Single-Switch Computer Access for Infants and Toddlers

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Computer access was studied with children between the ages of 6 months and 18 months with no known handicapping conditions. The research focused on determining at what age young children can access a computer using a single-switch system to run a simple cause-and-effect program. The sample consisted of 80 children divided into four groups (6 to 8 months, 9 to 11 months, 12 to 14 months, and 15 to 17 months). Results demonstrated that some children as young as 6 months of age could control a computer-based, cause-and-effect program using a single-switch access system. Therefore, professionals who work with children with disabilities may consider introducing computers to children at this age or to children who are functioning near this cognitive developmental level.

The normal process of development in which children experience consistent co-occurrences between behavior and environmental consequences leads to the expectancy that the world is controllable. According to Brinker and Lewis (1982), when children experience the effect that their behavior can have on the environment, they become motivated to attempt to control their environment in a variety of ways. As they experience success with these attempts, they are able to apply the same principles to other experiences and skills (Hildegard, 1988). Children who have motor impairments (e.g., those who have cerebral palsy or arthrogryposis) may have limited opportunities to experience consistent co-occurrences between their behavior and environmental consequences. These children may not develop the concept that they can control their environment, and may therefore begin to lose interest in their environment (Brinker & Lewis, 1982); consequently, these children may develop learned helplessness (Abramson, Seligman, & Teasdale, 1978).

Learned helplessness is generally viewed as the perception that one cannot control the outcomes that one experiences (Abramson et al., 1978; Weisz, 1979). Children with disabilities frequently experience more failure early in their lives and have a harder time recovering from failure (Dean & Rattan, 1987; Weisz, 1981). Therefore, it seems likely that these children will develop more learned helplessness than their peers without disabilities. The long-term effect of failure may be that these children do not learn cause-and-effect, choice-making skills, ways to exert control over their environment, or other perceptual-cognitive skills that are important in the normal process of development (Lahm, 1989; Lewis & Goldberg, 1969). Children who miss the experience of control may become passive and unmotivated school-aged children who give up trying to interact or communicate effectively with their environment (Douglas, Reeson, & Ryan, 1988). Thus, there is a need to explore ways for children with disabilities to learn that they can exert control over their environments and experience real success. This, according to Abramson et al. (1978), is a way that helplessness can be reversed or prevented.

Assistive technology is one possible means for children with physical disabilities to exert control over their environments. Appropriate devices can provide these children with the experiences of co-occurrence and increased interaction and control. The computer, through systems such as communication augmentation and environmental control, can provide a means for young children with physical disabilities to control, manipulate, and explore their world (Behrmann & Lahm, 1984). Children with limited motor skills who use the computer at an early age may have the advantage of applying and benefiting from technology throughout life.

Typically developing children learn co-occurrence and cause-and-effect relationships by physically manipu-
lating objects in their environment (Castle, 1985). Children with physical limitations can emulate this learning pattern by using a single-switch control to run a computer program. This system allows for the pairing of a single input to an environmental response and gives children the opportunity to learn that they can control their environment.

One of the challenges for the occupational therapist is to determine the age or developmental level at which to introduce the computer to children with motor impairments. It is inefficient to present the computer before the child is developmentally ready; however, because it is difficult to unlearn helplessness once it is learned, it seems desirable to introduce the computer as soon as the child is ready. To make optimal clinical decisions about the introduction of the computer to children with motor impairments, therapists need guidelines regarding the age at which typically developing children can begin to play simple cause-and-effect games on a computer. Even though recent literature reflects many possibilities for improving the quality of life for persons who have disabilities through use of computers (Lahm, 1989), little research has been carried out that addresses very young children with disabilities. However, at this time limited conclusions have been drawn (Behrmann, 1984), and further research is needed.

The purpose of this study was to determine the age at which young children with no known physical and cognitive limitations can access a computer using a single-switch system to run a simple cause-and-effect program. The following research question was addressed for children in each of four age categories (6 to 8 months, 9 to 11 months, 12 to 14 months, and 15 to 17 months): After a maximum of 5 min of training, what percentage of children are able to competently access a single-switch system to play a simple cause-and-effect game on the computer?

Method

Sample

The convenience sample consisted of 80 children divided into four groups (6 to 8 months, 9 to 11 months, 12 to 14 months, and 15 to 17 months). There were 10 girls and 10 boys in each age group. Because children develop rapidly between the ages of 6 and 18 months, the decision was made to break down the age categories into 3-month intervals. Each child had to meet the following criteria: (a) be between the ages of 6 and 18 months; (b) not have been born more than 4 weeks premature; (c) not have any known developmental deviations (physical or mental) as identified by parent report and the Denver Developmental Screening Test (DDST); (d) not have had any known medical condition (i.e., chronic lung disease, serious heart defect) during or shortly after birth that might have affected the child’s performance; and (e) not have been identified as having a visual or auditory deficit.

Testing was completed on 84 children, but data from four children were excluded because they did not meet the inclusion criteria. The actual age ranges of the children in each age grouping were as follows: 6 months, 2 days to 8 months, 28 days; 9 months, 5 days to 11 months, 27 days; 12 months, 0 days to 14 months, 22 days; and 15 months, 1 day to 17 months, 29 days. Most of the children who participated in the study were white. Most of the mothers of the children were white, five were Asian, and one was Hispanic. All of the fathers were white except for one who was a Native American and one who was Hispanic. On the parent questionnaire, parents indicated the number of years of formal education completed. Responses varied; 30% of the mothers had completed 12 years of school; 19% had completed 14 years; 39% had completed 16 years; and 12% had completed 20 years or more. Of the fathers, 24% had completed 12 years of schooling; 21% had completed 14 years; 39% had completed 16 years; and 16% had completed 20 years or more.

The children were recruited from cooperative preschool programs in the Seattle-Tacoma area and eastern Washington state as well as from developmental programs (swimming and gymnastics) at the Tacoma YMCA. Parents who participated in the study also referred friends whose children fit the inclusion criteria to the study. The parents were fully informed as to the purpose of the study and signed a consent form in adherence to the University of Washington’s Human Subjects’ requirements. All participation was voluntary, and subjects had the option to withdraw from the study at any time. The children were tested per protocol as they became available until the desired number of girls and boys in each age group was obtained. Data were collected even if the child appeared to have some delays in development or did not meet one or more of the other inclusion criteria for the study. In those cases, the child’s data were not used for the study.

Instrumentation

Screening Test

The DDST (Frankenburg, Camp, & Van Natta, 1971), which has demonstrated reliability and validity (Frankenburg, Goldstein, & Camp, 1971; Frankenburg, Sciarillo, & Burgess, 1981; Stowers & Huber, 1987) was administered to each child to determine whether there were any early indications of developmental concerns. When the DDST was scored, if the child did not demonstrate scores within the appropriate range for his or her developmental age level (if the child had scores that were questionable or abnormal), that child’s data were excluded from the study. As previously indicated, this occurred for 4 of the 84 children tested.
Computer System

An Apple IIGS computer system¹ with a color video monitor was used for data collection. This computer system was chosen for two reasons. First, Lahm has maintained that “color and realism of graphics are important when working with young children on computers” (1989, p. 24). Therefore, the color monitor of the Apple IIGS was chosen to make the computer graphics more interesting for the young child to interact with during the study. Second, the Apple IIGS system was the easiest of the available computers to adapt for the specific needs of this study.

Switch

The switch used during this study was a 3-in. × 5-in. touch switch developed by Rehab Equipment Systems Manufacturers² in Seattle. It was medium blue and provided little tactile or auditory feedback. These characteristics were intended to decrease the likelihood of a child hitting the switch because of interest in the switch itself rather than to activate the computer. A single switch was chosen instead of the standard keyboard because the switch appeared to be a more age-appropriate access system for the young child’s motor and cognitive abilities. Before data collection it was determined that typically developing children between 6 and 18 months of age had the motor skills necessary to activate this switch.

Software

The program used during this study was an adaptation by Anson and Swinth of the public domain software “Switches, Pictures and Music”³. For the purpose of this study, it was called “Switches, Pictures and Music II.” This program was controlled through use of a single, normally open switch. When the child closed and then released the switch, the program played approximately 6 sec of a common children’s song such as “Bingo” or “I’m a Little Teapot” while displaying a face that alternately winked and smiled at the child. When the music stopped, the child was required to hit the switch again to get the action to restart. Therefore, the child had to press and release the switch each time between songs to control the program. If the child kept a hand on the switch so that it was continuously closed, the computer would not continue to play the song for longer than 6 sec or start the next song. There were 12 different songs in this program. During the testing, the musical sequence of the program was standardized. Additionally, during the testing sequence, an internal timing loop in the program provided the data collector with a prompt to give the child a verbal cue at 10 sec and a second prompt to activate the program for the child at 20 sec.

Procedure

Pilot study: Before data collection, a pilot study that used a sample of four children, one from each age group, was conducted to finalize the procedures for data collection. No problems were noted with the procedures during this pilot study, so no changes were made in the data collection protocol or any of the data collection sheets. The data from these pilot subjects were not used in the study.

Training of data collectors. Data were collected by the primary investigator and two other professionals (one physical therapist and one physical therapy assistant) who had experience both with computers and with children. The data collectors were provided with information on the computer system being used and were trained in the data collection protocol to ensure that all data collectors followed the same procedures. Each data collector was involved in two training sessions. During the first session, each observed a data collection session with one child; during the second, each was observed following the complete research protocol for one child by another data collector. Procedural agreement was checked with a modified approach as described by Billingsley, White, and Munson (1980). Using the point-by-point agreement ratio (Kazdin, 1982), all data collectors achieved 100% procedural agreement before they collected data on their own. Midway through the study, procedural agreement was checked again for all three data collectors and found to be 100% for two and 98% for one. Scoring reliability checks on timing, percentage correct, and attending skills also occurred two times during the study at random intervals. On both occasions, agreement (with use of a frequency ratio) was 100% for all three data collectors for all variables.

Data Collection

The data were collected at Custer Elementary School in the Clover Park School District, at the local YMCA, and at the home of the primary investigator. As previously mentioned, once a child began the study, data were collected per protocol even if the child appeared to have some delays in development as indicated by the DDST or did not meet one or more of the other inclusion criteria for the study. In those cases, the child’s data were not used for the study.

When the child and his or her parent entered the room, the data collector first explained to the parent what activities the child would be performing and then gave the parent a consent form to read and sign. After the

¹Manufactured by Apple Computer, 20525 Mariani Avenue, Cupertino, California 95014.
²This company is no longer in business.
³Available from Colorado Easter Seals, 5755 West Almeda Avenue, Lakewood, Colorado 80216.
consent form was signed, the DDST was administered to the child, was scored after the data collection session, and was used to ensure that the child was functioning within normal limits for his or her chronological age. After the administration of the DDST, the data collector had the option of spending up to an additional 10 min playing with the child to establish rapport. Toys were not used during this time. The data collector and the child played simple finger and hand games (e.g., patty-cake and itsy bitsy spider) or played with puppets. This time was needed for only 3 out of the 84 children tested. For the rest of the children, the interaction during the administration of the DDST was enough to establish rapport. After rapport was established, the child was seated in front of the computer in a high chair with a tray. A foam insert was used with the smaller children to provide trunk support and height. The high chair positioned the child comfortably with a stabilized trunk and allowed for freedom of movement of the upper extremities. The computer screen was approximately 2 ft in front of the child and at eye level (see Figure 1). The area around the computer and child was devoid of distractions as much as possible to help the child attend to the computer rather than to other objects or persons in the room. The child’s parent was allowed to sit to one side of the child, where he or she could observe the procedures. During the training session, the parent was allowed to interact with the child and provide reinforcement for learning along with the data collector. During the testing portion of the data collection sessions, instructions were given to the parent not to provide the child with any additional directions or help. At this time, several parents removed themselves from their children’s sight because they thought that they were distracting their children or that it would be difficult not to give their children cues. All data were recorded on the data collection form. Once the child was seated according to protocol and the parent was seated comfortably, the data collector started the training session.

Training

The training session involved three steps. First, the data collector placed the switch so that it was within easy reach of the child and anchored it with self-gripping fastener at midline on the tray. The fastener was placed so that it would be difficult for the child to pick up or play with the switch during the data collection session. Second, the data collector showed the child the switch and what happened when it was pushed and released. Finally, the practice and training session was initiated. The data collector did not start the session if the child appeared uncomfortable, anxious, or afraid of the computer. If the child was visibly upset (crying, throwing a tantrum, pushing or looking away from the task, refusing to sit in the high chair, etc.), the child was given more time to acclimate to the situation. During the timed practice and training session, the data collector gave the child verbal and physical prompts and reinforcement as needed. As previously noted, the parent also was allowed to provide reinforcement during this time. A 5-min time limit was chosen for this session because during the pilot study it was determined that children were able to learn the task in this amount of time or less. The session was discontinued earlier than the 5-min maximum if the data collector felt that the child had adequately learned the task. Learning was demonstrated by either two consecutive correct responses with or without verbal cues within 5 sec of each opportunity or four consecutive correct responses with or without verbal cues within 10 sec of each opportunity. The amount of time taken for this session was recorded on the data collection form to the nearest second up to the 5-min maximum.

Test

Once the child had completed the practice session, the data collector tested the child’s proficiency at the task. The switch was removed from the child’s reach for 15 sec while the data collector loaded the test disk into the computer. This disk was the same as the practice disk, except that it had a standardized set of six songs and an internal timing loop to cue the data collector at 10 and 20 sec. The child was given 10 opportunities to activate the program. The data collector placed the switch back on the fastener after the test program was loaded into the computer and waited for the child’s response. If after 10

Figure 1. Position of the child, high chair, and computer monitor.
sec (as indicated by a slash mark in the lower right corner of the computer screen) the child did not respond, the data collector gave the verbal cue “Make the music go.” If, after another 10 sec from the verbal cue (as indicated by an asterisk in the lower right corner of the computer screen), the child still did not respond, the trial was scored as an incorrect response. The data collector then took the child’s hand and helped the child activate the switch, and the steps described above were repeated. If after another 10 sec from the verbal cue (as indicated by a slash mark in the lower right corner of the computer screen), the child still did not respond, the trial was scored as an incorrect response. The data collector then took the child’s hand and helped the child activate the switch, and the steps described above were repeated. If the child responded without the verbal cue or within 10 sec after the verbal cue, it was scored as a correct response, and the test was continued as described for up to 10 opportunities to independently access the program. If the child responded correctly for the first 5 opportunities, the testing was discontinued, and the child was considered to have obtained competency on the task. If the child missed any one of the first 5 responses, then all 10 opportunities were presented. For the child to activate the program, he or she had to hit and release the switch each time. It was scored as an incorrect response if the child kept a hand on the switch indiscriminately.

At the end of the session with the computer, the parent and data collector each filled out a short questionnaire. The data collector recorded information such as the child’s method of hitting the switch, the interest level of the child, and the behavioral responses by the child (e.g., smiling and verbalizations). Finally, the data collector rated the child’s attending behavior on a four-point scale: 1: attended consistently throughout the task; 2: occasionally distracted, but it did not appear to interfere with task; 3: occasionally distracted, and it did appear to interfere with task; 4: consistently distracted during the task). The parent recorded demographic information, answered questions related to the inclusion criteria, addressed whether the child had had previous experience with cause-and-effect toys or computers, and reported perceptions of the activity and the child’s responses.

Results

Results relating to the percentage of subjects meeting criteria for success with cause-and-effect computer activities are reported in Table 1. There did not seem to be a difference in the overall performance of the average total scores of boys versus girls.

The average amount of practice time used decreased as the children’s ages increased. The average amounts of practice time for each age group were as follows: 6 to 8 months - 4 min, 35 sec; 9 to 11 months - 4 min, 30 sec; 12 to 14 months - 3 min, 24 sec; and 15 to 17 months - 2 min, 6 sec. The number of children who lost interest in the task (i.e., playing with the switch but not activating the computer program; turning excessively in the high chair, indicating they wanted to get out of the high chair, not looking up or responding when the computer program was activated) was consistent throughout the age groups (see Table 2).

Attending skills were rated by the data collector on a scale of 1 to 4 as described previously. In the 6-to 8-month age group, 3 children had difficulty attending to the task (they obtained ratings of 3 or 4 on the scale). Of those children, none were successful with the task. In the 9-to 11-month age group, 6 children had difficulty attending to the task, and again, none were successful with the task. In the 12- to 14-month age group, 6 children had difficulty attending, but 2 of those children were able to perform the task. Finally, in the 15- to 17-month age group, 3 of those children had difficulty attending to the task, and none of those children were able to complete the task.

The child’s walking status also was rated 1, 2, or 3 with use of the results from the DDST. A rating of 1 meant that the child was not walking or pulling to stand; a 2 meant that the child was just learning to walk, which included pulling to stand, cruising, or walking up to three or four steps independently; and a 3 meant that the child was walking for more than five steps. In the 6 to 8 month age group, 3 of the children were just learning to walk and none of the children were walking. Of those children who were just learning to walk, all of them were able to demonstrate competency on the single-choice activity. In the 6- to 8-month age group, 3 of the children were just learning to walk and none of the children were walking. Of those children who were just learning to walk, all of them were able to demonstrate competency on the single-choice activity. In the

| Table 1 | Percentage of Subjects Meeting Criteria for Success With Single-Choice Activity |
| --- | --- | --- | --- |
| Group | Total | Boys | Girls |
| 6-8 months | 60 | 60 | 60 |
| 9-11 months | 55 | 50 | 60 |
| 12-14 months | 55 | 50 | 60 |
| 15-17 months | 85 | 80 | 90 |

Note: For the purpose of this study, competency (criteria for success) is defined as (1) the child obtains 100% on the first five trials of the test, or (2) the child obtains 80% accuracy on ten trials.

| Table 2 | Amount of Practice Time and Subject’s Performance on the Single-Choice Activity |
| --- | --- | --- | --- | --- |
| Group | Did Not Demonstrate Competency | Demonstrated Competency |
| Lost Interest in Task | Took All 5 Min of Practice | Took All 5 Min of Practice |
| Before 5 Min | % of Children | % of Children | % of Children | % of Children |
| 6-8 months | 3 | 15 | 5 | 25 | 7 | 35 | 5 | 25 |
| 9-11 months | 2 | 10 | 7 | 55 | 4 | 20 | 7 | 35 |
| 12-14 months | 3 | 15 | 6 | 30 | 2 | 10 | 9 | 45 |
| 15-17 months | 3 | 15 | 0 | 0 | 4 | 20 | 15 | 75 |

Note: n = Numbers of children out of 20.
9 to 11 month age group, 4 of the children were not walking, 12 of the children were just learning to walk, and 4 of the children were walking. Of those children who were not walking, one child did not demonstrate competency on the single-choice activity; of those who were just learning to walk, 4 children did not demonstrate competency on the single-choice activity; and of those who were walking, none demonstrated competency on the test. In the 12- to 14-month age group, 7 of the children were just learning to walk and 13 of the children were walking. Of those children who were just learning to walk, 4 children did not demonstrate competency on the single-choice activity; of those who were walking, 5 children did not demonstrate competency on the test. In the 15- to 17-month age group, all of the children were walking. Of those children, 3 did not demonstrate competency on the test.

Figure 2 depicts the numbers of children earning competency scores (80%-100% correct responses); mid-range scores (20%-70% correct responses); and failure scores (0%-10% correct responses). A majority of the children either learned the task or did not learn the task. In general, most children did not obtain mid-range scores, which suggests that there was not much trial-and-error behavior occurring during the testing sessions. However, there was a slight increase in mid-range scores in the 9- to 11-month age group and the 12- to 14-month age group.

Discussion

The findings of this study indicate that some children as young as 6 months of age can control a simple, computer-based cause-and-effect program through a single switch. When examining the data for subjects individually, it appears that at approximately 7 months of age, children consistently begin showing success with this task. Of the 10 children between the ages of 6 and 7 months, 3 were successful in the task. However, of the 10 children between the ages of 7 and 9 months, 9 were successful in completing the task.

Children in the different age groups showed different patterns of behavior when presented with the computer activities required for this study. The younger children seemed more interested in the graphics and sound from the program than the older children. By contrast, the children in the three older age groups appeared to become bored quickly with the activity as indicated by turning in the high chair, using less time looking at the computer, or asking to get down or to play with a different toy. Several children in the older age groups never demonstrated that they had learned the task during the 5-
min limit of the practice time. However, when tested, they demonstrated proficiency on the task. This may indicate that some children lost interest, but when the switch was removed and returned, the task became interesting again for the 2-min maximum required for testing. Children in the oldest group (15 through 17 months) responded to verbal cues to redirect them back to task more consistently than children in the three younger groups. These children responded to the verbal cue “Make the music go” during the testing session more consistently than the younger children. The children’s attending behavior may have influenced the outcome of the study. By contrast, the walking status of the children did not appear to affect their performance on the single-choice task.

One challenge in studying the behavior of very young children is discriminating between volitional and random behavior. Had the children’s performance on the task been random, the majority should have scored in the mid-range (20%-70%). Because few children had mid-range scores, it seems unlikely that the children were performing randomly, and likely that the results reflect volitional behavior.

**Study Strengths and Limitations**

Several factors in the design of this study worked well with this population. First, at the end of the 6-sec reinforcement after each switch activation, most children were still attending to the computer. This situation indicated that the reinforcement fit within most of the children’s attention spans and may have facilitated their continued attention to the task. Second, the testing areas were as free from distractions as possible. Third, for these young children, a high chair worked efficiently for positioning them in front of the computer with the monitor at eye level. Finally, the high chair tray provided a consistent location for the switch and also helped separate the children from the computer hardware. Though some children resisted being placed in a high chair, it is likely that they would have resisted any type of positioning device.

Two factors should be changed in future, similar research. First, the program used in this study provided a limited range of feedback, which may have led some of the children to become bored with the activity. As a result, this study may have slightly underestimated the children’s skills by suggesting that some of the children were unable to learn the task when they had simply lost interest in it. Had the program provided a broader variety of reinforcements, it might have been more interesting, and these children might have continued the activity. Second, the switch itself became a distractor for some of the children. Although self-gripping fastener was used to help keep the switch in position, some children learned how to lift the switch and were distracted by playing with it.

Dual-lock®, a plastic positioning material, is much stronger and might have removed this distraction.

This study looked at children with no known disability, thus, generalizations to children who have disabilities should be limited and made with caution. Children with reduced motor control may have more difficulty accessing the computer. Additionally, children who are disabled may have impairments other than motor control (e.g., rate of learning, postural control, visual closure, and auditory processing). These factors may affect how children with disabilities perform the tasks presented in this study.

On the other hand, the findings of this study may be a conservative estimate of what children with disabilities can do, because this study looked at children without disabling conditions. Children who have motor impairments may have fewer options for interacting with toys and other objects in their environment than those who are developing typically. This may actually increase their motivation to attend to a computer-based activity.

**Future Directions**

Because of the rapid changes in the area of technology and computer use in occupational therapy, empirical data are needed on how technology can be applied appropriately in clinics, homes, schools, and other community environments for children with disabilities. This study not only indicates the developmental level at which it may be possible to begin computer activities with young children, but presents three directions for future research. The first involves further exploration of the effects of using a variety of types of access systems on the age at which typically developing children can control a simple cause-and-effect game. The second is to study computer access with samples of very young children with disabilities. The third is to study longitudinally the effect of technological support on learned helplessness and self-efficacy in young children with disabilities.

**Conclusion**

This study suggests that computer skills can be introduced to children as young as 6 months of age with a single switch and a simple cause-and-effect program. Therefore, professionals who work with children with disabilities may consider introducing computers to children at this age or to children who are functioning near this cognitive developmental level. In addition, data from this study provide support for the funding of computers for very young children. It is hoped that early access to computers by children with disabilities may help to prevent learned helplessness and to develop competent and independent learners.

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References