioning of the infant on the blanket; assignment of sounds to particular switches; collection of data on the infant’s switch activations.

4) A graphing and data analysis program that summarizes the number and type of switch activations over time in a variety of formats, graphs them, and provides summary statistics.

5) Customized sound selection: Digitized sounds are entered into the Macintosh computer using the MacRecorder™ (Farallon, Inc.) or the Macintosh built in microphone. Sounds can be spoken directly into the microphone or entered from recordings through a line-in from a tape recorder. These can then be stored in a sound library. Alternatively, sounds can be selected from libraries of sounds supplied with the software. These include babbles at different developmental levels, early words, environmental sounds, and short sequences of music. The sounds can then be allocated to particular Powerpad switches.

2.1 Single-Case Study Software

Single-case study experimental designs [4] are particularly suited to intervention with severely impaired and multiply handicapped children since they provide the freedom to conduct studies on small groups of heterogeneous subjects. The children we are studying are heterogeneous, since they are diagnosed at different ages, and have different levels of motor and cognitive ability.
A requirement of single-case study experimental design is that the recorded data must consist of observable behavioral events. This frequently presents difficulty with children with motor and cognitive deficits whose responses often appear random or difficult to read. With the use of the BBB, the observable events are switch activations, that can be counted and tabulated by the program. While it may be assumed that some switch activations by infants with motor problems are the result of involuntary muscular activity, we expect that, with repeated exposure to the device, most infants will have sufficient motor control to respond to the sound output with a change in the frequency of switch activations. Through these changes in switch activations across time and in response to different sounds, we can evaluate how responsive the infant is to sound. We can track how quickly s/he learns to activate switches to hear the sounds, and whether s/he prefers one sound to another.

The fact that the software will record the switch activations has many experimental advantages: It eliminates the error of a human recorder; and it can record many data rapidly across many sessions. By examining the patterning of switch activations across time, in multiple sessions and with different reinforcers, we have a clear record of each child’s ability to learn. Unlike large group designs that rely on statistical analysis of data, single subject experimental case study designs utilize visualization of data, usually displayed in a line or bar graph format. One advantage is that statistically unsophisticated parents, teachers, or clinicians can determine by the slopes of the data in different phases, baseline versus treatment, whether the child is responding to the system.

2.1.1 Design and Data Collection Formats

The program at this point allows data collected in a variety of formats. These include:

1) Baseline or no sound
2) All sound-bound (A single sound is assigned to each switch.)
3) All sound-random (A set of 12 sounds is stored under each switch. Each switch activation selects a sound at random from the set.)
4) ABA (No sound, sound, no sound)
5) Totally random (sounds are randomly selected from sets but are unconnected to switch activations. This format allows us to test whether infants show an increase in movement in response to the noise that is to unrelated to their ability to cause the sounds occur.)
6) Single switch (Only one switch results in sound, but data are collected on all switches.)
7) Half and half (Six switches on half the blanket produce sound but data are collected on all switches.)

2.1.2 Configuration capabilities

The software has been designed to be used by one or many children in one day. The software can be setup differently for each child (See Fig. 2.) and remembers these individual configurations: the child’s name, session format, sounds and switch assignment. At each restart it opens with the last setup for easy use with a single child. Data on each session of use are automatically stored with the child’s name, data of session and time of day. This helps with later sorting and examination of data. Configuration for a new child is simple and can be carried out by a computer-naïve person.

2.1.3 Graphing program

A separate graphing program allows the parent, teacher, or clinician to view the total number of switch activations per minute and the number of times each switch was activated. Following the convention of single-case study design, switch activation frequencies are represented in an easily visualized form. The frequency of switch activations per minute is pictured in either bar graphs or numerically; the frequency of activations of particular switches is portrayed as bullets that vary in size or numerically. (See Fig. 3.)

2.1.4 Summary statistics

While single-case study design has generally relied on graphing of information, rather than statistical procedures, more recently researchers suggest that statistics may indicate trends that are not easily visualized. We feel that both forms of data are valuable and have built into the program summary statistics for each session including means and standard deviations. These may be particularly valuable for the study of at-risk infants whose responses are extremely variable from session to session.
3 Cause Effect Skills

Cause and effect is the understanding that an action brings about a consequence. For infants to use the BBB, they must have an elementary understanding of this notion. Normal infants, by exploring their environment, gradually develop the concept that an action brings about a consequence. The infant's early attempts at vocalization may be seen, in part, as explorations of cause and effect using the vocal mechanism. They also develop action schemata, such as banging and shaking, that are reinforced by interesting consequences (5). Physically disabled infants are frequently limited in their ability to explore the environment as well as to vocalize and, consequently, are slow to develop the concept of cause and effect. Interactions with objects as well as interactions with caregivers are often delayed. Lack of efficient motor ability effectively forces the child into a deprived environment. By using the BBB from an early age, infants with motor problems will be able to explore cause and effect.

Developmentally, cause-effect skills emerge over an extended period of time. The stages are described by Brinker and Lewis below. To answer the question -- At what age/developmental level can infants use the BBB for cause-effect -- we needed to establish, for each infant, the highest level of cause-effect skills achieved. The stages described by Brinker and Lewis (6) were appropriate for this purpose and we used them to establish operational definitions in terms of the BBB.

3.1 Stages of cause-effect development:

Stage 1) Primary circular reaction - generalized whole body activity in response to a reinforcing event. (Operational definition in terms of the BBB: Increase in total switch activation with sound output over baseline condition with no sound output.)

Stage 2) Secondary circular reaction - repeated use of one body part to bring about a response.
Normal children have completed this learning in the first year of life; some severely handicapped children have not learned this sequence by three or four years of age.

4 Research Methods

While the BBB was designed as a communication aid, in this case study, the focus was the potential of the BBB to train the infant in cause-effect skills and to increase muscle tone by reinforcing particular body movements. Preliminary questions on the use of the BBB include:

1) What motor movements can be used to activate the Powerpad?
2) At what age/developmental level do infants with motor problems understand the concept of cause effect, by reference to the stages described above?
3) Can the BBB be used to increase activity of particular body parts to increase muscle strength?
4) What stage of cause and effect can these infants reach?
Our own observation combined with those of parents, day-care providers and physical therapists answered the first question. Since the movements used to activate the switches are also manifestations of cognitive abilities, data on switch activations simultaneously provides answers to question two through four.

4.1 Experimental Design

The study employed a single subject experimental, multiple base-line design across behaviors with one male infant with poor muscle tone, hydrocephaly and club feet. Data were collected automatically by means of the BBB software. This subject met all entry criteria -- the subject should have at least one non-reflexive movement that could be used to activate the BBB as determined by a physical therapist, normal vision and hearing, and a cognitive developmental level under six months of age.

4.2 Subject Description

J.O. was five months old when he entered the study; he had motor problems, but normal cognitive abilities based on an observational assessment. Vocalizations and social interactions were normal for his age. As treatment for his club feet, his legs were in casts for the first four months of life but were removed immediately before the study. In his case, we had a particular goal of improving his motor skills, particularly leg movements. Motor skills were at a one month level with scatter up to two months for which he received physical therapy. The study on this subject was of limited duration since he was scheduled for surgery to repair his feet.

4.3 Home-Based Study Procedure

Researchers paid a preliminary visit to give a demonstration of the BBB and to provide information on the project. They explained the social validation form, which was filled out each time the BBB was used. The form provided information on the child's general state of alertness and comfort level, as well as any incidents such as illness or shots that might account for unusual behavior on the part of the child. A physical therapist then paid a visit to advise on positioning the infant on the BBB and to ensure that no reflexive movements would be reinforced by use of the BBB. J.O.'s Mother placed him on the blanket five times a week at a time of day when he was alert and in a good mood and completed a social validation form for each session. For each session she placed the infant in the same position, on his back, with head, bottom and feet each on a switch. If, during the session, the infant moved off a switch, she was instructed to reposition him back on the switch. She stayed within earshot and sight of the infant and responded to child as she would normally.

4.4 Validity of the data

In order to ensure that the system was acting reliably and to check the infant's movements, researchers videotaped a session in the infant's home every two or three weeks. These videotapes were compared with switch data. Data on any session with more than one minute of crying or fussing were discarded and the session was repeated.

4.5 Switch data collection

In order to establish a base-line of motor movement, J.O. was placed on the blanket for five sessions in a base-line condition, i.e. with no sound output. To determine whether J.O. would increase his overall level of activity in response to sound reinforcers, he was placed on the blanket for an additional five sessions with the software in the all sound, random condition in which all switches were capable of producing the same sounds. In the random mode upon activation, each switch accessed one of a set of 12 sounds. This prevented the infant habituating to the sounds. To determine whether J.O. was able to control a particular body part (head versus bottom), the software was used in a single switch format in which sounds were produced by the use of only one body part (head) but data was collected on all switches. The switches were then reversed so that sounds were produced only by the switch under the infant's bottom but data was again collected by all switches.

4.6 Reinforcers

The reinforcers for this study were digitized samples of J.O.'s mother's speech since the literature indicates that infants respond to their mother's voice from the first months of life. The utterances were short routines that J.O.'s mother used frequently with her infant. Used in the random format (section 2.1.1 item 3) they mimicked very well a mother's normal interactions with her infant. All sounds, for scientific purposes, were two seconds in length.

5 Results

The first question we asked was which motor movements would the infant be able to use to activate the BBB? Lying on his back, J.O. was able to activate
two switches easily -- the switch under his head by rolling his head from side to side and the switch under his bottom by raising his legs. Even though his head was large and his legs had been used little while the casts were on, J.O. quickly learned to move his head and legs. Data on switch activations provided numeric information on the increase in movement. The physical therapist was pleased with this increase in movement which was appropriate for her goals for J.O.

The second question we asked was whether cause effect skills would be evident in a five-month-old infant. Baseline switch activations showed very little movement, with a range over the five sessions of 0 to 3.87, and a mean across sessions of 1.13. With the sound of his mother's voice as a reinforcer in the random version of the program, J.O. caused the frequency of switch activations to increase considerably to a mean over the five sessions of 11.75 and a range of 6.33 to 18.25 switch activations per minute (Fig. 4). This was an indication that J.O. had reached the first level of cause and effect behavior and that, even with little or no previous practice with that movement, he learned to raise his legs to hear his mother's voice.

To answer the question whether J.O. reached Brinker's second level of cause and effect, refer to Fig. 5, summarizing switch activations when sound was introduced under first switch 3 (bottom) and then switch 6 (head). In J.O.'s case, the graphed data suggests that J.O. was able to switch from using one body part to another in response to the reinforcer of his mother's voice. As expected, with his normal cognitive abilities, J.O. was able to activate the BBB with two body parts and to increase one movement over another to elicit a reinforcing stimulus. The BBB was not used for a long enough period to determine whether the increase in movement had also brought about an increase in muscle strength. However, we believe that regular use of this system, perhaps with regular changes of reinforcers to maintain the level of interest, would increase the strength of the muscles used to activate the switches.

6 Discussion

While there is now an emphasis on early intervention with children who have disabilities and legislation to provide these infants with services, there are few devices that cater specifically to the control and communication needs of this age group.
Most communication and environmental control systems assume the infant is sitting and able to activate at least a single switch with a limb. However, these infants spend the majority of their time lying on floor mats or in a variety of positions in which access to a communication system by the usual methods is not possible. This is also true of older children with severe motor problems. The BBB overcomes this by utilizing a pad with pressure switches that even a very young infant can control with early developing movements.

A second limitation in working with these infants is the variability in their attention states, even more marked in infants with neurological problems. Consequently, it is difficult to establish whether these infants are really responding to the device or moving randomly. The data collection capabilities of the BBB software allow for careful monitoring of these infants' behaviors across time in response to different sound reinforcers. This information may be important diagnostically to determine the cognitive status of these children. In addition, it measures the amount of movement that can be reinforced by suitable digitized sounds. Finally, digitized sounds are now a useful resource for reinforcing young infants, or for a communication system, whichever is appropriate. We have preliminary evidence that the five-month-old infant in this study learned to use the BBB quickly to hear his mother's voice and was capable of activating it with two different early movements.

References


