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FIVE COLLEGE DEPOSITORY

Case Studies of Problem-Solving Abilities of Autistic
Children in a Computer-Based-Learning Environment

A Dissertation Presented

By

Richard Earle Frost

Submitted to the Graduate School of the
University of Massachusetts in partial fulfillment
of the requirements for the degree of

DOCTOR OF EDUCATION

May 1986

Education

Case Studies of Problem-Solving Abilities of Autistic
Children in a Computer-Based-Learning Environment

A Dissertation Presented

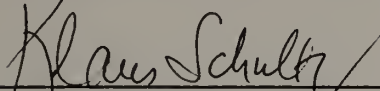
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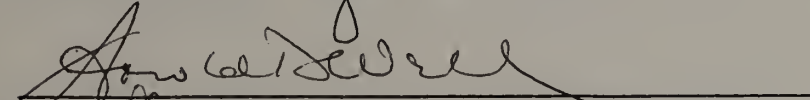
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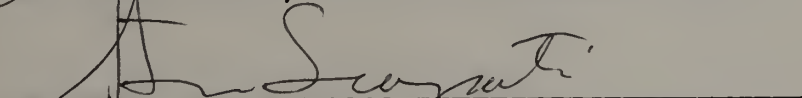



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ABSTRACT

Case Studies of Problem-Solving Abilities of Autistic
Children in a Computer-Based-Learning Environment

May 1986

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Directed by: Professors Howard A. Peelle,
Klaus Schultz, Arnold D. Well, Stanley E. Scarpati

This dissertation presents four case studies of autistic children interacting with specially designed software in a computer-based learning environment. An adaptation of LOGO designed by the author, the software allows the children to move and turn the "turtle" cursor in appropriate increments on an Apple IIe computer. Tasks, such as drawing and erasing geometric figures, were analyzed in terms of patterns of errors, which indicated that the children's level of development affected their solutions. Overall, these studies have demonstrated the potential of the computer as a viable medium of instruction for autistic students.

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C H A P T E R I

Introduction

The class-room telephone rang and the caller asked:

"Would you be willing to have an autistic student in your computer programming class?"

Until that moment, the word 'autistic' had not been in my vocabulary. Since that moment, autism has penetrated my thoughts and stimulated my curiosity almost daily.

General Characteristics of Autistic Children

Autistic children have characteristics that vary widely. While some might be quite verbal and inquisitive, others may use only sign language, while others may appear mute. Their cognitive abilities may range from twelve months to six years while their chronological age might range from ten to sixteen years. Some use words or phrases regularly and then not again for a period of time or not ever again. This variability and inconsistency presents the possibility that tasks which were once easily solvable might later become impossible to solve.

It was extraordinary that my introduction to autism occurred in connection with computers. I was also fortunate to have an atypical autistic student who, functioning at a relatively high level, provided me with a gentle introduction to autism. I was able to teach this student how to write some small programs in Basic on a DEC PDP 11/35 computer. It seemed that he had some difficulty making a connection between cause and effect within a program. It was in working with this student that questions began to evolve:

Would autistic students of far less ability be able to interact with the computer?

Would a less able autistic student be able to use a computer to solve a multi-step problem where cause-effect relationships are an integral part of the solution?

The Prognosis for the Autistic Child

The need to answer these questions is magnified by the generally poor prognosis for autistic children. According to the National Society for Autistic Children, ninety-five percent of all autistic adults need institutionalized care for much of their adult lives. The care required is dependent upon the level of cognitive development, the acquisition of self-care skills, and the acquisition of expressive language skills. A few autistic children do make

sufficient progress in these areas to enable them to live independent lives. The families of most autistic children are confronted with the pressure of providing continual care at home and/or resources for extended care in an institution when they are no longer able to provide that care. If improvements in the prognosis are to be made, the responsibility must be shared by the educational community. The improvement of self-care and expressive-language skills must be a constant focus for the educator. Indeed, we must continue to search for those teaching methods and modalities which can be successful with the autistic child.

A Rationale for Using Computers with Autistic Children

The search for alternative teaching methods and modalities for various disciplines and cognitive levels has led to some studies of the computer as a possible candidate. Like any tool, the computer can be appropriate in some situations and inappropriate in others. Assuming it is important to find a match between the modality and the student, the computer may be uniquely well-qualified to be used with autistic students. Autistic students are characterized by an insistence on sameness, an ability to handle spatial (as opposed to temporal) information, and a language deficit. Interestingly, the computer has these same qualities.

- 1) Insistence on sameness -- The computer will not accept any input to be processed unless it is precisely at the time and in the form expected.
- 2) Ability with spatial information -- The computer is especially adept at displaying graphical and spatial information on display screens.
- 3) Language deficit -- The computer has a vocabulary that is limited in size and a grammar that is rigid.

The computer environment may be one with which the autistic child is comfortable because "the computer seems autistic"!

Colby (1971), Weir (1976), Goldenberg (1979), and Frost (1984) have all used a computer experimentally with autistic children. All these experiences encourage further research on activities of autistic children with computers. For instance, using the computer to provide practice with sequencing tasks may lead to improvement of noncomputer sequencing tasks. It may lead to an improved ability to solve problems. If improvement does occur, use of a computer with the autistic child is well justified. If the autistic child is better able to work in a computer environment than in a non-computer environment, continued use of the computer

is justified. If improvement does not occur, the environment should be examined to determine if its modification might increase the likelihood of improvement. At the least it would provide a different modality for instruction. By providing an alternative modality, an untaught concept may become teachable. This growing list of questions and concerns motivated the following study.

Overview

A study was planned to make anecdotal records of autistic students interacting with a computer. This study was divided into two parts. The first, a preliminary study, acquainted the students with the computer and provided an indicator of the types of tasks they were capable of completing. The second, a detailed study, collected specific data about problem solving difficulties in a computer graphics environment. Here, students were asked to erase and to draw simple geometric shapes using an adaptation of the LOGO programming language. Students interacted with the system by pressing a single key on the computer keyboard. Two keys had been covered with icons denoting the functions that the two keys represented (fig. 1). Footprints denoted the "walk" or forward movement command, and a curving arrow denoted the "turn" command.

Output was provided to the students on a cathode ray tube (television-like display screen). At the beginning of a task the students would see the "turtle" (the graphical indicator of position and direction of movement). When the task was one of erasing a shape, a geometric shape would also appear (fig. 2).

There were several questions of immediate interest. Which tasks would the students complete? Would success depend on the student's level of development? Would smaller turtle-steps cause failure. Would smaller turning rates cause failure? Would drawing tasks be more prone to error than erasing tasks?

The tasks were also presented to a small non-autistic sample of children ranging in age from 3 to 5 years. The purpose here was only to gain insight into the cognitive processes used to solve the problems. It was not intended to use the non-autistic children as a control group.

In summary, the computer is viewed as a tool that has the potential of being an alternative modality for helping autistic children improve their problem solving abilities. We hope to determine whether that potential exists. We hope to find those constraints that, when placed on a computer-graphics environment, might improve the opportunity of improvement for the autistic child. Such knowledge would

be useful for the development of other learning environments to be used with autistic children. It would also be useful for the classroom teacher to decide if the graphics environment might be a valid medium for teaching subject content.

C H A P T E R I I

Literature Review

Part I - Autism

Any definition of autism has its roots in the characteristics of a syndrome identified by Kanner (1943). The characteristics include the failure of the autistic child to effectively relate to his environment. This is especially true with regard to interpersonal relationships. The most pronounced characteristic is the failure to use speech for communication. The refinement of the characteristics is described by Rutter (1978a). He points out that three symptoms were found in most all autistic children: 1) a "failure to develop social relationships", 2) "language retardation with impaired comprehension, echolalia, and pronomial reversal", and 3) ritualistic behavior including "an insistence on sameness". (Rutter, 1978a, p. 4) Echolalia is when one parrots or mimics speech. Pronomial reversal is when an individual refers to himself in the third person. An example is saying "He went to the store" instead of "I went to the store"

In terms of intellectual functioning, Rutter summarizes that autistic children have IQs that function "in much the same way as in any other group of individuals". He admonishes that "studies which set out to compare autistic

and nonautistic children must control for mental age as well as for chronological age." (p. 6)

In providing more details on the symptom of impaired social relationships, Rutter notes the "lack of eye-to-eye gaze". (p. 9) He expands on this by describing the impairment not in terms of amount of gaze but rather in terms of purposeful gaze. The autistic child typically does not use eye-to-eye gaze in a highly discriminating fashion. Language skill acquisition is delayed and half of all autistic children never gain useful speech. They talk much less than other children; they gesture with the entire hand rather than pointing with a finger.

Insistence on sameness is limited by Rutter to include firstly "intense attachments" to a particular object and secondly an "unusual preoccupation which they follow to the exclusion of other activities." (p. 12)

The etiology of autism is unknown, and Rutter points out there is not enough evidence to either support or deny biological or psychosocial causation. While brain lesions are a possible cause, there is no agreement on the location of such a lesion. He cites Hauser et al (1975) as giving "evidence of enlargement of the left temporal horn in cases of autism." (Rutter, 1978, p. 16) It is also not known whether autism has one or more causes. It would seem

reasonable that if a physical cause underlies the syndrome that there would be evidence especially when an autopsy might be performed. The fact is that autopsies are not frequently performed on autistic persons. They are typically very strong and healthy; autism does not appear as a cause of death and they live long lives.

In response to a lack of physical causation, attention is directed toward the symptomology, both cognitive and behavioral, of the syndrome. Wing (1978) reviews cognitive characteristics and points out that "poor eye contact is associated with poor cognitive skills." (Wing, 1978, p. 36) She further notes that the autistic child lacks the ability to "seek out and actively endeavor to make sense of experience." (p. 41) She suggests the hypothesis that "the social aloofness, the repetitive stereotyped behavior and the abnormalities affecting comprehension and use of all forms of communication and the development of symbolic thought are facets of the same underlying impairment of cognitive development." (p. 42) She also states

"The very close relationship among these three abnormalities is not self-evident, but the epidemiological study ... provides evidence of this association and also suggests that an organic lesion is the basic etiology." (Wing, 1978, p.42)

In another chapter, Rutter (1978b) more closely addresses cognitive deficits and autism. He points out that a shift has been made "from seeing autism as a condition involving social and emotional withdrawal to a view of autism as a disorder of development involving severe cognitive deficits which probably have their origin in some form of organic brain dysfunction. Further, current research is directed "to determine the nature and boundaries of the cognitive deficit." (Rutter, 1978b, p. 85)

Rutter draws the conclusion that there is true incapacity in the field of language on the part of the autistic child. He reaches this conclusion on three pieces of evidence: 1) when language develops it is "abnormal in many respects" (p. 86) and not the result of delay due to a lack of stimulation; 2) "autistic children perform badly on tests which require verbal or sequencing skills even when the tests do not involve any use of speech" (p. 87); and 3) "autistic children made relatively little use of meaning in their memory and thought processes". (p. 88)

Rutter states further that "the cognitive deficit is of basic importance". (p. 90) He supports this with studies that confirm that IQ scores and language skills are the most important predictors of educational capabilities and of social adjustment.

Rutter also refers to studies of autistic children with normal intelligence (Hermelin & O'Connor, 1970; Hermelin, 1976; Rutter, 1974) as a means of determining "which cognitive deficits must be present for autism to develop." (Rutter, 1978b, p. 90) The conclusions that he draws are as follows:

- 1) "the deficit in autism ... involves a wide range of language and language-related functions which include impairments in verbal understanding, sequencing, and abstraction."
- 2) "autistic children also have serious impairments in their understanding of language, in their use of symbols in play, and in their use of meaning in memory processes."
- 3) "autistic children are also impaired in their use and understanding of gesture and of written language."
- 4) "autistic children's problems in temporal sequencing are much worse than those in spatial sequencing".
- 5) "the disabilities ... tend to be with auditory rather than spatial sequencing"

6) "visuo-spatial defects do not play any essential role in the development of infantile autism" and "autism can and does develop in children who have no discernible visuo-spatial perceptual defect." (Rutter, 1978b, pp. 90-91)

A possible relationship might be suspected between the aforementioned suspicion of a lesion in the left temporal lobe of the brain and the autistic child's ability to handle problems of temporal sequencing. This is also the locus of speech and language. The autistic child's deficit in language helps lend credence to the theory of a physical lesion.

Rutter finishes with five principal questions that must be answered through further research:

- 1) "which cognitive processes are disordered in order for the language disability in autism to arise."
- 2) assuming there is a biological etiology, "which brain systems are involved and what is the locus or loci of brain pathology?"
- 3) is the "autistic child's relative failure to use speech for social communication ... a consequence of the severe disorder of language

and of central coding processes or is some rather different disorder involved?"

4) with regard to cognitive deficit and social abnormalities "does one cause the other or are they both different facets of the same basic disability?" and

5) is cognitive deficit involving language "a sufficient explanation of the genesis of autism? ... What is different about the biological makeup or experiences of the autistic individual?" Why is autism found more frequently 'in middle-class or professional families'? Does the fact that autistic children seem to benefit more from certain environments imply "that autism is more likely to develop in some sorts of environments than in others?" (Rutter, 1978b, pp 100-101)

The computer has the potential to be an important tool in answering these questions. Problem solving environments on the computer may provide a window through which we may be able to obtain a finer discrimination to identify those disordered cognitive processes. By looking at the child's ability, or inability, to solve these problems patterns may be observable to the physician enabling an accurate physical

diagnosis based on the latest behavioral models of the brain.

While a language deficit is a primary symptom of the disorder, the computer presents an alternative environment to explore language. A novel language for solving problems and/or a high level programming language, such as LOGO, might provide the framework to study the ability of an autistic child to acquire a language. If one of these languages can be adapted without the use of mnemonics or other abbreviations and if that language were close to the child's "natural language" then the child's expressive language might give evidence of transferal from the computer language.

By using the computer as a window it might be possible to explore the possibility of a causation that underlies the cognitive processes as opposed to the cognitive deficit being the root etiology of autism.

Menyuk (1978) states that the language behaviors of autistic children "appear ... to be a product of unique processing strategies or incapacities of these children to begin with, which, in turn, are probably due to unique neurological substrates." (Menyuk, 1978, p. 110) She observes that autistic children have a better memory capacity but have a poorer organization of memory when

compared to mentally retarded children. Their poorer memory organization (sequencing) could relate to the suspected lesion in the temporal lobe of the left hemisphere of the brain.

Regarding the abnormal sensitivity to sound she comments that it might be "a reflection of the fact that these infants have not discriminated between categorized speech versus nonspeech stimuli and categories of these stimuli. Lack of functional object use and of response to adult caretakers might be due to non-discrimination and categorization of those visual or visual-motor features which identify objects and people." (p. 113) She further notes that a normal child usually achieves the ability to perceive, discriminate, and identify visual and auditory stimuli by the age of five months. These abilities are necessary in order to learn language and speech. She concludes by pointing out the need for research that includes both what the autistic child can do and what the autistic child can learn to do.

Hermelin (1978) describes his work and methodology where he seeks to "establish how groups of children whose pathology is quite different will respond to situations and tasks which are defined in terms of certain specific underlying mental operations." (Hermelin, 1978, p. 141) Through the use of controlled experiments with autistic,

normal, blind, and deaf children where the children have been shown three number sequences, he has observed that autistic children (aged 10-14) tend to recall information based on a spatial representation even if the original sequence was presented temporally. Further, he observed that when the information the child was asked to recall required recoding of information from spatial to temporal, the autistic child did poorer than those in other groups. As he states: "This lack of mental mobility in handling information and their tendency to remain stimulus-bound, can make them in fact operationally blind or deaf or both."

(p. 152) He concludes observing that the cognitive deficit is one that underlies the language impairment and involves the failure to develop representational and symbolic systems. I would rather think that the autistic child may develop representational and symbolic systems that may just be different from what we would expect and that the problem is ours in our inability first to recognize the characteristics of that system (or systems) and second our inability to translate from our symbolic system into the one they have been able to develop. Many autistic children do develop language, stilted though it may be, and that their language deficit is evidence of the immense difficulty they have in trying to relate their system to ours.

The theory of Optimal Stimulation (Zentall and Zentall 1983) provides a framework for thinking about autism that is substantially different than the other views that have been described. The main principles of the theory are:

"1. Organisms will work to maintain optimal levels of arousal.

"2. A wide variety of internal and external conditions can affect arousal level".

"3. Activity functions to regulate levels of stimulus input or level of arousal." (Zentall and Zentall, p. 465)

The theory of Optimal Stimulation is used to describe autism as an incidence of over-stimulation. Autistic individuals seek various ways to reduce the amount of stimulation. They may exhibit withdrawal which could be viewed "as a means for blocking stimulation". Reduction may be achieved by narrowing of focus to a "selected feature of a stimulus". They may also achieve this "by focusing attention on highly repetitive, predictable, often self-produced stimuli." (p. 451)

Further, Zentall and Zentall point out that with careful modulation of the stimulus it may be possible to "moderate repetitive activity."

"Although environmental manipulations may not eliminate the cognitive deficits of autistic children, they do appear to reduce autistic behavior." (Zentall and Zentall, p.455)

The computer may be an environment that allows the autistic child to focus on a narrow visual field, decrease the amount of stimulation, and increase their goal directed behavior.

The role of contingent sensory stimulation is of much importance with regard to the autistic child. Murphy (1982) reviews and discusses several different aspects of the issue. In work with animals, a wide variety of sensory reinforcers were found effective. When a particular stimulus was found effective for a particular animal it was found to be effective for the species as a whole. Effective stimuli were found to vary from species to species.

Particular stimuli can be varied according to the mental age of the child. For younger children, stimuli such as vibration would be most effective as they use near-receptors. As the child matured, the use of stimuli that involved distance-receptors (light, sound) were of increasing importance with a corresponding decrease in importance of the near-receptors.

Murphy notes that for autistic children, "simple white light, flashing white light, and vibration stimulation" all appear to be reinforcing. (Murphy, p. 269) Particular note was made that satiation followed a rather slow path once an effective stimulus had been found. Some children did not show a reduction in performance until after 70 sessions and others after 8,000 responses.

Murphy found support for the role of contingent sensory stimulation in the work of Rehagen and Thelen (1972) and Johnson et al (1978). Both studies found that tactile stimuli in the form of vibration proved to an effective contingent reinforcer for student performance. Johnson found it to be more effective than contingent praise. Rehagen and Thelen found it more effective than contingent touching of the student by the investigator. Of further importance is that the reinforcement was given for appropriate button-pressing behavior.

Murphy concludes with a statement of implications for clinical and educational situations. Among the advantages of using sensory stimuli as reinforcers are:

- a) the relative ease of delivery
- b) the apparent slow satiation rate
- c) the variability

- d) the presence of dietary restrictions
- e) the possibility of being a better reinforcer
- f) their use with profoundly handicapped and unresponsive children
- g) the possible use of "automated equipment that would provide sensory stimuli contingent on a particular response". (Murphy, p. 275)

There are studies that relate sensory reinforcement and stereotyped behaviors. Williams (1978) feels that these may be learned behaviors that are triggered by occurrences in nature or which may be maintained by the acts themselves. Further, the presentation of sensory stimulation might cause a reduction in the stereotyped behavior. This has been observed and there seems to be cause to believe that the nature of the stereotype might well be able to suggest the type of stimulus that will reduce the behavior. This reduction has been observed by others (Goodall and Corbett 1978).

Clearly, the potential of the computer lies in its ability to provide both visual and auditory reinforcement that is contingent upon the child's action which would typically be in the form of a key-press. It is possible to

provide a variety of reinforcers that are perhaps more effective and at the least non-threatening.

Dyer (et al 1982) investigated the effect produced by delaying the child's response. Autistic children sometimes display a high level of perseveration. A question which they addressed was whether the physical postponing of the student's response might break the perseveration and allow a response, even a correct response (that might have been hidden by the perseveration) to occur. They conducted a controlled experiment with three children who were identified as having autistic features although autism was not the primary diagnosis (developmental delay and childhood psychosis). These children all "exhibited moderate to low self-stimulatory behavior" (Dyer et al, p. 232) and were limited in language development.

The delay was achieved either by physically holding the child's hands thus preventing a response or by presenting task related materials and delaying the question. In each case the delay was from three to five seconds. According to Dyer, "the response-delay condition always produced higher levels of correct responding relative to the no-response-delay condition." (p. 234)

In the same article, mention is made of a study that showed a child's response time lengthens as the child grows

older (Messer, 1976). This indicates that Dyer's own success may have resulted from working with children who were functioning between five and seven years old. Further, the improvement observed in discrimination tasks may have been due the child attending to more relevant clues than had no delay been present.

An interesting observation made by Dyer was that the children would "frequently spontaneously verbalize the relevant cues during the delay period." (Dyer et al, p. 237) This author (Frost, 1984, p. 249) has reported a similar observation when working with a Down's Syndrome child. The child began to spontaneously sign the key, on the computer keyboard, that he was going to press in response to visual stimuli present on a CRT display.

Further results of the Dyer study show that as soon as the response delay was removed, the percentage correct dropped immediately. Some children did have a subsequent increase in correct response that may have resulted from learning the delay to be contingent upon the presence of a particular stimuli.

Dyer extended the response delay study to include students in the classes of 12 additional teachers. A modification of the type of delay was necessary. Some of the additional students rejected all physical contact with

other persons. Delay by physically holding them was not a reasonable method. For them, the stimulus materials were placed physically out of reach for the delay period after which the materials would be placed within reach and the child would be permitted to respond.

The response delay was more effective for the autistic child who reacted on impulse. Children who displayed high levels of self stimulation (perseveration) did not seem to reach the same levels of benefit as did the child who did not engage in self-stimulatory behavior. A question raised but not answered was whether the effectiveness of delay was inversely proportional to the level of perseveration or if it was proportional to the level of cognitive ability.
(Dyer, pp. 238-239)

Although not presented as an educational methodology, Richman (1979) presents a methodology to be used in the treatment of autism yielding an improvement in the total life functioning of the autistic child/adult. It is an unproven methodology but one that seems applicable in utilizing a computer based learning environment with the autistic child.

The methodology describes three non-harmful learning environments.

- 1) A catalytic environment acts upon the child and necessitates some behavioral response. The stimulus is almost totally external to the child.
- 2) A neutral environment does not act upon the child and he may choose to ignore it, respond to it, or take part in some atypical behavior.
- 3) An operational environment is one in which the child is capable of operating successfully. In this case the child makes a decision to act because of some internal motivation. The response that the child may make to any of these environments may either be harmonious (meaningful, joyful, eye-contact, self-motivated, etc.) or disharmonious (passive, fearful, nonsense vocalizations, distractable, self-injuring, etc.). (Richman, pp. 30-31)

The teacher may respond to the child's behavior in one of three ways.

- 1) Intimate involvement includes the use of physical and verbal support, protecting the child, and reassurance such that "the teacher, therapist and the child are bodily related". Here the intention is to let the

environment motivate the seeking of help by the child.

2) Proximate involvement refers to the teacher and child being close to each other and includes some verbal prompting or reinforcement.

3) Distant involvement requires separation either by space or by time and tends to be more direction or supervision than a direct involvement with the child. (pp. 32-33)

Richmond points out that the teacher must be prepared to present a variety of learning environments to the child dependent upon the response that has been elicited from the child. Further there should be progress from intimate involvement to distant involvement. He concludes in saying that this methodology does "provide a new dimension for structuring and coordinating treatment as well as program organization". (p. 33)

Of the three learning environments only the catalytic environment seems inappropriate as a model describing work with a computer. The characteristic of necessitating some response suggests responding to some basic need in response to an environmental demand. The attraction of the computer as a tool to use with handicapped individuals is that it is non-threatening. We ought not to use the computer to demand performance! The neutral and environmental environments are

practical models of computer based learning environments. The neutral environment lets the student decide whether to interact or not to interact and to accept that response. This would be the initial type of environment that the autistic student would encounter and would concentrate on discrete events, key-presses. In time and with practice and increased ability, the student might be expected to function in an operational environment. Here the student would be past the need to learn the characteristics of the environment. Rather, the student would begin to execute a planned sequence of steps to solve specific problems. Perhaps the student would even be willing to relinquish some control over the computer and let it automatically execute a sequence of commands that had been defined earlier by the teacher or perhaps even the student. Weir (1976) experienced an unwillingness on the part of one autistic student to relinquish that control.

Intimate support for the autistic child would have to be handled on an individual basis with verbal support being the more prevalent. The non-threatening nature of the environment would not require any protection of the child. Frost (1984, pp. 246-249) worked with an autistic girl who had received punishment in the form of electric shock. This had occurred in a different educational setting and it had been used to extinguish what was considered an undesirable

behavior. In the computer setting, concern that the computer might prove to be a threatening environment was dispelled with the observation of her outstanding progress.

Proximate involvement is the more likely model for the role of the teacher in providing support for the student in a gentle manner. The danger exists that the teacher may feel the desire or even the necessity to give the student more help than the the student actually needs. The teacher must be acutely aware of the need to allow the student to begin to explore the environment on his own. Distant involvement, allowing the student to work either with minimal intervention or the student's self direction would be a worthy goal but may not be practical with most autistic students. Using Richman's model we should expect to see either a neutral or an operational environment with proximate involvement on the part of the teacher.

Part II - Computers and Autism

One of the early uses of technology with autistic children was started in the early sixties by Kobler and Kobler (1971). Among a variety of learning instruments they designed was the Talking Typewriter (TT). They described an approach that had four components. It included 1) a new theory of thinking, 2) a theory of learning and personality development, 3) a suggestion of a possible cause of autism and 4) a learning therapy.

Their theory of thinking is founded on the concept that our humanity is based in the fact that we are able to ask questions. This means that we are able to place ourselves into another viewpoint and look back at ourselves. They base their theory of personality development on the assumption that it is necessary for us to be able to hold a conversation with ourselves in order to develop normally. It is this ability to be mildly and consciously schizophrenic that enables us to phrase the best questions that will lead to learning. They point out that it is those "learning dialogues" that involve a struggle which are "real and valid learning processes." The universal presence of bi-attributes (eg. north-south, plus-minus, male-female, left-right, etc.) is used in part to support the importance given to the "split personality". They view a possible cause of autism as being the loss or lack of development of the ability to

split one's personality and hold that internal conversation. Thus the autistic child "lacks the capability of learning, of real learning." (Kobler and Kobler, p. 7) They postulate that echolalia inhibits this inner dialogue. They support this idea by pointing out that society is relying more and more on things to take up the time which might be spent carrying on this inner dialogue. Television might be an example to which they were referring but they do refer to background music that is listened to in elevators, while we are shopping, or while we are working. All this occurs at a time when we could have been reconstructing a symphony remembered from times past. They view the autistic child as one who cannot carry on this conversation with self. Therefore methods of treatment should be directed to establishing the inner dialogue and hopefully to beginning a dialogue with the outside world.

The learning theory of the Koblers was implemented in a structured environment where simple mental games could be played and enjoyed by the autistic child with himself. The tasks were real (learning to read) and the machine used was the TT. It consisted of a typewriter keyboard and an associated printing element. It also had an electromagnetic speaker which would produce sounds and voices either from a "machine voice" or from an unseen human observer.

The dialogue that exists when the child is using this environment includes the child posing a tactile question by the pressing of a key. The TT answers the question by speaking the name of the key pressed. If the TT were to ask the child to press a particular key then he would have the opportunity to give a tactile answer. If the key pressed was correct, a large image of the key would be printed on paper for visual positive reinforcement. If the answer were wrong, nothing would be printed leading possibly to an internal dialogue. In fact, if the child were to press an incorrect key it would not even depress let alone print.

Echolalia was observed by the Koblars as the autistic children participated in a free play period. During this time they would either press keys in a repetitive pattern or they would continuously press the same key.

The Koblars conclude with a description of their work with a particular autistic boy. He was five years old and essentially mute, having spoken only three words in his brief lifetime. Seated at the TT he entered into the first exercise, pressing a key and listening to the verbal response. He began to perseverate almost immediately. The TT was turned off in an effort to stop the perseveration with the result that a "game" evolved (pp. 18-20). He would position his finger over a key (the same one each time) in order to get the machine turned back on. As soon as it was

turned on he would again persevere on the same key he had first pressed. The tactile response evolved to a shaking of his head to indicate a negative response and an attempt at vocalizing the letters that he was typing. Progress continued through a total of 40 sessions, one-half hour in length, after which time he was able to carry on a limited conversation.

The Koblers did their work at a time when the thinking of causes of autism was a reaction against the concept of the "cold mother" or the "unloving parents". The consideration of a causation that was not so guilt ridden was infinitely more desirable than the alternative. By directing interest to the thinking processes, asking a question of one's self, they helped to encourage dialogue on the cognition of the autistic child. Most important was their decision to employ their "high-tech" and to observe the behavior of autistic children while they worked with the "talking typewriter". It was a necessary first step that would wait almost a decade for the use of sophisticated electronic computers.

The second reported use of computers with autistic children was reported by Colby and Smith (1971). They concentrated on the deficit of language acquisition because of the poor prognosis accompanying such a deficit. Their design involved children interacting with a computer through

a keyboard and with a CRT display. Following each keypress the child received both visible and audible reinforcement.

The interaction was organized in eight different exercises. In the first, a voice would pronounce an appropriate sound and the shape would be displayed on the screen as keys were pressed. The second exercise would display the key that was pressed keeping it on the screen until the screen was completely filled. The audio portion would pose questions about the key just pressed or it would suggest the key to be pressed next. Third, a word or a phrase containing the key that was pressed would be displayed and spoken. In the fourth exercise a simple level of animation and different sounds were added to make an amusing reinforcement. In order to teach two and three letter words, the fifth activity would ask the child to press a specific key. When a key was pressed, it would be followed by either positive or negative feedback with clues that would lead to the correct key. The sixth game seems to be a more passive activity than the preceding. The screen shows the letters of the alphabet on the boundaries of a square and they are "drawn" (sic) into the center of the square to spell a predetermined word. Exercise seven presents and speaks a preset phrase to the student following a specific keypress. The voice repeats the phrase continuously until after the third keypress when it repeats

the phrase but leaving out a word which the child is then supposed to type on the computer keyboard. The final exercise responds to a keypress by printing a word, either a verb or adjective dealing with motion or affect. A voice then speaks the word in a manner that represents the word itself. For example the word "laugh" is laughed as it is spoken.

Colby makes mention of other activities that were discontinued but makes no mention as to their nature. The games mentioned were retained because the child was attentive and interested in them.

The method used in these exercises was to have the child in a large room, around which he was free to move at any time. A "sitter" was present at all times who would passively monitor the interaction of the child, select different games, and respond to child initiated communications. They are giving the child "a chance to play with a machine that happens to be a linguistic entity. The child is placed in control of the environment (the display and the symbols). As they point out, failure is non-existent; a relatively minor act yields large consequences on the display. This treatment was designed to provide "the right symbols in the right amounts at the right time from the right sources" and to "catalyze the reaction

rates of natural...language processes" (Colby and Smith, p. 8).

The results of the Colby study included a success rate of 76% of 17 cases. Success was defined as "improvement" as judged by four to six observers and with no dissenting opinion from any other observer. The observers included parents, peers, siblings, professionals, and other interested persons. Observer bias was not considered an important factor because in the four failures of the program, all observers were in agreement that that the children had not benefitted. The children who did not improve showed no interest in the display nor could they be persuaded to take part in the activity. Although language development was the sole criterion for improvement many other covariant benefits were observed. Those who showed improvement also began playing with other children, were more willing to be taught, and were less likely to withdraw from strangers. It is claimed that if a child accepts this treatment method, it will have "a powerful catalytic impact on his language development" (p. 10).

Colby's work could be criticized for its lack of experimental design. However, it is argued that the small number of subjects and the desire to help the largest number of subjects precluded the establishment of a control group. With sufficient observations before, during and after

treatment, an interrupted time-series design may be used and changes in behavior may be attributed to the treatment. If when the level of activity is plotted on a graph there exists an abrupt change in the smoothness of the graph immediately following the application or the removal of treatment, then it is credible to infer that the treatment had more effect on the change than did other potential explanations. Six alternatives were considered by Colby with the following results.

The method of selection may include a bias to success based on the selection of or the presentation of only the "better" cases. Subjects for whom this would be a "first" treatment might show a good response irrespective of the treatment. The subjects chosen varied in age from two to thirteen, came from a variety of living situations, represented all socioeconomic classes, included the nonspeaking autistic child who is considered to have the poorest prognosis. Further, all the children had experienced other treatment.

When working over a long period of time, it is possible that other events may initiate the improvement rather than the treatment method being studied. With regard to language development, no spurt causing event was known to be effective in the development of language. Colby did ponder the possibility that the seven month old program "Sesame

Street" might have some affect on the autistic child because of similarities in the style of audio-visual presentations (Colby and Smith, pp. 13-14).

They found it difficult to accept the premise of a sudden and spontaneous maturation causing improvement in language. They speculate that for this to be true some unknown chemical, as opposed to symbolic, catalyst would have to be introduced.

The natural variability of things observed seems not to be a factor because in the use of a time-series design and sufficient pretreatment observations, the pattern of variability would have been established. In fact the performance curves of the subjects showed very little variability and the change observed could not be attributed to stability.

When an attribute being observed is an extreme occurrence then statistical regression toward a mean or average value is a possible explanation. However, this would occur when the subject was at the ebb of a great fluctuation in performance. Clearly this is not the case considering the negligible variation that had been seen over a period of years.

Colby concludes with a consideration of other coexistent treatment methods. The fact that a particular

treatment seems not to have been successful should not discount the possibility that in the presence of another and perhaps new treatment, some improvement with the latter may in fact stimulate an older and "ineffective" treatment to have some benefit, leading to further improvement from the second treatment, leading to further improvement from the first, etc. The important point being made was not that the computer based treatment was solely responsible for the improvement but that method served as a catalyst. Similarly, it seemed unreasonable to assert that his treatment method had no benefit. it was especially noted that several parents noted increased receptive and/or expressive linguistic activity on those days when the computer was being used and especially important is the fact that this information was volunteered without any prompting in several cases.

Colby (1973) later described his rationale for his computer based treatment. Central to his work was the idea that the primary problem of the autistic child was dissymbolia, an inability to process symbols. The machine was described as being "untirable, predictable, always saying the same thing the same way, never angry, never bored and controllable" (Colby, 1973, p. 255). He points that there are apparently several autistic syndromes. These include both speaking and non-speaking autistic children. The non-speaking include those who lose their expressive

language between one and two years of age. The speaking group includes those who have had a history of difficulty with language.

Treatment followed three principles. First, it should "provide an opportunity for exploratory play with keyboard and video display" (Colby, 1973, p.257). Second, the "sitter" must exercise great self restraint and not interfere with the the interaction but be ready to offer positive reinforcement in a social context. Third, the experience should guarantee success for a child who has repeated failure with regard to language. These three principles form a nucleus around which other use of computers with autistic children is based. Colby puts the difficulty with language in a social context as he says "they have so much difficulty with language that they withdraw from people that unwittingly flood and overwhelm them with meaningless noises" (p. 257). Colby seems to agree in principle with the theory of Optimal Stimulation later presented by Zentall and Zentall. If the child is in the speaking group, the echolalia is merely a repetition of what has been heard but which cannot be processed.

Improvement was defined as the use of speech for social communication on the child's own initiative where it had previously been lacking. This was not meant to imply the

mature speech characteristically appropriate for a given age but rather an interest to experiment with speech.

Among the children who did not benefit from the environment, a relative few shared some common features. The children were those who showed no interest in the machine at all. In addition if the autism had a late onset, not early infantile autism, there was no success whatsoever. Among the non-autistic children who had an opportunity to use the system, work with schizophrenic children was a failure. Children suffering from expressive aphasia did not experience any success.

Colby closes his second article with the statement "we believe there is something powerful but not well-understood about this method. The treatment is a general prescription, the effective ingredients of which are unclear. We need other workers in the field to adopt the method, improve it, and perhaps help us find stronger catalysts for language acquisition ... Once we can get the misconceived Satanic image of the computer out of the picture, I hope others will join us in discovering more about this technique for treating nonspeaking dissymbolic children" (Colby, 1973, pp 259-260).

Colby and Kraemer (1975) later described a method for measuring the performance of non-speaking children. This was

done to be able to add the possibility of objective measurements which was missing from his earlier study (Colby, 1971). Their goal was to compare response patterns of non-speaking children with those of normal children. Changes in the observed pattern toward the norm would be considered to be improvement. The computer was used to record the child's performance as well as be the instrument of learning. Data retained included which activity was being used, which key was pressed and at what time, and whether the sound for that key was made over the systems speaker. If there was a burst of key presses the computer would play the sound for the first key pressed and further sounds would be inhibited until the child paused.

The analysis included: the duration of perseveration both in time and in discrete key-presses; the number and duration of periods of inactivity. By fitting the data on normal children to a curve, a formula was derived to which the performance of an atypical child could be compared. The two most important criteria were determined to be 1) the percentage of time that perseveration did not occur and 2) the ratio of the number of inactive periods to the sum of the durations of all periods of perseveration.

With this method of measurement a relative performance for the atypical child can be determined. It is possible to identify change or the lack of change over time. Given that

no change has occurred, the termination of a particular treatment can be justified.

The third instance of utilizing computers with autistic children was done by Weir and Emmanuel (1976). Weir was a physician doing work in computer science at the University of Edinburgh. Her study of autism was for gaining insight into interpersonal relations, language development and learning. Cognitive development, in her view, was dependent upon the child being able to act as the "AGENT OF HIS OWN LEARNING" (Weir and Emmanuel, p. 4, her emphasis) which in turn depended on "spontaneous social gesture". Of special interest was the potential of the computer for therapy. The hypothesis was that individuals must share common perceptions of the world if they are to communicate and that the autistic child does not communicate because of a lack of these common perceptions. Central to their hypothesis is that the child's active exploration of his world is necessary for learning to occur. The atypical behavior of the autistic child is something of a mystery to be decoded in order to discover his perceptions of the world so that we will have something in common to talk about.

The task of Weir and Emanuel was to provide an environment through which the perceptions of the child might be seen and with which the child would be able to explore a micro (sic) world. This was accomplished with a subset of

LOGO utilizing a small external box of electronic buttons with which the child could control the movements of a floor-turtle (a robot) with but a single key-press. Pictorial representations of the turtle functions were used as descriptors for the child. It was also felt that the autistic child's preference for machines over people would make the computer environment with the mechanical turtle a motivating influence on the child.

They had adopted the position that meaning must be sought in the behavior and expressive language of the child. The computer world was reduced to one where the heading and position, coupled with angular and linear movement, allowed a significantly smaller frame of reference from which meaning might be deduced. Attempting a task meant, for the child, that his act had been externalized. It became more than just a thought but an action that could be observed with the senses and in which errors could be readily seen and thus corrected (Weir and Emmanuel, p. 7).

Weir and Emanuel worked with a single child, passively verbal, and who was described as having "'odd behaviour with autistic-type features'". He was about seven years old, had learned to read and write, was somewhat withdrawn, avoided eye-contact, and would respond to questions in a very high pitched voice. There had been no spontaneous speech except at times of high stress (p.10).

They saw the boy a total of seven times over six weeks with five meetings in the first two weeks. During his "play", he began to predict the movement of the turtle by his corresponding body movements. He also began to verbalize the actions of the turtle spontaneously. At these times he underwent significant behavior changes, his voice pitch was lower, he laughed, he hummed, and he was excited. This was not a constant feature of the sessions and he would quickly return to his more "typical" self if he didn't understand what was being asked of him or if he thought he could not do what was asked.

The first sessions were an exploration of the environment. During the second session he was asked to use the turtle to knock over an object on the floor with the turtle. The result was his immediate withdrawal. However, in the third session, while alone in the room, he did proceed to push the object over. The fourth session showed him to be more tolerant of interruptions than he had been in the past. He displayed greater control over the environment. As the sessions progressed, his language began to show greater structure and complexity.

The most obvious feature of this environment was the quickness with which positive results were seen. This is qualified by the fact that he had been taught to read through behavior modification and thus was capable of

handling the symbols used to represent the different turtle functions. They point out that if a child is unable to read or to label objects then the task will be significantly more difficult. With the environment he was able to develop a body-turtle correspondence which formed the common perceptual knowledge upon which the spontaneous communication developed. LOGO was successfully used as a catalyst with this relatively high functioning boy but "If we can get results only as good as those achieved using operant conditioning, we will have offered something to replace the battle of wills which pervades such circumstances" (Weir and Emmanuel, p. 20).

Weir and Emmanuel brought the autistic child to a three-dimensional world of graphics and robotics where the child could explore a microworld, learn and ultimately communicate to those around him. It presented him with an alternative world of symbols with which to think and solve problems. He was now given problems to solve that required movements similar to his own movements in a physical world.

Paul Goldenberg (1976) brought considerable insight to the problem of handicapped children but especially to the autistic child. His study included four children who had at some time been diagnosed as being autistic; he was somewhat skeptical about the diagnoses. The first student, a girl, preferred pressing the buttons with its immediate results,

similar to the system used by Weir (1976), rather than a delayed execution of a series of turtle commands. She was also more interested in working with the floor turtle than the screen turtle, displayed on a CRT. Labeling the keys with the letter on a different background produced an improved response rate and she eventually labeled one of the keys herself. She periodically investigated to see if it had acquired a new turtle function. She would talk to the turtle and gained increased control over herself and the turtle.

One boy was not attracted to the keyboard control but preferred to manually push the floor turtle. When the pen fell out of the bottom of the robot, the boy spent considerable time trying to replace it. He was able to make it stay in place but its position would not allow further drawing on the floor. After Goldenberg (G.) fixed the pen and returned the turtle to the floor, he pressed a button and mechanically raised the pen off the floor. The boy stopped pushing the turtle and after a short pause said "Down", repeatedly, until G. caused the pen to drop to the floor. Somewhat unclearly, the boy then said "Thank you". His first words were thus recorded on video-tape.

(Goldenberg, p. 76)

Goldenberg's work with a second boy raises questions about the meaning of perseveration. The activity was one in which the child decided what direction and how far to throw

a cybernetic dart at a target, on a CRT, in order to put it in the bull's-eye. He would consistently use very large angular rotations to aim the dart and use one or two values most of the time. This strategy required a large number of keypresses but eventually would succeed. When the dart was correctly oriented, the boy would stop and concentrate on the second sub-goal of how far to shoot the dart. In this case, perseveration "was a reasonable activity to engage in" while other and better strategies were developing. (p.78)

Another subject of study was a boy who was disinterested in the screen but who attended to the keyboard upon which he would type. He typed letters organized into four words which included minor misspellings of store names. As he typed he would verbalize only the letters in a monotone and unnatural voice. Goldenberg began to read the letters with the boy and the boy's voice lowered in pitch and intensity as G. began to imitate the chant. At one time G. began to imitate the boy's self-stimulation, fluttering his hands in front of the boy's eyes. The boy stopped G. as if that had a special and different meaning from the chanting with which he was willing to have accompaniment.

Goldenberg looks at the characteristics of autism with a view to exploding some myths in light of other research and to support the idea that the computer is a worthwhile therapeutic device for the autistic child. He cites Hermelin

and O'Connor (1970) who have shown that the autistic child does not necessarily prefer things to people but rather his social gestures may be more passive and thus perceived to be lacking. With regard to verbal language he cites the same source which found that the power to discriminate was abnormal with respect to sound and speech but not as deficient in the visual or tactile senses. In non-verbal language, the autistic child is deficient in imitation (a reference to DeMyer et al. 1972) but less so if there remains a model that can be followed or observed after the action has ceased.

Goldenberg concludes with two important statements:

"The implications are clear. If...autistic children have little or no verbal or manual language, extinguishing their repetitive behaviors possibly destroys the only communicative ability that these children possess.

"The computer's flexibility makes it a perfect extension for a child who is not flexible. We can give the child new opportunities for stimulation using whatever behaviors the child normally exhibits." (Goldenberg, p. 91)

Goldenberg continued Weir's initial use of robotics and a graphical environment. He extended that work by using a CRT display for a planar turtle in two dimensions. He also clearly demonstrates with the second student, a boy, that one must be open to the initiative taken by any student even if it is to man-handle a piece of "high-tech" equipment and not use the full fancy of the devices.

Geoffrion and Bergeron (1978) discuss an experiment designed to be used with children experiencing communication handicaps. Although their study did not include any children diagnosed as having autism, the approach used was unique and it did include three children suffering from developmental aphasia. The purpose of the CARIS system was to provide an environment that would help children learn a symbol system for communication utilizing animation for positive feedback.

CARIS has three phases of involvement. In the first phase, a noun is selected with a light pen from a menu of five nouns. This is followed with a similar selection from a menu with a list of verbs. After the second selection, a figure representing the noun goes through the action determined by the verb. The menus gradually increase in size until the complete vocabulary is available for selection. It is possible to add words of the teacher's choice to the system. The second phase differs in that the presentation of words in the menu is randomly rearranged each time. In

addition, the picture associated with the noun is not shown until the complete "sentence" has been selected. In the third phase, the light pen is used to select a menu and then the child has to correctly type the word selected. The computer, knowing the list of possible words, would give prompts and ignore incorrect letters should they be entered.

All the participants were receiving some form of reading instruction but apparently were not reading. The two cases reviewed indicated an increase in their ability to identify words. One girl although able to recognize nouns had difficulty working with verbs. Her stage of cognitive development may have been a contributing factor but this was not addressed by the authors.

They found that although the system was easy to use interest declined because of the limited number of activities. Increased practice with the learned vocabulary was deemed essential both with and without the computer. They did feel that the computer contact should be increased from weekly to daily. The CARRIS system was a good example of employing intrinsic motivation.

From the Koblars to Geoffrion and Bergeron, the use of computing instruments and computers has evolved to include language, vocabulary, and spatial relationships as material suitable for presentation to the autistic child. The

technology has ranged from human intervention through a machine to robot turtles following the commands of an autistic child in an attempt to solve problems. A start was made and the results were promising enough to encourage others to duplicate and extend the methods that have been developed.

C H A P T E R I I I

Preliminary Study

The use of computers with autistic children by Colby (1971), Weir (1976), and Goldenberg (1979) prompted the author to undertake a study of how autistic children interact with a computer-controlled graphics environment. Beginning in 1980, the author conducted pilot studies in Pittsfield, Massachusetts and in Wilmington, Vermont. An additional "preliminary" study was conducted in Canton, New York beginning in December, 1982. It is presented here in order to describe the background of the students who were subjects of both the preliminary study (described here in this chapter) and the subsequent study (described in chapters 4 through 6).

Subjects of Preliminary Study

A self-contained class for children who were diagnosed as having autism or displaying autistic characteristics provided a group of four subjects. It was located in northern New York. The state agency which provided instruction for the class and the parents of the children gave permission for the studies. Of the original four children, three were included in both the preliminary and detailed studies (the fourth student was moved to another school prior to the preliminary study). The names given

below are pseudonyms used instead of the real names of the subjects.

Alan was a white male who was 10.0 CA at the beginning of the preliminary study. At 9.10 CA he was administered the Stanford Binet Form L-M and the Peabody Picture Vocabulary Test Revised. The results of the first indicated a mental age of 3.0, basal 2.6, and ceiling 4.6. The Peabody test indicated a receptive MA of 3.3. He was described as being generally cooperative but displaying autistic like behaviors. He spinned objects, displayed a great deal of self-stimulation, and was occasionally self-abusive. He responded well to tactile reinforcers and even sought closeness to people which is contrary to the diagnosis of autism. He talked at 2.0 and then stopped suddenly. He did verbalize one-word "phrases", and his thought processes were on a concrete level. He perseverated and had problems in fine discrimination tasks.

Betty is a white female who was 10.0 at the beginning of the preliminary study. She is nonverbal but knows about 100 signs. If she is presented a word in its written form, she can give the sign for that word. She was administered the Columbia Mental Maturity Scale but it was not completed because she did not understand the concepts of same and different. Completion of the test was complicated by a great deal of response perseveration. She subsequently was given

the Hiskey-Nebraska Test of Learning Aptitude on which she achieved a MA of 3.6 and an IQ score of 52. She will go off by herself and work alone rather than with someone else.

Charles is a white male who was 11.4 at the beginning of the preliminary study. He was evaluated at 8.10 and achieved a score indicating 3.6 MA. His major symptoms were diagnosed as severe receptive and expressive language problems although he does understand simple commands. He prefers to play alone. He is easily distracted by both visual and auditory stimuli. He makes inconsistent responses and echoalia is present if the task is above the ability of his cognitive level. As an infant, he did not make the normally accepted baby sounds. After he first started to talk, he did not continue to add words to his vocabulary and his language development progressed very slowly from 2.0 to 6.0. During a speech and language evaluation he spoke two- and three-word phrases but these were requests for food which was being used as a reinforcer. He is still verbal with much of it taking the form of questions to which he knows the answers. These questions usually have no relevance to the task that has been undertaken.

Review of Preliminary Study

The preliminary study began in December, 1982 and concluded in May, 1983. The students interacted with a

computer under the guidance of this author and sometimes with the assistance of the regular classroom teacher or a college student assistant. The sessions were conducted in a room separate from the child's regular classroom with only the observers present.

The software used in the study included programs written by this author under a grant given by the Apple Education Foundation. The programs are written in LOGO and represent an elaborated version of a LOGO program known as Instant. In this environment, the children were asked to move objects on a screen (CRT) and to erase or to draw designs on the screen. Movement tasks included 1) move the turtle to an object on the screen, 2) move the turtle so that it is inside the box, and 3) move the turtle up, down, left, or right. Drawing tasks included 1) draw anything, 2) draw a letter, 3) draw a square, 4) draw a picture of a house, and 5) draw a line from object-one to object-two.

Appendix D includes the operating manual for the software used in the preliminary study.

Charles was the highest functioning of the three children. His first experience with the computer took place in a room equipped with one-way mirrors so that other educators could assess the potential value of using a computer with Charles and possibly with other

developmentally handicapped children. He adapted well to both the strange environment and the computer. During the course of that first session he not only pressed the appropriate keys but he also drew a picture of a house, first with the instructor's direction and second by himself when the instructor was out of the room.

In a later conversation with the mother of Charles it was learned that three days after the computer work, she had found a picture of a car and a house on her living room table. When she asked Charles who had drawn them, he responded "I did". To the best of her knowledge and of Charles' teachers, this is the first time that Charles had ever drawn a recognizable picture.

The period from 14 January to 10 March was used for exploring the environment and learning the various turtle functions. For a brief time, he was given the functions necessary for "dragging" letters of the alphabet around on the screen by the turtle, and then leaving the letters at a new location. If the turtle were placed in close enough proximity to a letter on the screen (within one turtle length) the turtle could be "attached" to the letter. The letter would then follow the turtle around until it was "dropped". With prompting, Charles was able to move a letter to a desired place on the screen, for example placing the letter inside a box located in the center of the screen. On

figure-drawing tasks, he was asked to close the shapes he was drawing and to duplicate geometric figures such as an octagon. He was able to learn that by continuing to press the "turn" key he could correct a rotational error caused by turning past the desired direction. Errors were sometimes the result of a slow speed of processing commands by the computer.

From 17 March until 5 May, the primary effort was on analyzing the particular difficulties that Charles had when attempting to draw a geometric shape on the screen. These are the rotational errors and linear movement errors. A rotational error is defined as making the turtle point in a particular direction, recognizing the misalignment, and rotating the turtle to the intended alignment before making the turtle walk. A linear movement error is defined as making the turtle point in a particular direction, not recognizing the misalignment, and then making the turtle walk in an inappropriate direction with regard to the solution of the problem.

It was observed that Charles seemed to be more prone to making both the rotational and movement errors when the turtle was pointing in certain directions. In addition, errors seemed to be more frequent when the preset rotational change was reduced below 45 degrees (to 30, 15, or 10 degrees). (The preset rotational change is the number of

degrees the turtle will turn when the "turn" key is pressed.) It was observed that with practice, the number of errors decreased regardless of the rotational change but that he was able to draw the square first with 45 degrees, then 30, and finally 15 degrees. The movement errors, making the turtle walk in the wrong direction, also were reduced with time and with decreasing rotational change. The occurrence of rotational errors still persisted but was greatly reduced. Where Charles had been unable to complete the more difficult squares early in the two month period he was able to complete the drawing of a square with rotational change of 15 degrees beginning on 28 April.

Betty learned the functions of "turtle walk" and "turtle turn" quickly but she was less able to use them to solve problems than was Charles. She was able to draw an octagon by pressing the walk and turn keys alternately (the environment constrained her "turtle turns" to 45 degrees). It was evident that one of her objectives was to close the figure she was drawing. On several occasions, she erased the entire screen when the shape did not match the perfect octagon which she had been able to draw in the same or earlier sessions. Betty used a greater variety of environments. In one session, she was placed in the normal LOGO environment and asked to type her name and address. She quickly completed this task and learned the function of the

escape-key (delete the last character) to edit the line that she was typing. A maze was created especially for Betty where she had to direct the movement of a non-turtle cursor around numerous obstacles to a visual goal. With no obstacles she had little difficulty. With numerous obstacles, she was able to complete the task with some verbal prompting.

Returning to the earlier turtle movement environment, Betty was asked to draw a box. The angular rotation had been preset to 45 degrees. Her attempt to draw a square-like box met with failure. There were two types of errors. First, she would rotate the turtle past the desired direction for the turtle to walk. Second, she would make the turtle walk when it was pointing in the wrong direction. Her error-correcting strategy frequently was to erase the entire screen and then start again from scratch. In fact this was used consistently when the turtle actually drew a line in the wrong direction. However, if the error was in rotational alignment, she gradually began to use the strategy of turning the turtle until it was pointing in the desired direction. It was noted that when the preset angular rotation was changed to 90 degrees, the only errors were ones of rotational alignment as she never attempted to make the turtle walk in an incorrect direction. This indicated that she was aware of how the turtle should look when it was correctly aligned.

When the preset angle-change was set back to 45 degrees, she made a rotational error once but walked in the incorrect direction several times. Unlike her earlier attempts with 45 degrees, she did succeed by completing the square.

Alan's work in the preliminary study was characterized by self-stimulation (finger flapping), lack of eye contact with the screen, and random keypresses. During the period of 14 January to 10 March, he would at times press appropriate keys (turtle walk, turtle turn) but usually without the eye-screen contact necessary for establishing awareness of a cause-effect relationship. The session on 10 March was especially discouraging with constant finger flapping and no appropriate responses. During this session I either tried to bring his attention back to the problem or I tried to do his fingerflapping for him. The latter was an activity not liked by him as he would stop my hands from moving and then continue his own movement. The period from 17 March to 5 May was significantly different: his self stimulation was greatly reduced. When asked to press a specific key, he would press either the walk or turn key with increasing frequency. His response in pressing a task specific and correct key also increased at this time. Sometimes he would perseverate while pressing a key but would press so lightly that nothing would happen on the screen. He would slow his rate of pressing, stop, and start pressing again. With time

the frequency of perseveration seemed to diminish. Finger flapping seemed to be reduced if there was accidental or purposeful contact with the teacher. One of his best sessions occurred when a transparency of a world map was taped to the screen and the turtle could walk from one continent to another. He would respond with the name of the continent in which the turtle was located. In this same session it was noted that if the author lightly supported his hand, with which he was pressing the keys, his rate of pressing was reduced. When the turtle became dynamic, that is the computer would control the forward movement of the turtle and he controlled only the angular rotation, he was more attentive to the task (perhaps he perceived a dialogue between himself and the computer). This particular session had taken place on a day when his earlier behavior had been most disruptive yet none of that behavior was observed during the computer session. When letters were drawn on the screen with the turtle he would easily identify the letters drawn with few exceptions.

The preliminary study was able to show that the three autistic subjects were able to interact satisfactorily with the computer environment. Intervention, however, both physical and verbal, was sometimes needed to bring the autistic child's attention back to the task. While there was evidence of specific errors, we did not know the complete

nature of these errors or if there were any observable patterns. A more detailed study was needed to gather more information regarding the errors and autistic subjects' problem-solving abilities in general.

CHAPTER IV

Design of study

While it has been shown that the autistic child is able to benefit from working with a computer, little effort has been made to explore the variety of environments and tasks that might be tried with the autistic child. Except for the author's preliminary study, no known effort has been made to analyze the errors ("bugs") that the autistic child might make while attempting to complete a task in a computer learning environment.

Therefore, this study presented a graphics environment to the autistic child and provided a variety of problem solving tasks for him,her to complete.

Subjects of the Study

The primary subjects of the study were those three autistic children that were included in the preliminary study (chapter 3). Each of these children had been either diagnosed as being an autistic child or identified as having characteristics of an autistic child. The existence of the second of these two categories is sometimes the result of a reluctance to diagnose a child as being autistic. One additional child was included. He shall be referred to as David. David filled a gap in cognitive skills displayed by Alan, Betty, and Charles.

David displayed many of the characteristics of an autistic child and as a result was placed in the same class for autistic children. There was a deficit in expressive language, but he was verbal. He had to be reminded to attend to task. There was a frequent lack of eye contact both with his teachers and with the task material. With regard to language, he would be placed between Betty and Charles. David performed significantly below both Charles and Betty in regard to cognitive skills and better than Alan.

The same problem solving tasks were also presented to 20 non-autistic children aged 2 to 5 years. They were children from regular elementary school classes for pre-kindergarten and kindergarten children. The selection process involved a simple random selection. These students were included in the study only to be able to determine both the types of tasks that children might be able to complete and the types of errors that might be typical for this age group. An attempt was made by this process to have the chronological age of the non-autistic students approximate the mental ages of autistic students.

Methods and Tasks

All the children were shown how to use the computer graphics environment prior to the presentation of the tasks. Children in the first group were also given instructions in

sign language. The tasks have been limited to graphical problem solving tasks. The child's attempt to draw or erase pictures provided immediate feedback of correct and incorrect keypresses.

The first task presented to the students was to identify the symbols that represent "WALK" and "TURN". Ability to point to and press the keys covered by the appropriate symbols was a precondition to the presentation of other tasks.

All the subsequent tasks involved the erasing or drawing of figures on the display screen. The shapes used are illustrated in Figure 3. The tasks for any shape were to 1) erase the figure or 2) draw the figure. These tasks were modified by changing the shape of the "turtle", changing the length of each forward step ("WALK"), and changing the amount of angular rotation ("TURN").

Each child was asked to attempt to complete the tasks by coordinating the WALK and TURN keys.

During the erase-problems the shape was presented on the screen and the "turtle" was located either on or near the shape to be erased. When the turtle traced a line already drawn, the line was erased. (Ordinarily the turtle will draw a new line when it walks on a blank screen.)

Successful completion of the task was a screen clear of the original shape and any extraneous lines.

When the figure to be erased (a square - see Figure 2) was drawn with three turtle-steps on each side and with the turtle-turn preset to 45 degrees, then the minimum solution of erasing the square was:

F F F L L F F F L L F F F L L F F F (L L L)

"F" represented one turtle-step and "L" represented one turtle-turn. When the student deviated from this sequence, one of several errors occurred. The student was then given an opportunity to correct the error, to start the task over, or to end the session at the computer.

When a fresh shape was to be drawn (a square), the turtle was located in the middle of a blank screen. Turtle movements and the resulting lines or their erasure were as above. Successful completion of the task was the production of the desired shape without any extraneous lines appearing on the screen.

In the drawing tasks, the student was given more flexibility in solving the problems. While the number of consecutive turtle-turns were the same as in the erasing task described above, the size of the shape drawn was determined by the individual student. For example, the

following two sequences were considered to be correct solutions to the problem of drawing a square with the turtle-turn preset to 45 degrees:

F L L F L L F L L F (L L)

F F L L F F L L F F L L F F (L L)

The second sequence produced a square twice as large as the first.

In each of the three preceding lists, the last two key-presses "(L L)" were considered optional and not necessary for a correct solution to the problem. If the student used these added key-presses, it served only to return the turtle to its original heading.

Students were faced with erasing a square which had sides of one turtle-step each, a turtle-turn preset to 90 degrees, and an initial heading pointing to the top of the screen from the lower right vertex of the square. A possible solution for this problem could be:

F L F L F L F (L)

This solution would take the turtle counter-clockwise around the square. It is the shortest solution given that the turtle-turn rotated counter-clockwise. With the same constraints, some students elected to solve the problem by

erasing clockwise from the same starting point with the sequence:

L F L L L F L L L F L L L F (L L)

Each task had three attributes coded in the naming of the task.

- 1) the letter B (indicating a "Border square" - a square drawn around the edge of the screen) or a Roman numeral from I to VII to indicate one of seven different graphical shapes that could be used
- 2) the letter D or E to indicate Draw the figure or Erase the figure
- 3) a number indicating the amount of preset angular rotation relative to the current heading of the turtle (90, 45, 30, 15, or 10 degrees) or the letters "UDLR" indicating an absolute heading change to up, down, left, or right regardless of the current heading of the turtle.

For example, V E 45 would describe a task requiring a student to erase a house shaped figure using a preset angular rotation of 45 degrees. There were 90 possible combinations of which 32 were actually used. A strict

sequence of tasks was not maintained. Rather, cues were taken from the relative difficulty a student had solving a task and from the spontaneous activity of the student.

Characteristics of the Environment

The computer-learning-environment was chosen for its ease of operation by young children. The environment had been used by children ranging from eighteen months to 10 years of age over the preceding five years. The tasks were chosen because the errors are presented immediately to both the child and the observer. The tasks were closely related to the child's own body movements. The "walk" function is analogous to the child taking a single step. The "turn" function is analogous to physically turning or pivoting so as to face a new direction.

Despite the general ease of working with the environment by young children, some limitations to the environment were evident. The limited visual resolution of computer displays may present perceptual problems manifested by the child not being able to determine in which direction the turtle is pointing. This limitation could be reduced by restricting the number of different headings the turtle may assume and, if necessary, changing the actual shape of the turtle. The speed with which the system operates may also prove to be a limitation due to its inability to respond

with sufficient speed to every keypress the child makes while attempting to complete a task. This could have either a positive or a negative effect on persisting or dormant perseveration depending on the severity of the autism and the child's cognitive or perceptual development.

A major departure from traditional mathematics was made in an attempt to remove a possibly distracting occurrence on the screen. In a traditional mathematical graphics environment, the addition of vectors, lines, drawn in different directions make the possibility of exact closure difficult if not impossible. This is due to the irrational values generated from trigonometrical functions. A modification was made to guarantee closure if the preset angular rotation was set to 90 or 45 degrees; the student was always able to move back to the exact starting point. Specifically, if the heading was an odd multiple of 45 degrees (pointing in a diagonal direction) the turtle would move forward an amount equal to the preset linear movement multiplied by 1.414 (approximately the square root of two). This has the effect of being able to draw a 45-45-90 triangle that is also equilateral (sic). It is equilateral in the sense that one walking step on each side of the triangle would bring the turtle back to its original location.

It should be clear that this is not the way the mathematics which we know really works. The hypotenuse would have had to be about 1.414 turtle-steps to form the triangle. In this software, the magnitude of the turtle-step was multiplied by 1.414 when two criteria were met: 1) the turtle-turn was preset to 45 degrees and 2) the heading of the turtle was an odd multiple of 45 degrees (45, 135, 225, 315). Under these conditions, when the turtle was located at vertex 0, Figure 4, it could move to any vertex, one through eight, in a single turtle-step. If the turtle-turn were preset to 90 degrees, the turtle could reach only vertices 2, 4, 6, or 8. If the turtle-turn were preset to any other angle the turtle would obey the normal rules of trigonometry.

Turtle-turns of 45 degrees led to a distinct advantage when the software was being used with younger children. It was possible for a student to return exactly to any vertex, having once left that vertex. This author's earlier experience has shown that students would try to close many figures that they attempted to draw. It was a difficult and often impossible chore if this unique rule forcing closure was not used. With this system, the student was able to spend less time being distracted by the sub-problem of closing a shape.

Data Collection

Data were collected during the problem solving tasks in one or two methods: 1) observer notes and/or 2) a computer record of individual keypresses.

Observer notes included a graphical representation of the child's attempt to solve the problem. The computer records contained each of the individual keypresses made by the child.

In order to facilitate analysis of student performance, a naming of coordinates was developed. This made it possible to express the sequence of vertices reached by a student or to identify the vertex at which an error occurred. For erasing-tasks, the coordinate system is shown in Figures 5 and 6.

Bugs and Errors

The analysis of the data was focused on the "bugs", errors, that occurred in attempting to solve the tasks of drawing and erasing shapes.

Of the tasks the child attempts:

- 1) which tasks were completed without error
- 2) which tasks were completed but included child corrected errors

- 3) did modification of the computer learning environment result in a task becoming unsolvable
- 4) did modification change the nature of the errors
- 5) did modification make unsolvable tasks solvable
- 6) what tasks were completed by only one group

See Chapter 5 for a complete discussion of errors.

The author was aware that co-variant benefits might occur including changes in receptive or expressive language, the reduction or extinction of perseveration, echolalia, ritualistic or other behaviors either while working with the computer or in regular classroom activities and either preceding, during or following sessions with the computer. If such events did occur, it was not interpreted to mean that the computer was the direct cause of the event. Rather, the intent was to make note of unusual events for which the computer may or may not have been a catalyst (Weir 1976).

In order to perform an analysis of the sequence of keypresses, errors, and patterns of errors between the subjects, a classification system of protocol analysis was used. This system was based on results obtained from the preliminary study and was used to extend the system

developed by Chait (1978) and modified by Maniatis (1983). That system was designed to help analyze the work done by children in the graphics environment of LOGO and the work was carried out at McGill University in Montreal, Quebec.

Software Used in the Study

The detailed study made use of the programs used during the preliminary study and adapted those programs so that the child could control the turtle through relative commands ("turtle walk", "turtle turn") and absolute commands ("move up", "move down", "move right", "move left"). Other modifications of the software were made in order to better analyze the abilities and the inabilities of the students involved. See Appendix D for details.

The Computer Learning Environment

The sessions with the autistic children generally took place within the regular classroom but physically separated from other areas in the room by distance and the use of soft visual barriers. The non-autistic children were taken to a teacher work area adjacent to the school principal's office some distance from their own classroom. The schedule for working with children was coordinated with the parents, teacher, or other individuals responsible for the the child in either a home or school setting. The work with the child

typically took place in a school setting, once or twice a week, and for fifteen to thirty minutes per session.

The author was responsible for the supervision of the interactions between the students and the computer. A copy of the dissertation proposal and the required forms were filed with the Human Subjects Review Committees of both the School of Education, University of Massachusetts, Amherst, Massachusetts and of the State University College, Potsdam, New York. Other people that were involved in some activities included the regular classroom teacher, teacher aides and specialists who work regularly with the children.

Conceptual Hypotheses

It was expected that the autistic children would successfully complete some tasks presented to them and that these successes would be commensurate with their level of development. (It was felt that the tasks, which were to be presented to the autistic children, could be solved both by autistic and non-autistic children.) It was also expected that as the preset angle of rotation was decreased in size there would be correspondingly less success in completing the task. (The limited visual resolution of the CRT screen might distort the image of the turtle so that the student might not be able to determine in which direction the turtle was pointing. Also, the student might not recognize the

shape of the turtle even with a higher degree of resolution.) Further, it was expected that the autistic students would fail to complete more tasks when they were drawing and that they would succeed more in completing erasing tasks.

(Erasing tasks would not require an internalized model of the figure which would be required for the student to draw the figure. Erasing a figure would thus rely on recognition rather than recall.) In general, the autistic student would experience more success when input to the computer was constrained and when those values which affected the change of state of the screen were similarly constrained. (Zentall and Zentall (1983, p.451) hypothesize that the autistic child tries to reduce the total amount of stimulation available to him. The constraining of the environment by the teacher would reduce implicit stimulation - the number of and the complexity of factors that needed to be weighed in order to reach a decision.)

C H A P T E R V
Analysis of Results

The analysis of the responses is based on the tabulation found in Tables 1 to 4. This tabulation is in turn based on the detailed summary of activity contained in Appendix B and on the record of keypresses maintained in disk files created during the actual session with each subject.

Table 1 is a tabulation of the frequency of the type of error for each subject. There were five basic types of errors:

- 1) Rotational Corrected
- 2) Rotational Uncorrected
- 3) Movement Corrected
- 4) Movement Uncorrected
- 5) Border Limited Movement

Errors

1) Rotational Corrected - This error resulted from rotating the turtle past the desired heading. This required the student to recognize the error and to continue pressing the "turn" key until the turtle was pointing in the desired direction. This error was subject to effects of perseveration where the subject would press the key too fast

and miss the desired heading. This error was also affected by the slow response time of the computer operating under the author's software. As a result, perseveration may not be recorded as such if it occurred at a sufficiently rapid rate have such that it occurred in the interval of time during which the computer did not look for keypresses.

An example of this error was seen in Charles' completion of task I D 90 on 30 October. The task was to draw a square with the angular rotation preset at 90 degrees. The actual keypresses used to complete the task were:

F F C F (L L L L L) F F F L F F F L F F F L L L L L L L L L L

Two anomalies can be observed. The third keypress was the letter "C", an inappropriate key but adjacent to the subsequent keypress "F". The rotational error occurs in the sequence "L L L L L" enclosed in parentheses (Figure 7). A single press of the "L" or "Turn" key was the expected step in the solution of the problem. The sequence "L L" or "L L L" would have the turtle heading in a direction other than that required for a counter-clockwise solution traversing vertices 1,2,3,4, and 1. The minimum required sequences to correct the error would be "L L L" or "L L" respectively. This would bring the turtle to the desired heading with one complete rotation of 360 degrees (4 times 90 degrees) plus

one additional key press of 90 degrees. Though this is an error in obtaining the minimal solution the student is subtly being exposed to modulus arithmetic (mod 360). Another rotational error does occur at the end of the sequence where the student brings the turtle back to its original heading but this is inconsequential to the solution of the problem.

2) Rotational Uncorrected - This potential error is not detected in this study as it is the necessary prerequisite for a "Walk" error. That is, the subject must leave the turtle pointing at an incorrect heading before pressing the "walk" key and causing the turtle to move in an inappropriate direction. As a result all entries for this error in Table 1 have the value of zero.

3) Movement Corrected - This error is analogous to the rotation corrected error in that having made the error of moving in the wrong direction, the subject must recognize the error, rotate the turtle so that it is facing the location from which it just moved, walk back over that line and thus erasing. The subject in order to have the opportunity to complete the task must then also rotate the turtle to the desired heading before again pressing the "walk" key.

An example of this error was seen in Charles' completion of task I D 15 on 30 October. The task was to draw a square with the angular rotation preset at 15 degrees. The actual keypresses used to complete the task were:

F F F L L L L L L	(1)
F F F L L L L L L L	(2)
F F L L L L L L L L L L L	(3)
F F L L L L L L L L L L L	(4)
F F F L L L L L L	(5)
F F F L L L L L L	(6)

Charles began his solution by drawing the first side and then rotating the turtle 90 degrees to the left, 15 degrees multiplied by 6 (sequence 1). He drew the second side and then proceeded to turn the turtle 15 degrees past the desired 90 degrees (sequence 2 and Figure 8a). It may be postulated that he thought the turtle was aimed correctly because sequence 3 first shows that he walked in this incorrect direction. This sequence also shows the start of the error correction. First he turned the turtle around 180 degrees (sequence 3 and Figure 8b) so that the turtle could retrace its steps and erase the erroneous line segment (sequence 4 and Figure 8c). He then turned the turtle to the correct heading and proceeded to complete the square (sequences 5 and 6 and Figure 8d).

4) Movement Uncorrected - This error results from rotating the turtle to an inappropriate heading, moving the turtle in that direction, and then being unable or unwilling to correct the error. This error was determined to occur if the subject continued to draw a path with the turtle whereby the error was compounded into a much larger error. Frequently the subject would either attempt to close the figure, move the turtle back to the starting point, or would cease all activity until asked if he, she would like to start again from the beginning.

5) Border Limited Movement - This error was the result of the subject pressing the "walk" key so that the turtle reached the border of the screen. This was a barrier beyond which the turtle would not move. Continued pressing of the "walk" key was an error but it did not result in any larger movement on the screen that would have to be corrected.

There was a difference pattern of errors each subject made. It is helpful to keep in mind the relative ability of each of the four autistic subjects. In ascending order of ability are: Alan, David, Betty, and Charles with Betty and Charles being relatively close to each other in ability.

Alan made significantly more rotational errors in comparison to his other errors. This may be attributable to a degree of perseveration or his losing eye contact with the

television display. It is important to note that he had no walk errors that were subsequently self corrected. This analysis of his work is limited in that over a period of about three months, he worked on only 10 tasks most of which resulted in failure. Despite the small number of tasks attempted, he had the second highest number of border limited errors. This is, perhaps, another indication of perseveration or loss of eye contact.

David was of a higher ability level than Alan and the errors made reflect this fact. David made 52 "walk" errors 13 of which were corrected by him. He made relatively few errors that were strictly rotational indicating the likelihood that his errors were less affected by perseveration or by loss of eye contact with the television display. This is despite the fact that there was a higher number of border limited errors.

Betty showed a significant difference from David concerning the types and frequency of errors made. She had no border limited errors whatsoever. The number of uncorrected walk errors was significantly reduced, from David's 39 to her 22. The number of corrected walk errors was about the same but her corrected rotational errors of 17 was significantly higher than David's 4.

Charles showed a continuation of the differences observed between Betty and David. First, the number of border limited errors was significantly less than David's although slightly higher than Betty's zero errors. The number of corrected walk errors showed only a small increase. The number of uncorrected walk errors showed another significant decrease from Betty's 22 to his 13 errors. Finally, there was again a significant increase in the number of corrected rotational errors.

Based on these observations, the following may be inferred:

- 1) Border limited errors are more likely with lower ability students or students displaying a high rate of perseveration
- 2) The frequency of corrected rotational errors increases with the ability level of the subjects
- 3) The frequency of corrected walk errors remains relatively constant
- 4) The frequency of uncorrected walk errors decreases steadily with increasing level of ability.

Table 2 is a tabulation of the different possible tasks attempted by the subject. The frequency of successful

completion without errors, the completion of a task with self corrected errors, and the failure to complete a task are recorded together with the total performance under these three categories for the four subjects. Table 3 is a tabulation of tasks completed or failed for each subject.

Alan's work showed no task completed without errors and more tasks failed than completed. Alan was not presented with tasks involving angular rotations smaller than 45 degrees because of both his failure to complete any task without error and the increasingly distorted image of the turtle as the amount of angular rotation per keypress is diminished.

David failed to complete 44 of 53 tasks attempted. As with Alan, the attempts to introduce angular rotations of less than 45 degrees led to complete failure. As with Alan, David failed to complete any tasks without error.

Betty's work shows a significant difference when compared with David's work. She completed 24 tasks without error and the number of tasks failed completely was significantly reduced from David's 44 to her 25. There was an increase in the number of tasks including self corrected errors over David's performance.

Charles presents mixed results based on the comparison between David and Betty. Charles, despite having the highest

ability level, completed fewer tasks without error. However, there continues the significant drop in tasks failed and an significant increase in the number of tasks completed with self corrected errors.

The following may be inferred from the above analysis:

- 1) The frequency of completed tasks increases with increased ability of the subjects
- 2) The frequency of failed tasks decreases with the increased ability of the subjects
- 3) The number of tasks completed with self corrected errors increases with increased ability level of students

Table 4 summarizes the performance of each autistic student with regard to the percentage of tasks completed without error (c), tasks completed with self-correction of error (s), and tasks failed. This is organized according to the preset angular rotation and to drawing versus erasing tasks. Alan was better at erasing tasks (the only one) than at drawing tasks. The reason is two-fold. First, he attempted the fewest number of tasks and the data available is the smallest sample for analysis. Second, most of the tasks he attempted were border squares. Erasing a square, especially a border square, is easier for the child who has

not internalized an image of a square and cannot work from memory. As can be seen from the table, the reduction of the preset angle from 90 to 45 degrees resulted in total failure to complete drawing tasks.

David was better able to draw than erase figures. In addition, the data from table 4 shows a definite and substantial decrease in performance on drawing tasks as the the preset angle was reduced from 90 to 30 degrees. Interestingly, there was no significant change on the erasing tasks as the angle was reduced.

Betty's performance based on these criteria is not as clear. Drawing tasks were generally more likely to be completed than were erasing tasks (angle presets of 45 and 15 degrees). There was a decrease in performance as the angle was reduced for both drawing (angle presets of 45, 30 and 15 degrees) and for erasing (angle presets of 90, 30, and 15 degrees).

Charles was also not as clear as Alan and David. Generally, he did as well or better on drawing tasks when the angle was preset to 90, 30, and 15 degrees. He did show a definitely decreased level of performance on drawing tasks as the preset angle was reduced from 30 to 10 degrees. This pattern was certainly not evident in the data on his erasing tasks.

Considering the four autistic subjects as a group, drawing tasks were characterized by a higher level of performance than were erasing tasks. Decreased performance resulting from decreased preset angles was observed in drawing tasks. There was no clear pattern of decreased performance on erasing tasks when the angle was decreased.

A more detailed observation of the work of the individual autistic students revealed additional interesting information. These observations were based on the fact that for the drawing and erasing of geometric shapes a minimum solution for each problem exists. The minimum solution is here defined as being the correct sequencing of walking and turning tasks. A single turning task of 90 degrees could consist of L L if the angle preset was 45 degrees. A single turning task of 90 degrees could also be L L L L L L if the angle preset was 15 degrees. Thus each turning task consisted of pressing the "turn" key the minimum number of times so that the turtle was pointed in the correct direction. Each time the turtle was turned passed the desired heading, the number of tasks attempted was increased by one task.

In the case of "walking", each task could also consist of one or more presses of the "walk" key. If the student caused the turtle to move in an unwanted direction, there was no increase in the number of tasks attempted beyond the

last uncorrected movement. However, each of the student's self-corrected movement errors increased by 4 the number of tasks in the problem solution:

- 1) movement in the wrong direction
- 2) rotation of 180 degrees
- 3) retrace and erase the extraneous line
- 4) turn the turtle to the desired heading

The minimum number of tasks required for specific movements about a square are illustrated in Figure 9 where vertex 1 is both the starting and ending point in the solution. In each case the turtle has 0 degrees (pointing straight up) as its initial heading.

Of David, Betty, and Charles, David made consistently more errors and at least 21 % of his tasks resulted in error (Figure 10d). He made movement errors regularly (Figure 10a). His frequency of self-corrected errors diminished and disappeared after 1 November (Figure 10b). At about the same time there was a dramatic increase in the percentage of border limited errors (Figure 10c). Looking at this last figure one can see a definite drop in the number of border limited errors on 6 November. On this date there is a dramatic increase in uncorrected movement errors. A

comparison of David's percentages of total error versus uncorrected movement error shows similiarity of shape.

Betty seems to show a decline in the percentage of tasks that include an uncorrected movement error (Figure 11a) while there appears to be an increase in the percentage of tasks that have a rotational error (Figure 11c). The percentage of self-corrected movement errors seems to oscilate at a low level (Figure 11b). Over all there seems to be a decline in the total percentage of error. Comparing the graphs for total error versus rotational error one finds a similarity of shape if the data for 4 October is deleted.

Charles, similar to Betty, seems to show a decline in the percentage of tasks that were uncorrected movement errors. He shows a much higher percentage of rotational errors (Figure 11c) and after a sharp decline at 23 October, the percentage approaches its previous high level. His self-corrected movement errors are always 5 % or less. The graph for percentage of any error (Figure 11d) shows great similarity to the percentage of rotational error.

The dominant error for David is uncorrected movement error. Betty and Charles have rotational error as their dominant error.

The individual progress of both Betty and Charles may be explained in terms of two cognitive processes. The first

is the ability to identify the direction in which the turtle is heading. The second is the level of perseveration engaged in by a student. The poorer a student is at discriminating the direction in which the turtle is pointing the more likely the student will make an uncorrected movement error. As the student's discrimination skills improve, there will be more self-corrected movement errors and fewer uncorrected movement errors. As the student is better able to aim the turtle, less likely to make a movement error, we see that the ratio of rotational errors increases. There are different reasons for this. First, the student may perseverate while working on a task. The perseveration may have been a component of the movement errors and have given inflated ratios for those errors. When the movement errors were reduced, the perseveration would continue and result in turning the turtle too far -- hence, rotational errors. Second, the rotational errors could be the result of an enthusiastic student pressing the turn key until the turtle is pointing in the correct direction. Here the student has not realized that un-executed key-presses wait in the keyboard buffer still to be executed even after he stops pressing the key(s). Third, the computer system may process commands at a sufficiently slow speed that causes the student to think that although he has pressed a key, the computer has not recognized his key-press. Therefore, the student presses the key again increasing the likelihood of

turning or moving the turtle too far (delay-of-processing factor).

In Summary, the autistic children were able to successfully complete graphical tasks presented to them in a constrained computer-based learning environment. Success was dependent on their level of development. The preset angle of rotation ("TURN") affected the level of success. As the rate of turning decreased from 90 to 10 degrees, the level of success also decreased. Contrary to the hypothesis, drawing tasks were easier for the student than were erasing tasks. This was due to a greater freedom in the actual size of the objects being drawn, whereas erasing the figures increased the possibility of erasing a line too far (drawing a new line that would itself have to be erased). These results point to other topics and methods that should be pursued.

C H A P T E R VI

Suggested Research

Controlled Studies

It is important that controlled studies be done to obtain results that have a larger sample than this study. However, with an incidence of one in two-thousand births, it is sometimes difficult to be able to work with a group of autistic children large enough to make the controlled study practical. It may be necessary and even desirable to have the research conducted on a cooperative basis with two or more primary investigators. Each could divide their separate groups of autistic children into experimental and control groups irrespective of their numbers with confidence in the larger population of the total group. Even if the intended research requires the use of inter-rater reliability each investigator could serve in this capacity for the other. To date, the numbers of autistic children, who have been observed while using computers, is so small that some innovative methods may have to be employed so as to guarantee sizable populations for study.

Improvements in Existing Environment

Future research should endeavor to incorporate improvements in the computer environment so as to improve both the collection of data and the quality of the data

collected. Graphical information that is presented on the display screen frequently appears distorted to our eyes. It may be that this distortion is perceived by the autistic child to be several orders of magnitude greater than what we perceive. Therefore, high quality RGB color monitors should be used to provide the most clear images possible. It also is necessary to consider the computer system being used in the study. Some computers, including those used in this study had a high-level resolution of only 192 dots high by 280 dots wide. A television picture has a resolution of 525 dots high and this should serve as a minimum level of resolution. In fact, it might even be preferable to use displays that have a resolution of 1000 dots by 1000 dots. This would provide a screen with over eighteen times the resolution used in this study. This would effectively remove much, if not all, of the effect of misinterpretation of graphical information based on distortion and the subsequent clouding of details that one wishes to observe. One should also consider the effect of color on the task. Is there a color, or combination of colors, that is superimposed as "visual noise" onto the information on the screen and thus interferes with the information we are attempting to communicate? Further, are there colors that may reduce the effect of noise for a particular child?

Speed of System

Systems that are sufficiently slow may be unable to identify the occurrence of a characteristic behavior displayed by many autistic students: perseveration. Perseveration in a computer environment frequently takes the form of the continuous and rapid depressing of a single key or group of keys. If the response time of the system to a key press is sufficiently slow, the function which the key-press is to activate may be delayed. One may press several keys in quick succession only to wait several seconds for all the functions to be carried out. If the speed is extremely slow it may be possible that as a key-press is placed in the keyboard buffer a subsequent key-press may not be noticed because of processing taking place. A slow system may also result in completely filling the keyboard buffer. As long as it is full, additional key-presses would be ignored.

Normally, one would want to have the operating speed be fast enough so that its effect on processing would be transparent to both the student and the observer. However, it may be possible to benefit from having a delay in the processing of key-presses. As Weir (1976) pointed out there was a reluctance on the part of her subject to relinquish control to the computer. In this case the student had been working with the computer for some time. He was encouraged

to assign a sequence of LOGO steps to a name, so that specifying only that name would execute the entire sequence of steps. The student did not like to relinquish the control that he had when he typed the statements individually. Immediate reinforcement was important to him and he was unwilling to postpone this particular reward. By delaying the execution of steps, it may be possible to have the student gradually accept postponement of reinforcement. The disadvantage of not being able to tell if individual statements are correct until after all have been entered may encourage the development of an intrinsic motivation to use a procedure name to refer to a block of statements which were once tested and found to be correct. This use of a new name, thrust into his vocabulary for practical reasons, may further encourage language development or the forming of concepts.

Speech Synthesis

With the introduction of improved quality speech synthesizers, a new dimension can be added to the use of computers with autistic students. Again, a primary concern is the clarity with which information is transmitted from the computer to the student. Early synthesizers included a level of distortion which made it difficult for most people to decode what was being said. With improved clarity, it

could be used to provide audible reinforcement for each key-press. That could encourage a slower rate of key-pressing as the student might pause to hear the reinforcement following each key-press. This might lead to a reduction of the student's level of perseveration. If the student has a perceptual difficulty with auditory stimuli that is aggravated when the stimuli are not consistent, a speech synthesizer could be used to provide a consistency in the form of speech: frequency, amplitude, rate, and specific "voice" characteristics.

Speech Recognition

Schools spend considerable time trying to overcome the autistic student's deficit in language. Part of that time addresses verbal expression. The more severely afflicted student may not have any recognizable speech but he may use non-word utterances in an attempt to communicate or respond. A speech recognition system could be used to match a sequence of vocal sounds to one of a series of "learned" sound patterns. Typically a speech recognition system learns a pattern of sounds by having the same word or words repeated many times so that the computer can perform a statistical analysis to determine specific characteristics. The autistic student may be unable or unwilling to "teach" the computer in this way. It would then be necessary to tape a large quantity of his "speech", possibly on video tape so

as to provide a visual clue to the context in which each was used. After these utterances with similar sound content have been identified, it would have to be determined if they were used in essentially the same context. After these associations have been made, the student could be given the opportunity to communicate with the computer, and even to control it with his own "speech". Being able to do this verbally removes a very real problem for some autistic students: meaningful (identifiable) speech when the student is not capable of producing recognized speech sounds but only non-speech utterances. If the student is using the keyboard for communication, there is a physical visual distance between the keyboard and the screen. If the distance is too great, the student may have difficulty going from the screen where he has determined the desired action to the keyboard where he is to act. Similarly, there may be difficulty going back to screen to see the effect of his action. The speech recognition system removes the visual distance problem if the student is attending to the screen. The student is then able to maintain eye-contact with the screen at all times.

Tactile Screens

Another method to remove the problem of visual distance is by using touch-sensitive screens to communicate with the

computer. This would have an advantage over the speech recognition system. While eye-contact is being made with an icon or some other visual representation, a tactile signal, much less susceptible to noise, would be given at point of focus of the eye-gaze. This eye-to-computer gaze is in contrast with the autistic child's apparent lack of eye-to-eye gaze with other people.

New Environments

It should not be assumed that graphical environments are the only ones in which an autistic student can work. With sophisticated speech synthesis and speech recognition systems it may be possible to design a completely audible environment without keyboard and without displays. Or, what of a musical environment? Many exist today. Would that be an intrinsically motivating environment for the student to work in? We must let our imaginations run. By not constraining our thoughts, we may find alternative structures within which the student may succeed.

New Graphical Tasks

This study has concentrated on the autistic student's ability to draw or erase geometric shapes. The students have demonstrated their ability to move the turtle around on the screen. Can that ability be channeled for the learning of

new tasks? These might include: 1) assemble the following words on the screen by moving them into a correct sentence order, 2) use the turtle to visually link (match) objects in two different groups that share some property, and 3) use a set of predefined shapes to construct drawings. This could be accomplished either by having the student use predetermined programming tools (procedures) or by actually defining the procedures himself.

The advances in technology enable us to look beyond our current horizons to new paths of communicating. Whatever paths we follow we must be ever cognizant that with the autistic child we should carefully constrain our environments to limit the variety of information. This will help to match the channel capacity of the autistic child so that he is not cognitively over-stimulated. We should anticipate areas of difficulty in order to modify them so that learning of a specific concept may be accomplished. We should then restore the environment to its unmodified form so that the area of difficulty may be addressed. The computer-based learning environment has been shown to be a practical medium for graphical problem solving. With careful selection of constraints and tasks this environment may become not only an environment of learning but also a window through which we may observe and hopefully understand the cognitive processing of the autistic person.

Recommendations for Integrating Computers in Schools

Using computers with autistic children should be viewed as an alternative instructional medium. Some care should be used in planning for its use. The physical environment should, if possible, be removed from the actual classroom so as to minimize possible distractions. It should be in an area that is free from extraneous noise. Even the high-pitched sound of fluorescent lights can distract the autistic student. Clanging heat pipes and unexpected outbursts from their peers can be an attention grabbing event in an otherwise quiet room. Visual disturbances can also be disruptive, but they seem to be less of a problem than audible disturbances. The student can physically block selected visual images with his hands and leave others at their full level of intensity. The same cannot be done for audible images. One must also make sure that the image on the CRT screen is not disturbed by reflections from lights or windows.

The computer itself can be a source of problems. We who are poor typists are grateful for the automatic repeat feature of today's typewriters and computer keyboards. No longer do we have to press repeatedly on a key in order to underline a phrase. Instead, we hold a finger on a key and the computer does the rest, providing an endless string of characters until we lift our finger. The autistic child

easily perseverates by pressing on a key and producing his own endless stream of characters. When it is possible to reduce the amount of perseveration, it is frustrating to the teacher to have the child just push down a key, not lift his finger, and produce his character string (maybe the child is enjoying this new found power). It may be better if the computers which are used by autistic students did not have the automatic repeat feature. If the computer that is to be used does have this feature, it may be possible to have a computer store technician make a hardware modification, inside the machine, to disable the repeat. It may be possible to find software that disables the repeat feature from the program, but a more general solution would be to make the modification permanent. Of course, such a change would usually be possible only if the computer was dedicated for use with autistic or other developmentally handicapped students. It might be a very undesirable modification if the computer were used with non-autistic students.

The work of Weir (1976) suggested the use of less confusing keyboards with fewer and larger keys. However, it has been this investigator's observation that if the software effectively ignores inappropriate keys (that is keys that have no function) and if the desired keys are easily identifiable (use of an icon that is taped or attached to the key) a regular keyboard should not prove to

be a limitation. If icons are attached to the keys, they should have a high visual contrast when compared to the unused keys (the icons should not have the same color as the unused keys). The benefits of using the existing keyboard are 1) if you wish to replace the icon with the letter under the icon you have only to lift the icon off the key and 2) when the time comes to use a regular keyboard the student doesn't have to learn a new keyboard. In fact, the student may have already learned the position of many keys by scanning the keyboard as he moved from icon to icon.

Autistic children have been shown able to maneuver a turtle in a two-dimensional graphics environment. Teachers should see this as a medium into which they can move classroom content where the child can be asked to move the turtle to a specific object on the screen. Some educational software today makes use of a function that picks up and drops objects. This could be used to help students work on categorization skills.

Computer based learning environments are so consistent in response to keys, that the autistic child may soon cease testing a key to see if it still does the same thing as it did five minutes ago. The function of each key becomes predictable. By removing the uncertainty of key functions, the child may be free to explore similar but yet unlearned key functions. More importantly, he may be free to explore

higher level cognitive skills that are not yet tried or mastered. In fact, if autistic children can maneuver a turtle in an artificial two-dimensional environment, they may be better able to work in a three-dimensional graphics environment.

Final Comments

The nature of autism observed in the students taking part in this study merits additional comment. They did not perform as poorly or as well as some autistic subjects with whom the author has had occasion to work. Severe language deficits were evident, but all four were verbal to some degree. Alan was the most severely affected, and he sought out his teachers many times with a most intense eye-to-eye gaze (Rutter, 1978a, p. 9) to have them recite an advertisement for headache medicine. He would add his voice or he might recite alone. The fact that all were verbal, though not necessarily with useful speech, may have had an affect on the study in that they were better able to accommodate the visual icons used to represent the "turtle functions". (They did use a limited verbal symbolic notation.)

When solving graphics problems on the computer, the autistic subjects experienced difficulties similar to the non-autistic subjects. Both the autistic and non-autistic

subjects made the same types of errors described in chapter 5 as they attempted the different drawing and erasing tasks. The difficulties included the delay-of-processing factor. When similarities in performance did occur the subjects had developed cognitive structures that produced the same result. It cannot be determined if the structures were similar or were fundamentally different. An investigation of similarities and differences in cognitive structures would be a most important study to be undertaken at a future time. Such a study might help determine a possible site for a lesion if definitive differences can be shown to exist in the contrasting cognitive structures. (Wing, 1978, p.42).

Rutter (1978b, p. 91) pointed out that autistic children are better able to handle spatial sequencing than temporal sequencing. This is consistent with the findings in this study. The subjects were able to solve spatial problems on the computer display despite their cognitive deficits. The error that predominated for Betty and Charles at the end of the study was rotational error and it was influenced to varying degrees by perseverating on a particular key-press.

Rutter (1978b, pp.100-101) posed more general questions to be answered by further research. Most importantly, what is the nature of the cognitive deficits? We can help begin to answer this by identifying those processes which may have

been necessary to successfully complete the tasks presented to each subject:

- 1) identify the screen turtle
- 2) determine the turtle's heading
- 3) determine the turtle's position
- 4) learn the turtle operations
- 5) let operations be represented by specific symbols
- 6) establish a sequence of commands (key-presses) to place the turtle in a sequence of positions on the screen
- 7) identify movement or rotational errors
- 8) correct errors

Processes 1, 2, and 3 are a prerequisite for processes 6, 7 and 8.

Because the autistic child is able to solve problems of the nature described here, we may infer that success indicates that the following processes are intact:

- 1) discriminate between shapes
- 2) use of a symbolic system

- 3) plan a temporal sequence of commands to control an object with a spatial reference
- 4) internalize a visual model of anticipated changes in shape that follow use of a command

This is a takeoff point for a more involved study of the cognitive processes autistic students use to solve a variety of different problems.

Menyuk (1978) among others mentions the poor memory organization and sequencing abilities of autistic students. Success with these problems suggests that if the environment is sufficiently constrained, then the autistic child is capable of organizing a problem solving strategy that is spatially specific.

Zentall and Zentall (1983) made observations regarding optimal levels of stimulation. This can be directly related to the child's behavior while interacting with the computer environment. They hold the view that the autistic child is over stimulated and would thus have a tendency to reduce the level of stimulation. This is especially true in the case of Alan and Charles. Alan was sensitive to auditory stimuli including ambient room noise. When it reached a certain level he would sometimes walk away from the computer. There were times that the stimulation did not subside (water banging in the heating pipes) and he did not

return to the task. Charles, on the other hand, was a frequent questioner of trivial data. His own speech was a source of stimulation. As he would begin to work on a task, he would also reduce the number of questions.

With regard to earlier studies of autistic subjects using computers, there are similarities and differences. Colby and Smith (1971) judged success as improved language development. In this study, success was judged on the autistic child's performance solving problems in a graphics environment. While Colby was interested in the very important issue of meaningful communications, this author chose to address those skills relevant to the task itself. It was noted that all four subjects made progress in their ability to solve the tasks they were given. Anecdotal information showed that simultaneous to the work on the computer, there were other changes occurring in the subject's behavior. Most notable was Alan, our subject with the least cognitive development. He became more verbal during the course of the study as described above. He also began to seek out more contact by touching his teachers hands and arms.

In contrast to Colby's work (1973) where he viewed autism as a form of dissymbolia, this author has shifted to an alternative opinion. The autistic students in this study were presented with a symbolic representaton of the turtle

operations in the form of iconic images taped to the keyboard. All four subjects were able to use the symbols to successfully solve the problems. Perhaps it is not so much a problem of using symbols but rather that they are able to work with representations of knowledge that are different from what we expect. We are lucky when we choose a form of representation for an idea that is sufficiently close to their "natural" form and that they are able to accommodate their structures so as to understand our world. These subjects, like other autistic people, have been able to organize their world so that they can function as a developmentally handicapped person. They do have an organizational framework though it may be severely constrained. It is theirs; they own it. It is our responsibility to learn about their cognitive structures and to teach to those structures. If we are smart enough we may even find a way to help them adjust their structures so that they can function in "our world". However, we need to decide if our structures are the ones they should possess. We could destroy the only structures that are working for them (Goldenberg, 1976, p.91), and they may not be able to learn those we call our own. We might destroy structures that would greatly enhance the cognitive structures we want to give them. We must learn as much as possible about their structures because we might be in a greater need of their skills. We just don't know!

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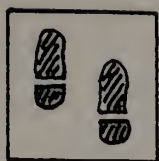
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APPENDIX

APPENDIX A
Figures and Tables



Walk (F key)



Turn (L key)

Figure 1

Icons Attached to Keys

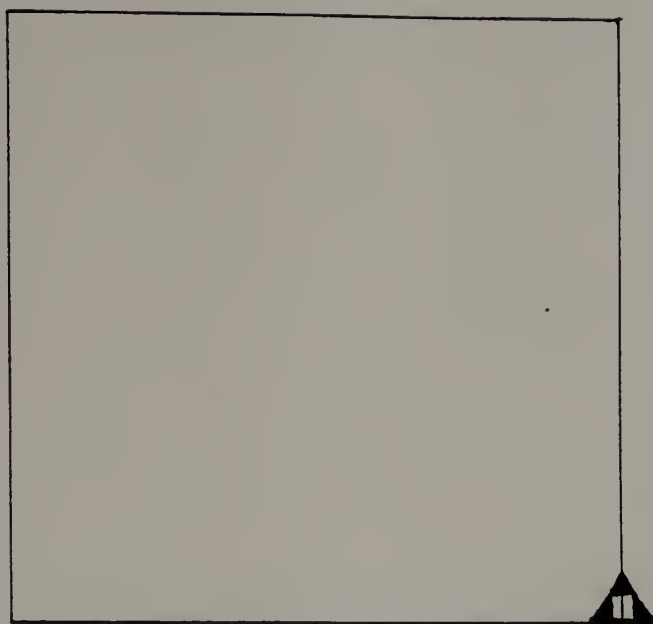


Figure 2

Computer Screen at Start of an Erasing Problem

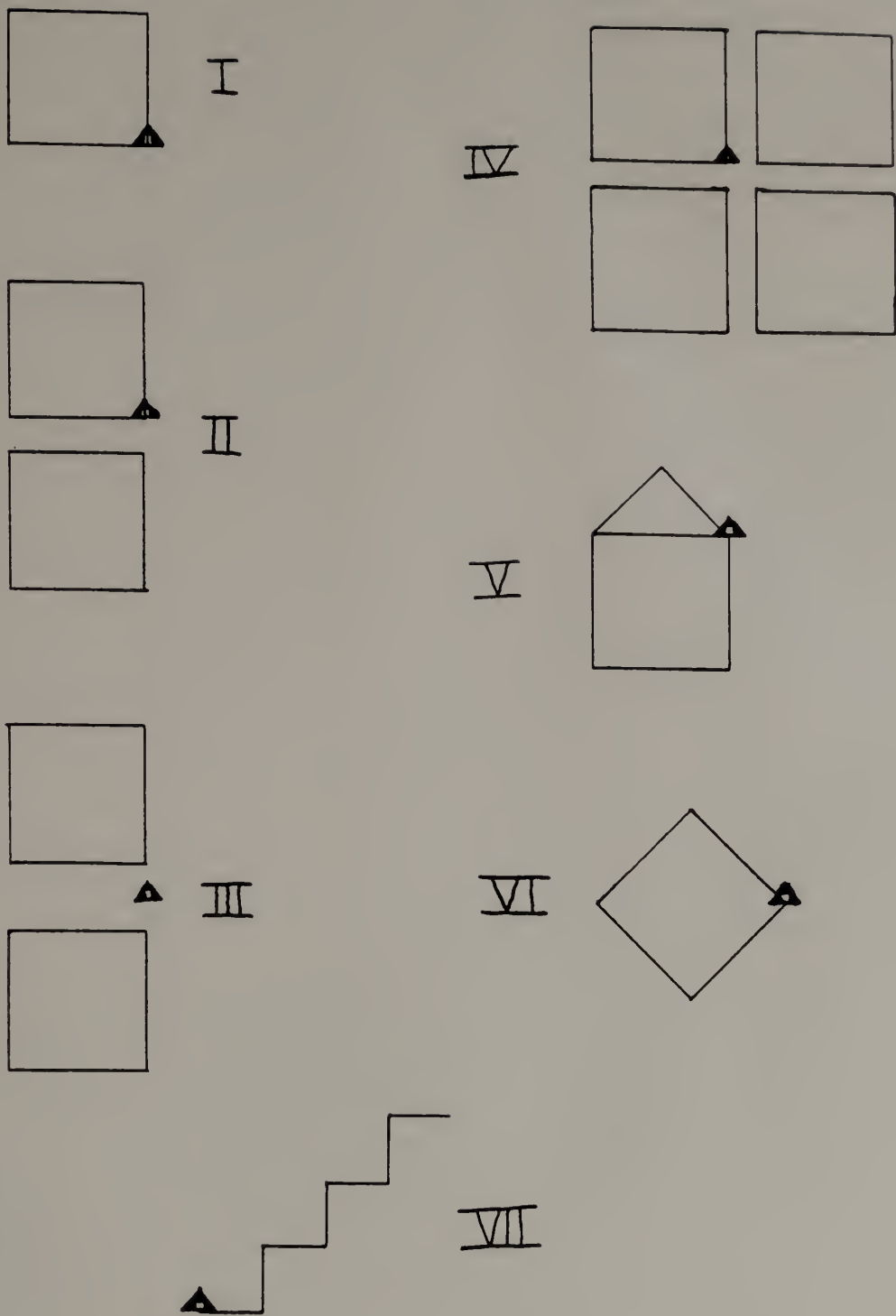


Figure 3

Figures Used for Drawing and Erasing

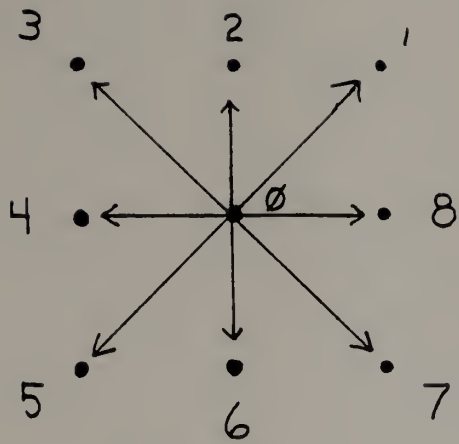
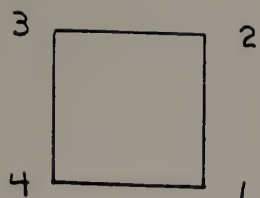
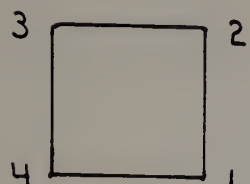


Figure 4

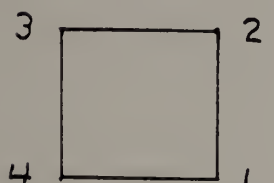
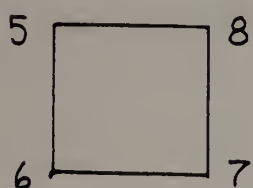
Points Reachable with One Turtle Step from Point 0
(angle preset = 45 degrees)



Task I



Task II



Task III

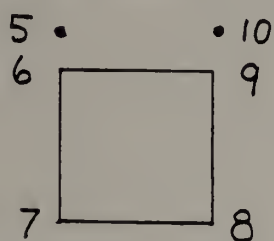
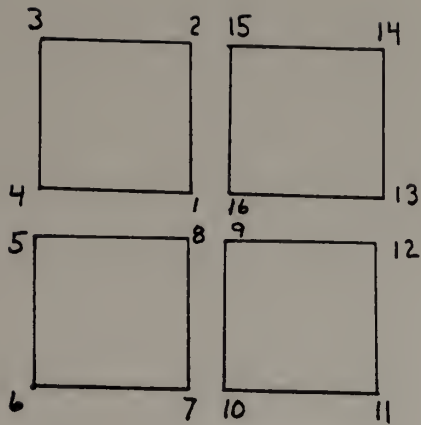
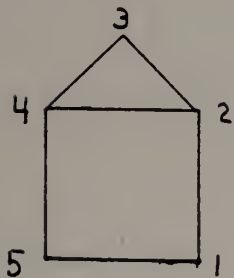


Figure 5

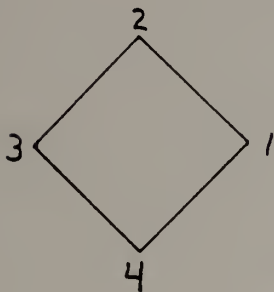
Coordinate Numbering System for Shapes I - III



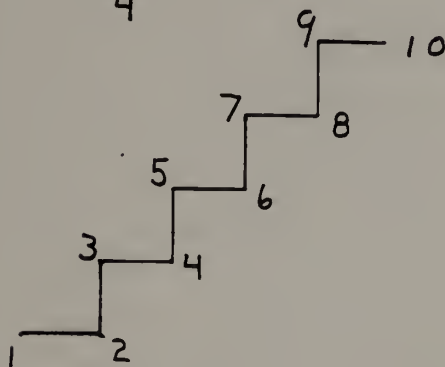
Task IV



Task V



Task VI



Task VII

Figure 6

Coordinate Numbering System for Shapes IV - VII

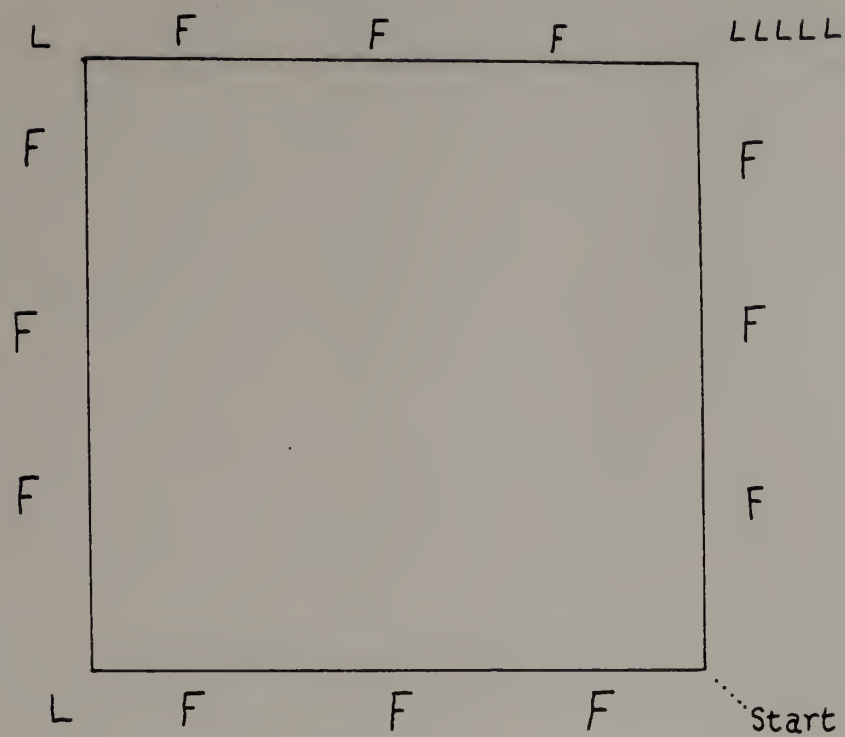


Figure 7

Self-Corrected Rotational Error

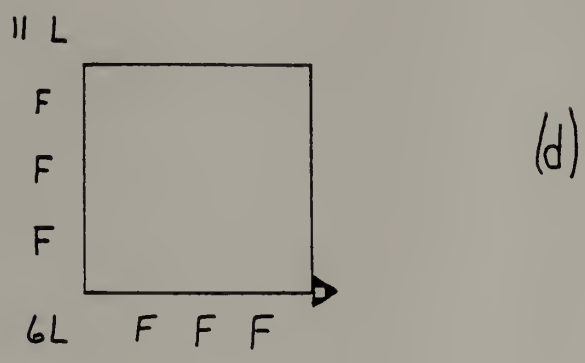
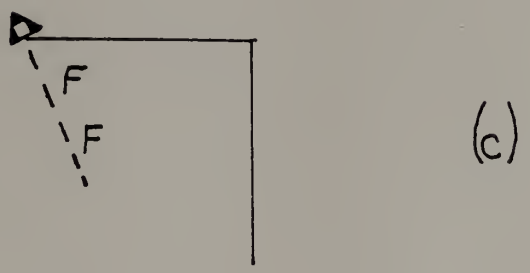
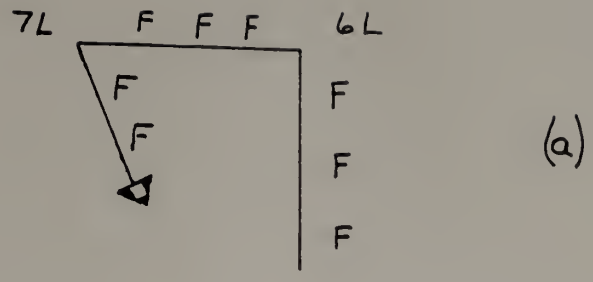
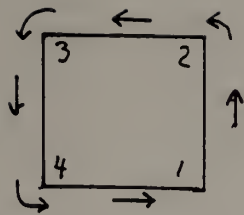
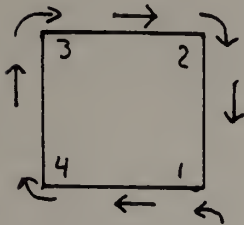


Figure 8
Self-Corrected Movement Error



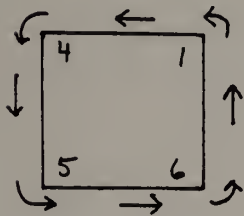
1.2.3.4.1

7 tasks



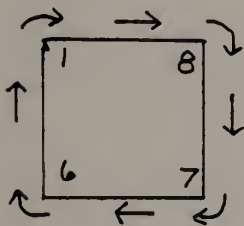
1.4.3.2.1

8 tasks



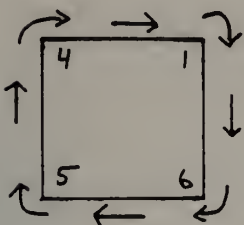
1.4.5.6.1

8 tasks



1.8.7.6.1

8 tasks



1.6.5.4.1

8 tasks

Figure 9

Number of Different Tasks Required to Draw a Square
from Different Starting Positions

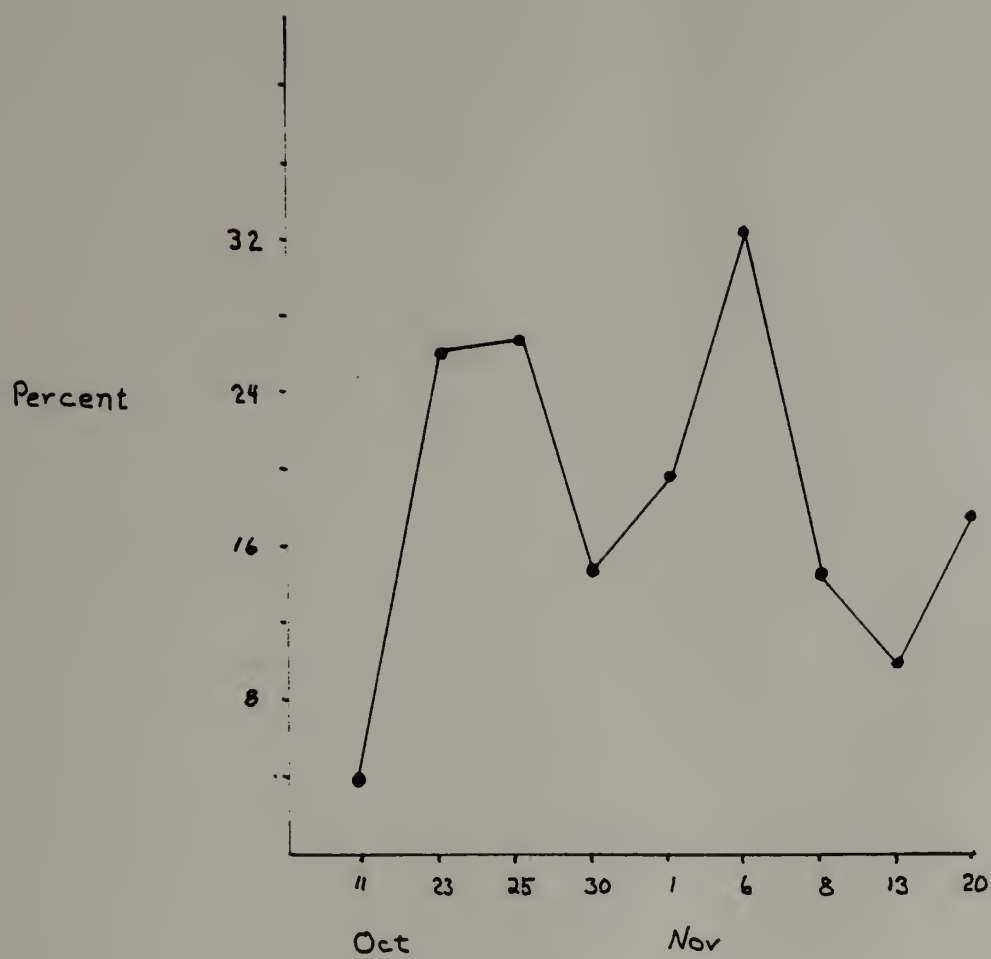


Figure 10a

David - Percentage of Error - Movement Error

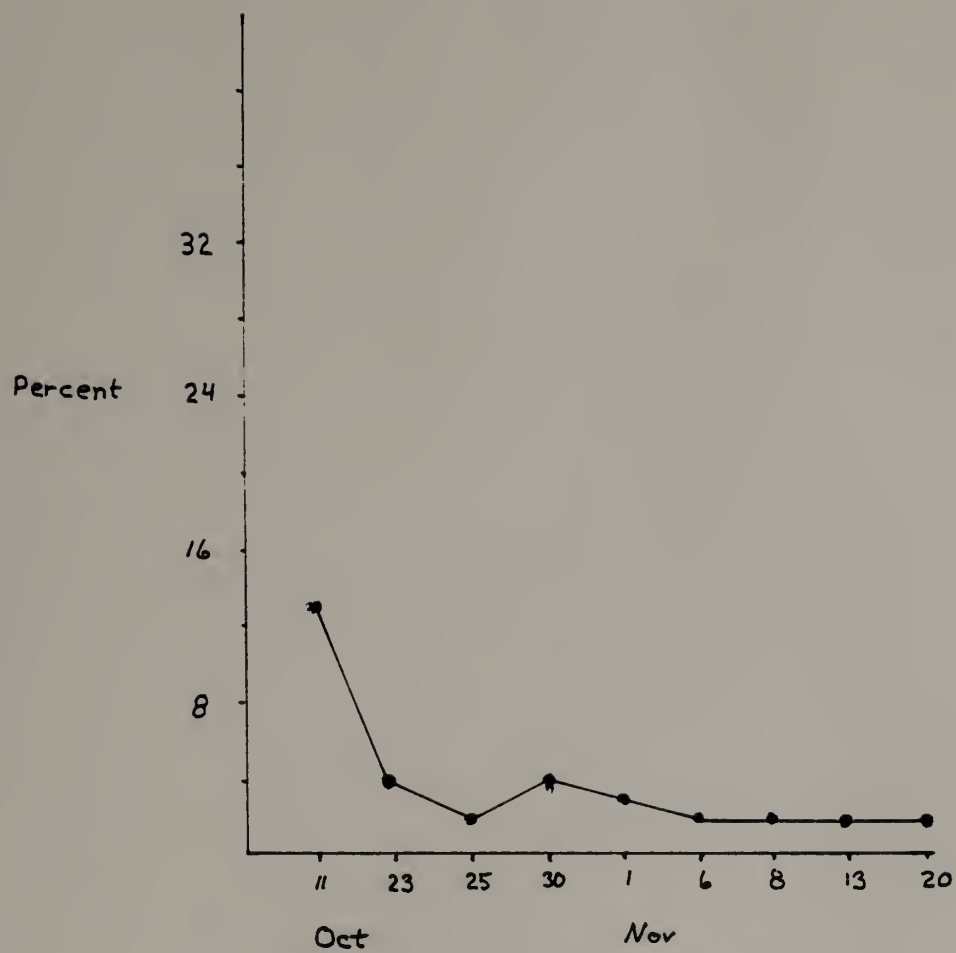


Figure 10b

David - Percentage of Error - Self-Corrected Movement Error

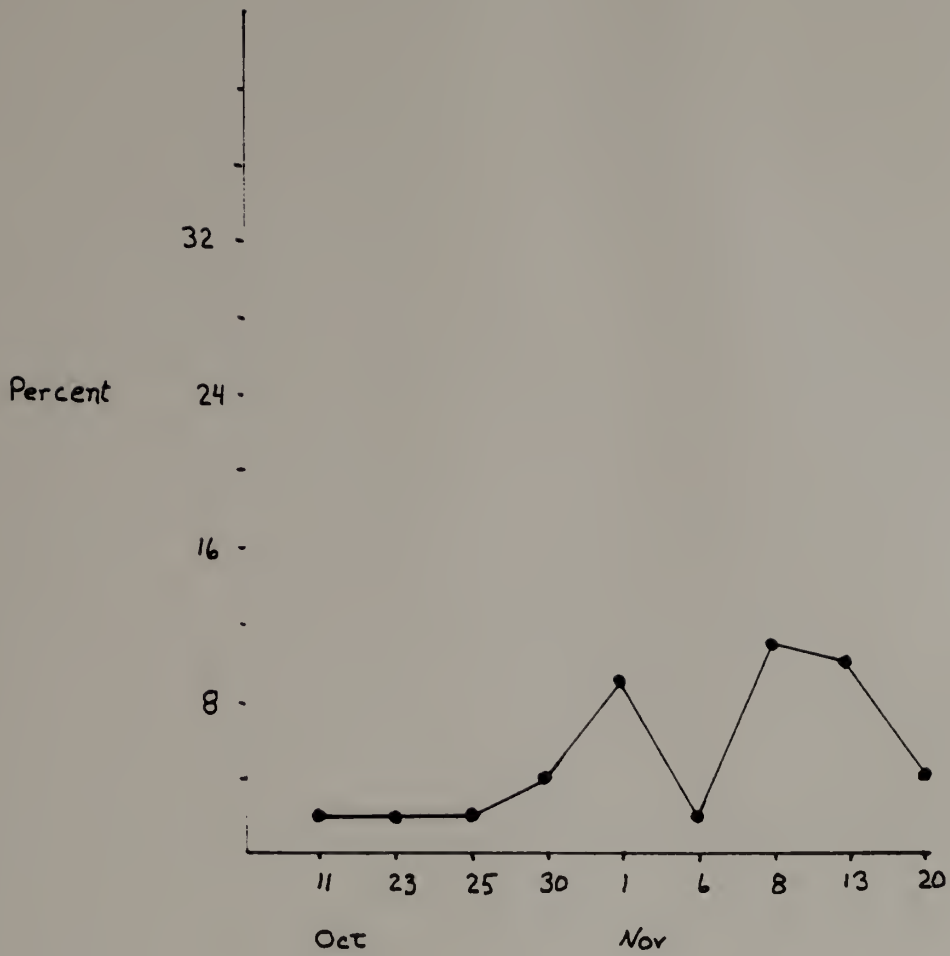


Figure 10c

David - Percentage of Error - Border Error

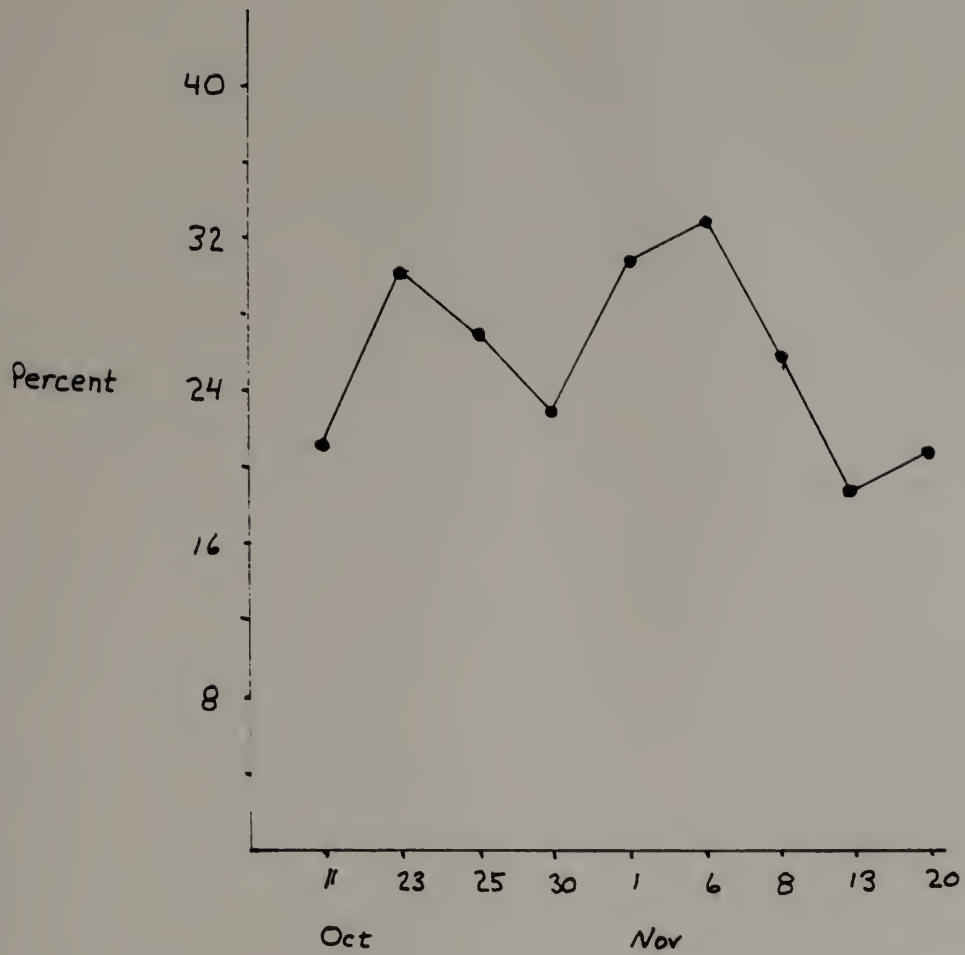


Figure 10d

David - Percentage of Error - Total Error

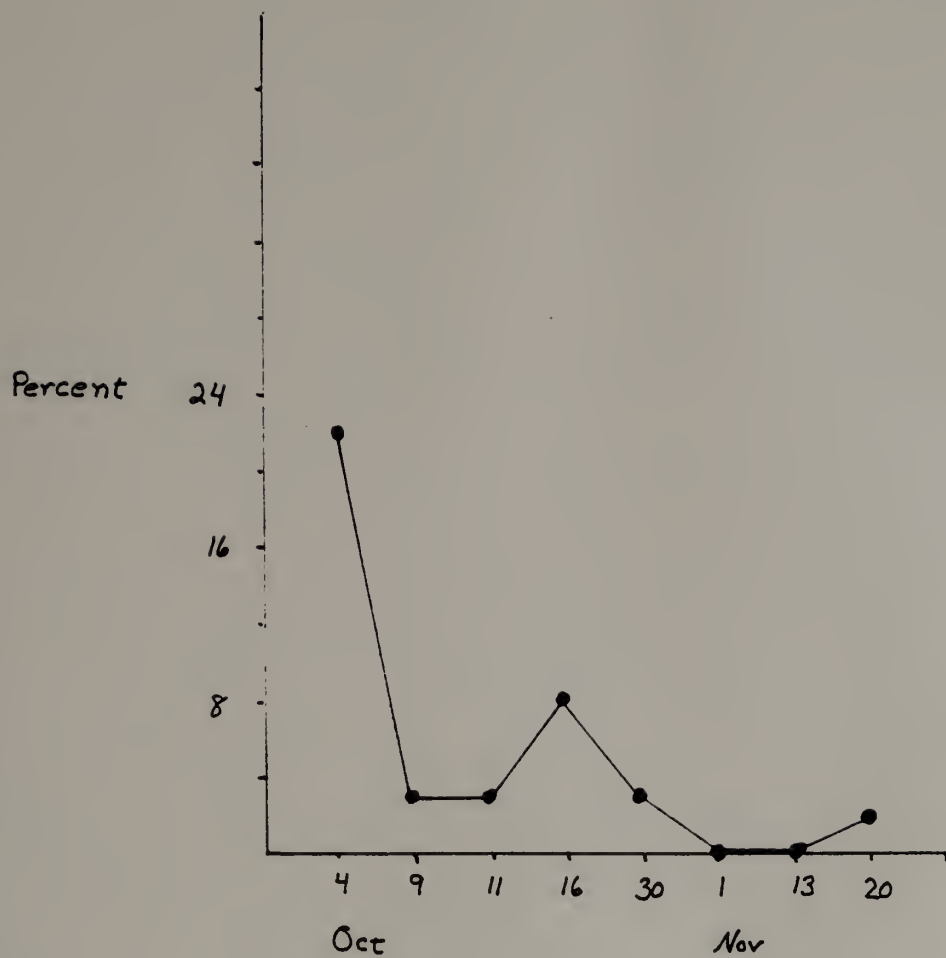


Figure 11a

Betty - Percentage of Error - Movement Error

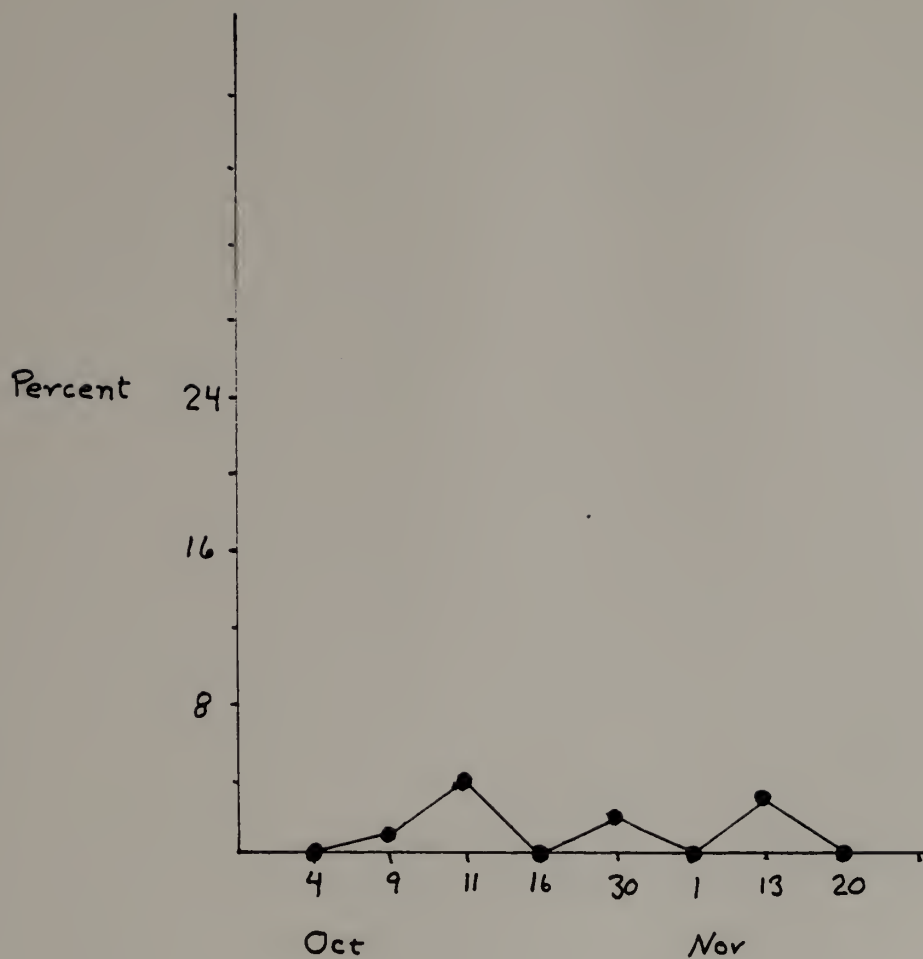


Figure 11b

Betty - Percentage of Error - Self-Corrected Movement Error

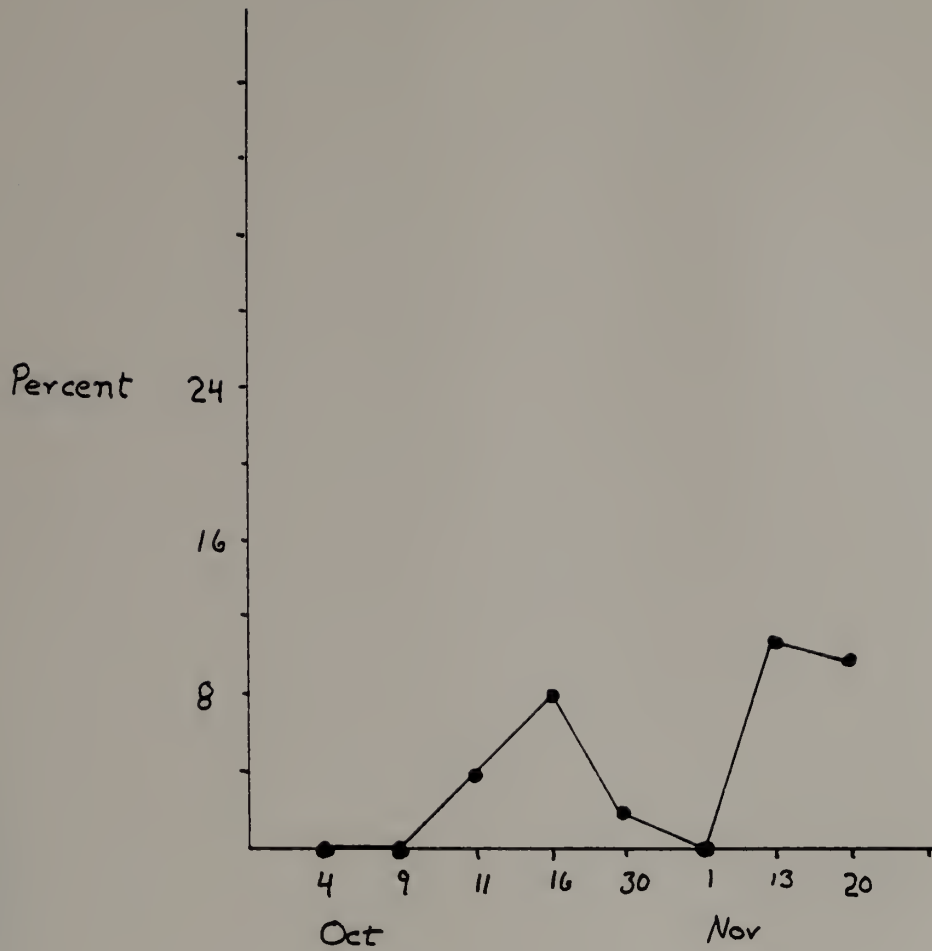


Figure 11c

Betty - Percentage of Error - Rotational Error

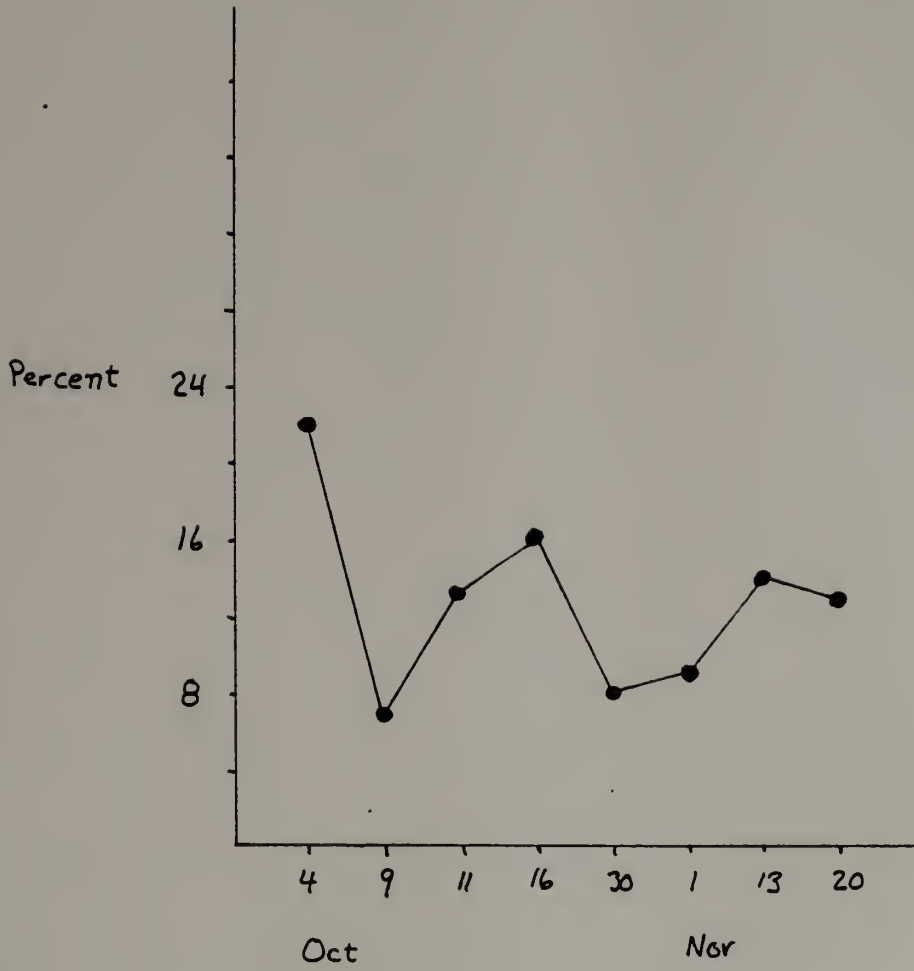


Figure 11d

Betty - Percentage of Error - Total Error

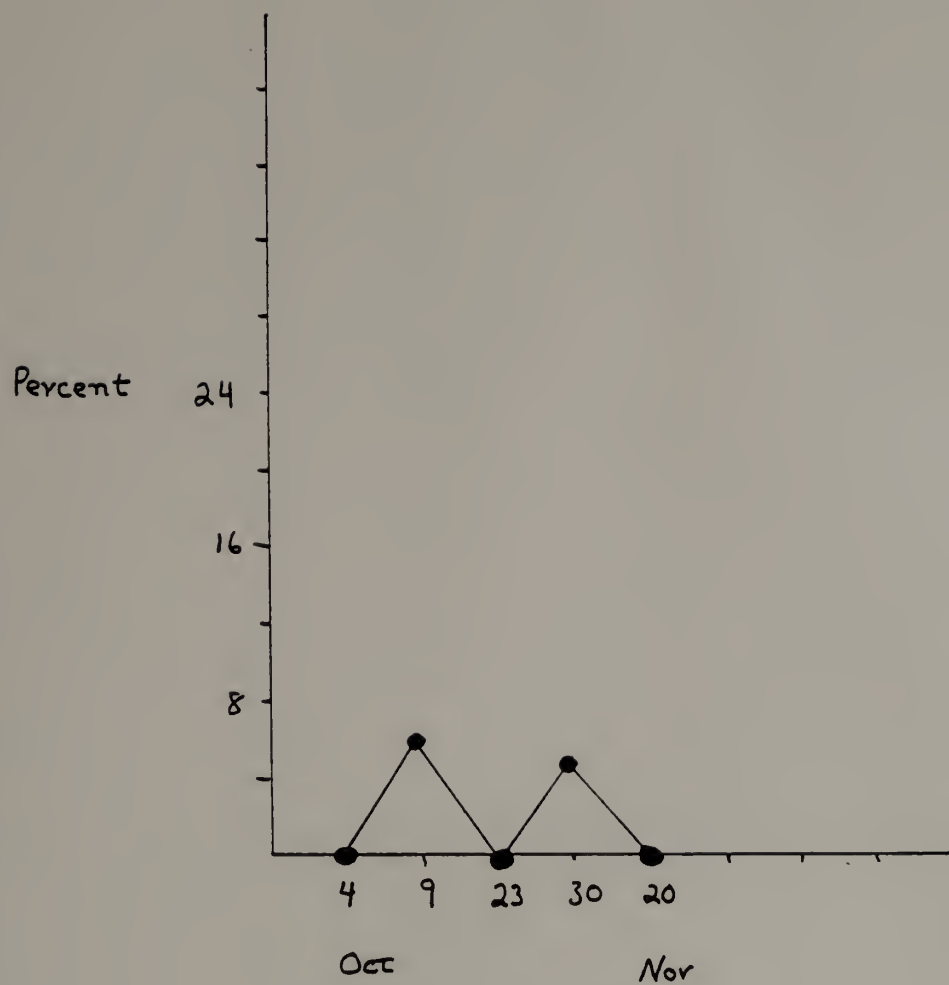


Figure 12a

Charles - Percentage of Error - Movement Error

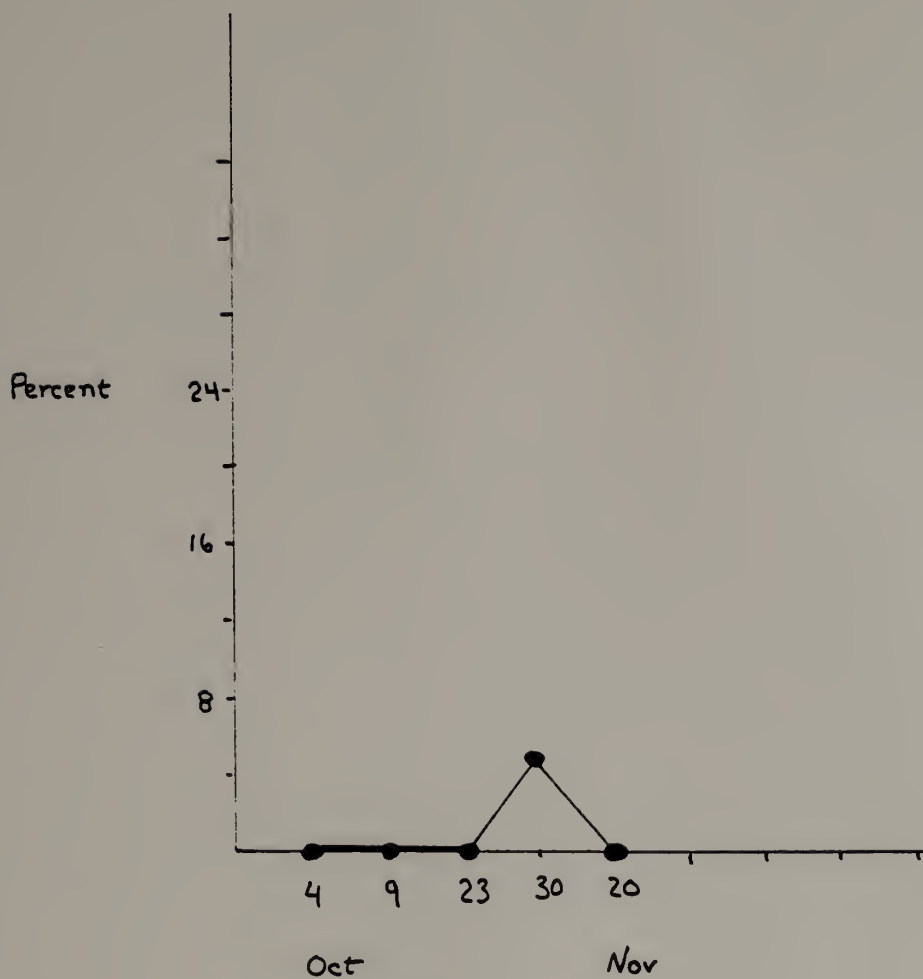


Figure 12b

Charles - Percentage of Error - Self-Corrected Movement Error

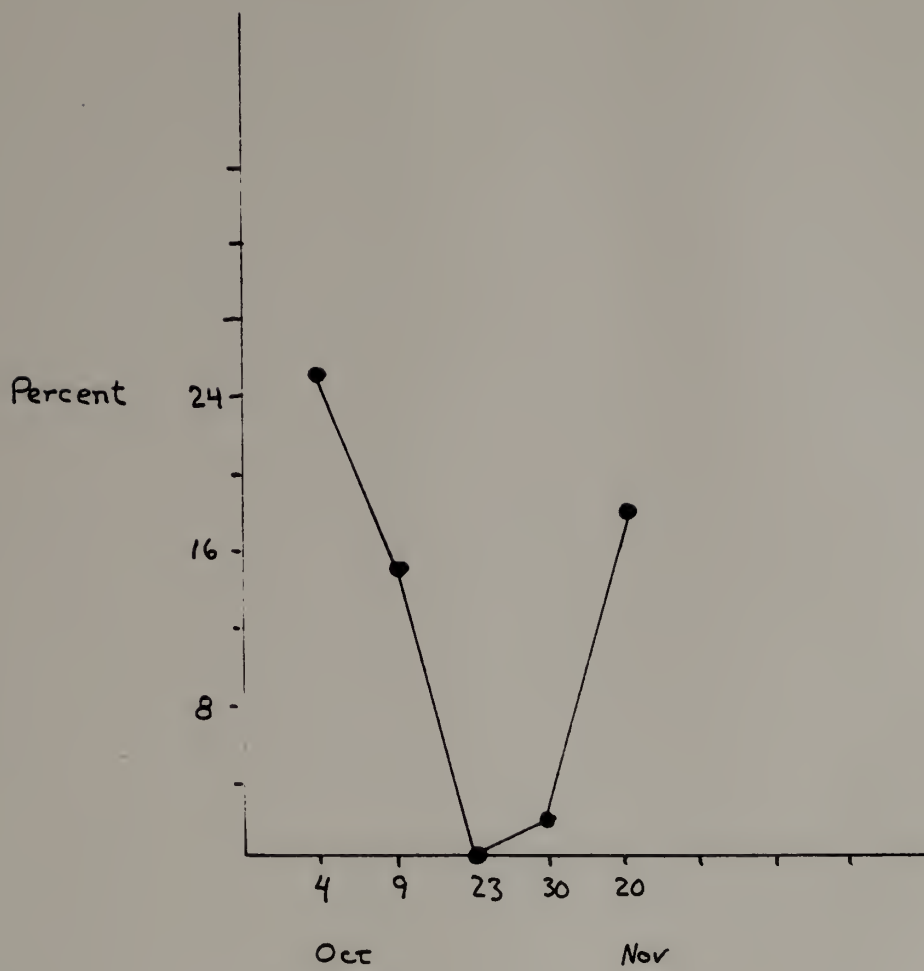


Figure 12c

Charles - Percentage of Error - Rotational Error

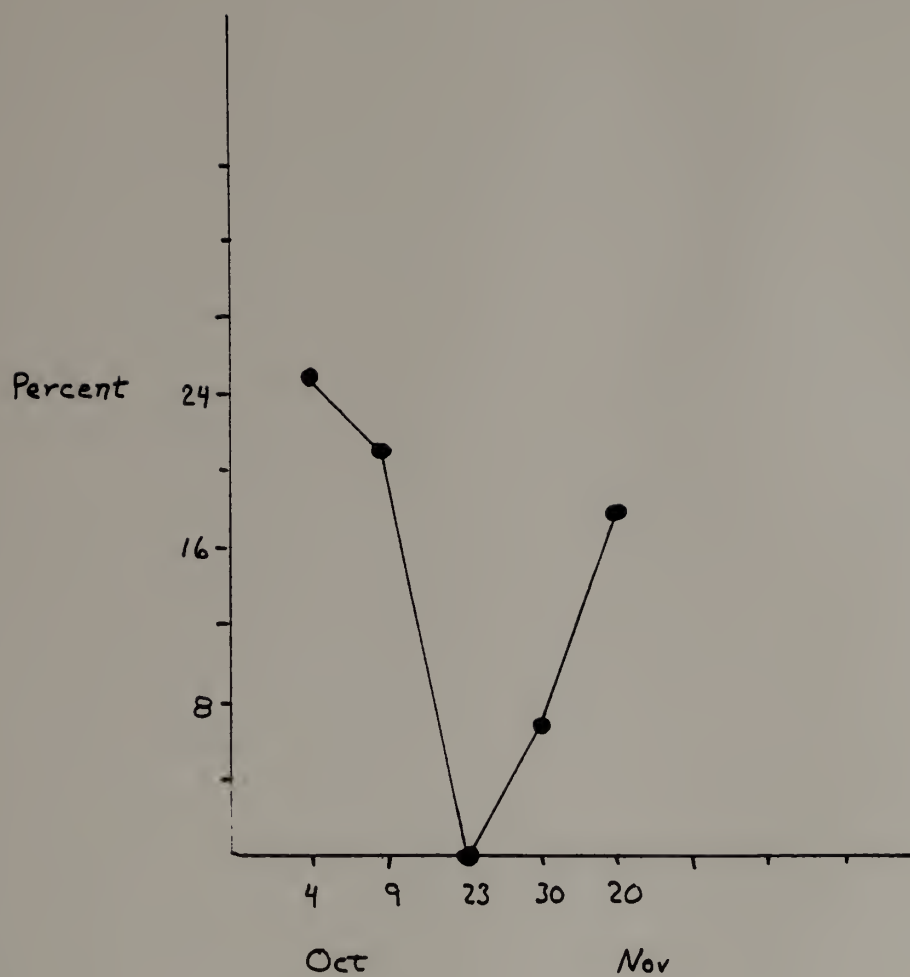


Figure 12d

Charles - Percentage of Error - Total Error

Error Type	Alan	Betty	Charles	David
Rotational Corrected	26	17	70	4
Rotational Uncorrected	0	0	0	0
Walk Corrected	0	15	18	13
Walk Uncorrected	1	22	13	39
Border Limited	3	0	2	11

Table 1

Percentage of Error per Subject
(errors , (errors + tasks))

Task	Alan			Betty			Charles			David		
	C	S	X	C	S	X	C	S	X	C	S	X
B E 90	0	1	0	0	0	0	0	0	0	0	1	0
B D 90	0	1	3	0	0	0	0	0	0	0	3	1
B D 45	0	0	1	0	0	0	0	0	0	0	1	0
B D UDLR	0	0	1	0	0	0	0	0	0	0	0	0
I D UDLR	0	0	0	0	1	0	1	1	1	0	0	0
I E 90	0	0	0	2	0	0	0	3	0	0	0	11
I D 90	0	0	0	2	0	0	0	2	0	0	2	3
I E 45	0	0	0	4	3	13	1	2	0	0	0	14
I D 45	0	0	0	5	1	0	1	3	1	0	2	9
I E 30	0	0	0	2	2	2	0	2	0	0	0	0
I D 30	0	0	0	4	2	0	2	1	0	0	0	6
I E 15	0	0	0	1	0	2	2	0	2	0	0	0
I D 15	0	0	0	2	2	7	2	1	2	0	0	0
I D 10	0	0	0	0	0	0	0	1	0	0	0	0
II E UDLR	0	2	0	0	0	0	0	2	0	0	0	0
II D UDLR	0	0	1	0	0	0	0	0	0	0	0	0
II E 90	0	0	0	0	1	0	0	1	0	0	0	0
II D 90	0	0	0	0	0	1	0	1	0	0	0	0
II E 45 N	0	0	0	0	0	0	0	1	0	0	0	0
II D 45	0	0	0	0	0	0	0	1	0	0	0	0
III E 90	0	0	0	1	0	0	0	0	0	0	0	0

Table 2

Frequency of Completed, Corrected, and Failed Problems

Task	Alan			Betty			Charles			David		
	C	S	X	C	S	X	C	S	X	C	S	X
V E 45	0	0	0	1	1	0	0	0	0	0	0	0
V D 45	0	0	0	0	0	0	0	1	0	0	0	0
VI E 45	0	0	0	0	0	0	1	0	0	0	0	0
VI D 45	0	0	0	0	0	0	1	1	3	0	0	0
VII E UDLR	0	0	0	0	0	0	0	1	0	0	0	0
VII D 90	0	0	0	0	0	0	0	1	0	0	0	0
VII E 45	0	0	0	0	1	0	0	1	0	0	0	0
VII D 45	0	0	0	0	0	0	1	1	1	0	0	0
VII E 30	0	0	0	0	0	0	0	1	0	0	0	0
VII D 30	0	0	0	0	0	0	0	1	0	0	0	0
VII E 15	0	0	0	0	0	0	0	0	1	0	0	0
TOTAL	0	4	6	24	14	25	12	30	11	0	9	44

Code: C - Completed without errors
S - Completed with all errors self-corrected
X - Not completed - at least one error not self-corrected

Table 2 (continued)

Student	c	s	x
Alan	0	4	6
David	0	9	44
Betty	24	14	25
Charles	12	30	11

Code: C - Completed without errors
S - Completed with all errors self-corrected
X - Not completed - at least one error not self-corrected

Table 3

Completed, Corrected, and Failed Problems per Subject

Name	Angle	Drawing Tasks			Erasing Tasks		
		c	s	x	c	s	x
Alan	90	0	25	75	0	99	0
	45	0	0	99	-	-	-
Betty	90	66	0	33	75	25	0
	45	80	20	0	20	20	60
	30	66	33	0	33	33	33
	15	18	18	63	33	0	66
Charles	90	0	99	0	0	99	0
	45	20	46	33	33	66	0
	30	50	50	0	0	99	0
	15	40	20	40	40	0	60
	10	0	99	0	-	-	-
David	90	0	55	44	0	8	92
	45	0	18	81	0	7	93
	30	0	0	99	-	-	-

Table 4

Percentage of Completed, Corrected, and Failed Problems
per Preset Angle

APPENDIX B

Activity Summary of Autistic Subjects

Activity of Alan

4 October

spontaneous activity
good eye contact with the screen
pressed taped keys consistently
some perseveration

9 October

spontaneous activity
some screaming
right ear pressed closed

press specific keys
(F.F.L.L.F.F.L)
L.F.L.F.F.;.F

spontaneous activity
pressed letters of the alphabet in keyboard order
verbalized the letter names
spelled his name several times

11 October

spontaneous activity
pressed walk and turn keys consistently
better eye contact than on 9 October
used white lines on a black background

16 October

spontaneous activity
dynamic turtle (walk)
pressed turn key
stayed on task ffor about 20 minutes
verbalized different colored backgrounds
correctly identified a figure on the screen as a
square

18 October

spend as much time on task as possible (UDLR)
00:00 start
02:36 walked away
02:56 came back to the computer
04:28 finger flapping

05:26 finger flapping
 06:06 establishes eye-eye contact
 07:06 finger flapping
 07:36 self stimulation and screaming
 09:00 verbalized that the turtle had stopped
 moving
 09:25 covered left ear when hiss of heating
 system came on
 11:50 distracted by banging in pipes
 12:02 uncovered ear
 15:08 covered both ears when banging in pipes
 began again
 16:15 uncovered ears when banging subsided
 18:00 end of session

**** NOTE **** Beginning at 09:28 Alan drew a square around
 the border of the screen. When he reached
 the limit of turtle movement at the edge of
 the screen he would persevere on the same
 key for a short time and would
 spontaneously stop. He would continue
 moving the turtle around the screen
 sometimes with false starts in the wrong
 direction. This was his first planned and
 spontaneous use of the turtle.

23 October

draw border around the screen (UDLR)
 00:00 finger flapping
 00:15 finger flapping stops
 01:12 finger flapping starts
 01:27 finger flapping stops
 02:17 verbalizes "Mommy home?"
 03:20 went to a magazine
 03:30 self stimulation
 04:48 finger flapping
 10:00 best eye contact of session
 slower and more deliberate keypressing
 11:00 end of session

**** NOTE **** Border square was complete on three sides and
 part of the fourth.

25 October

draw border around the screen
 did not move turtle as easily with walk and turn
 less screaming and self stimulation than before
 no finger flapping
 verbalized "stop"

leaned forward toward the monitor when the turtle
 drew at a 45 degree angle
 attempted to close the figure
 failed to complete the border square

30 October

spontaneous activity

(1.6.5.3.9.7) border square
 8 rotational errors at 1
 border limited movement
 4 rotational errors at 6
 border limited movement
 4 rotational errors at 5
 1 rotational error at 3
 border limited movement
 1 rotational error at 3
 1 movement error at 3
 failed

** NOTE ** during session he pressed and verbalized
 letter and number keys

1 November

spontaneous activity A=45

8 periods of rotational errors
 45 degree angle decreased constraints to where he
 was unable to draw a border square
 he pressed the taped keys consistently
 incorrectly pressed keys were adjacent to taped
 keys except in a single instance

** NOTE ** Alan did more touching of my arm during this
 session

20 November

** NOTE ** Excessive amount of screaming in class before
 he began to work with the computer.

spontaneous activity (P)

different turtle shape did not lead to an
 improvement
 45 degree angle is a limiting factor
 left for five minutes while he covered his ears
 hit key that played "Mary had a little lamb"

paused and continued working
 erased a line (accident?)

27 November

border square
 numerous erasing and drawing of lines
 physical pointin clues were provided
 with significant prompting he completed border
 square

Activity of Betty

4 October

I E 90

(1.2.3.4.1)
 completed without errors

I D 90

(1.2.3.4.1)
 completed without errors

spontaneously erased figure

I E 45

1 movement error at 1
 failed

1 movement error at 1
 failed

1 movement error at 2
 failed

1 movement error at 3
 failed

1 movement error at 1
 failed

1 movement error at 2
 failed

1 movement error at 3
 failed

1 movement error at 2
 failed

1 movement error at 3
failed

1 movement error at 1
failed

1 movement error at 1
failed

completed without errors

9 October

I E 45

(1.4.3.2.1)
1 movement error at 4
self corrected
1 movement error at 3
failed

1 movement error at 4
failed

(1.4.5.6.1)
spontaneously drew square
completed without errors

spontaneously erased square
completed without errors

I D 30

(1.4.5.6.1)
completed without errors

I E 30

(1.4.5.6.1)
1 movement error at 5
failed

I D 90

(1.2.3.4.1)
spontaneously drew square
completed without errors

I E 90

(1.4.3.2.1)
spontaneously erased above square in reverse
direction
completed without errors

11 October

I E 30

(1.2.3.4.1)
completed without errors

I D 30

(1.4.5.6.1)
completed without errors

I E 30

(1.4.3.2.1)
1 rotational error at 4
1 movement error at 3
failed

1 movement error at 4
self corrected
1 rotational error at 4
1 movement error at 2
self corrected
completed

II E 90

(1.4.3.2.1.8.7.6.5.8.1)
1 rotational error at 2
1 rotational error at 1 second time
completed

II D 90

(1.2.3.4.1.8.7.6.5.8.1)
drawn as two adjacent squares sharing a common
side
failed

16 October

I D 45

(1.4.5.6.1)
spontaneously drew square
completed without errors

I D 15

(1.4.5.6.1)
2 rotational errors at 4
1 movement error at 4
failed

1 movement error at 1
failed

1 movement error at 2
failed

1 rotational error at 6
completed

spontaneously erased figure
completed without errors

III E 90

(1.4.5.8.1.2.3.4.5.6.7.8.1)
completed without errors

18 October

I D UDLR

(1.6.7.8.1)
1 movement error at 6
self corrected
1 movement error at 7
self corrected
1 movement error at 7
self corrected
completed

II E UDLR

(1.2.3.4.1.8.7.6.5.8.1)
1 movement error at 6
self corrected
completed

II E UDLR

(1.2.3.4.1.8.7.6.5.8.1)
1 movement error at 6
self corrected
1 movement error at 6
self corrected
1 movement error at 6
self corrected
1 movement error at 5
self corrected
completed

II D UDLR

(1.2.3.4.7.6.4)
two squares share a common line
failed

25 October

V E 45

(1.5.4.3.2.1)
1 rotational error at 3
1 movement error at 2
self corrected
completed

completed without errors

30 October

I D 45

(1.4.5.6.1)
completed without errors

I E 45

(1.4.3.2.1)
completed without errors

I D 30

(1.4.5.6.1)
completed without errors

I E 30

(1.4.3.2.1)
1 movement error at 4
self corrected
1 movement error at 2
self corrected
completed

I D 15

(1.4.5.6.1)
completed without errors

I E 15

(1.4.3.2.1)
1 movement error at 3
failed

I D 15

(1.4.5.6.1)
pressed erase screen after 1.4.5
failed

I D 15

(1.4.5.6.1)
1 rotational error at 4

1 movement error at 4
failed

I E 15

(1.2.3.4.1)
1 rotational error at 2
pressed erase screen
failed

1 November

I D 15

(1.2.3.4.1)
1 movement error at 2
failed

completed without errors

13 November

I D 45 (R)

(1.8.7.6.1)
completed without errors

spontaneously erased
1 rotational error at 6
completed

I D 30 (R)

1 movement error at 6
self corrected
completed

spontaneously erased
completed without errors

20 November

I D 45 (P)

completed without errors

spontaneously erased
completed without errors

VII E (P)

1 rotational error at 7
completed

I D 30 (P)
 (1.4.5.6.1)
 completed without errors

spontaneously erased
 (1.6.5.4.1)
 1 rotational error at 6
 2 rotational errors at 4
 completed

I D 15 (P)
 (1.2.3.4.1)
 1 rotational error at 4
 completed

spontaneously erased
 (1.2.3.4.1)
 2 rotational errors at 2
 1 movement error at 3
 failed

Activity with Charles

4 October

I E 90
 (14321)
 rotational errors at all vertices
 completed

(14321)
 rotational errors at 4, 3, and 2
 completed

I D 90
 (12341)
 2 rotational errors at 2
 1 rotational error at 3
 3 rotational errors at 4
 completed

(14321)
 spontaneously erased square
 1 rotational error at 4

I E 45
 (14321)
 1 rotational error at 4
 completed

I D 45

(12341)
3 rotational errors at 2
completed

(12341)
spontaneously erased square
1 rotational error at 2
completed

9 October

I E 45

(12341)
completed without errors

I D 45

(12341)
1 rotational error at 2
2 rotational errors at 3
completed

I E 30

(12341)
1 rotational error at 4
completed

I D 30

(12341)
2 rotational errors at 4
completed

I E 15

(12341)
1 movement error at 3
failed

(12341)
1 movement error at 3
failed

(12341)
completed without errors

I D 15

(12341)
1 movement error at 1
failed

(12341)
 1 rotational error at 2
 1 rotational error at 4
 1 movement error at 4
 failed - attempted to close the figure

11 October

II E 90

1 rotational error at 1
 3 movement errors all self corrected
 completed

II D 90

(12341764)
 1 rotational error at 1
 1 rotational error at 1.5
 1 rotational error at 7
 2 rotational errors at 6

II E 45

(12341876581)
 1 rotational error at 4
 1 rotational error at 8 returning to 1
 completed

II E 30

(12341876581)
 1 movement error at 7
 1 rotational error at 25
 2 rotational errors at 7
 1 rotational error at 6
 1 rotational error at 8

18 October

I D UDLR

(12341)
 1 movement error at 3
 failed

(12341)
 1 movement error at 4 self corrected at 20
 1 movement error at 1 self corrected at 8
 completed (left side was longer than right)

(12341)
 completed without errors

II E UDLR

(14321876581)
 1 rotational error at 3
 completed

(14321876581)
 1 movement error from 4 to 5
 1 movement error from 5 to 20
 self corrected from 20 to 4
 self corrected from 4 to 5
 completed

VII E UDLR

(11.10.9.8.7.6.5.4.3.2.1)
 3 movement errors at 11
 self corrected from 10 to 25 to 26 11
 1 movement error at 10
 self corrected to 10
 1 movement error from 8 to 24
 self corrected from 24 to 8
 completed

23 October

I D 15

(12341)
 completed without errors

25 October

spontaneously drew VII
 (10.9.8.7.6.5.4.3.2.1)

VII E 45

3 rotational errors on inside points (3.5.7.9)
 2 rotational errors on outside points
 (2.4.6.8.10)
 completed

VII D 45

(1...10)
 1 movement error at 2
 self corrected
 1 rotational error at 4
 completed

VII E 30

(10...1)
 1 rotational error at 10
 1 rotational error at 4
 completed

VII D 30

(1...10)

1 rotational error at 3
1 rotational error at 4
1 rotational error at 6
1 movement error at 7
self corrected
1 rotational error at 9
completed

VII E 15

(10...1)

1 rotational error at 9
2 movement errors at 9
2 errors self corrected
1 rotational error at 9
1 movement error at 6
self corrected
4 movement errors at 4
failed

30 October

I D 90

(1.2.3.4.1)

1 rotational error at 2
completed

I D 45

completed without errors

I D 30

(1.2.3.4.1)

completed without errors

I D 15

(1.2.3.4.1)

1 movement error at 3
self corrected
completed

I D 10

(1.2.3.4.1)

1 movement error at 2
self corrected
completed

VII D 90
(1...10)
2 rotational errors at 1
1 rotational error at 3
1 rotational error at 8
2 rotational errors at 9
completed

VII D 45
(1...10)
drew a square
failed

(1...10)
completed without error

1 November

V D 45
(1.2.3.4.5.1)
1 rotational error at 2
2 boundary errors at 3
completed

13 November

I D 45 (R)
(16.15.14.13.16)
1 movement error at 15
failed

1 rotational error at 13
completed

I D 30 (R)
(16.15.14.13.16)
completed without error

I E 30 (R)
(16.15.14.13.16)
1 rotational error at 13
completed

I D 15
(16.15.14.13.16)
completed without error

I E 15
(16.15.14.13.16)
completed without error

15 November

VI D 45

(1.2.3.4.1)
 1 movement error at 1 to 5
 1 movement error at 5 to 11
 self corrected 2 errors 11.5.1
 1 rotational error at 3
 completed

VI E 45

(1.2.3.4.1)
 completed without error

20 November

I D 45 (P)

(1.2.3.4.1)
 1 rotational error at 2
 1 rotational error at 3
 1 rotational error at 4
 completed

I E 45 (P)

(1.2.3.4.1)
 completed without error

VI D 45 (P)

(1.2.3.4.1)
 1 movement error at 1
 failed

(1.2.3.4.1)
 1 rotational error at 1
 1 movement error at 4
 failed

(1.2.3.4.1)
 1 movement error at 2
 failed

(1.2.3.4.1)
 completed without error

Activity of David

4 October

** NOTE ** First session on the computer.

press specific keys
 consistently pressed taped keys
 75% accuracy

identify direction turtle is pointing
 verbalized up, down, left, and right
 direction stated not always correct

would stop pressing "walk" within two keypresses
 of reaching the border

9 October

press specific keys
 (F.F.L.L.F.F.L.F.L.F.L.L.F.F.L)
 *L.F.F.L.F.L.F.F.L.F.L.F.L.F.T

identify direction turtle is pointing
 correctly identified direction in response to:
 "Is the turtle pointing at my finger"

I D 90

(1.2.9.8)
 2 rotational errors at 2
 1 rotational error at 9
 1 movement error at 8 to 7
 did not draw bottom side
 failed

I E 90

existing figure (7.9.2.1)
 1 movement error at 2
 self corrected
 failed

11 October

I D 90

(1.4.3.2.1)
 1 rotational error at 1
 1 movement error at 2
 self corrected
 completed

I E 90

(1.2.3.4.1)
 1 movement error at 2
 self corrected
 1 movement error at 2

self corrected
 1 movement error at 2
 failed

draw anything A=45
 drew a border square
 no rotational errors
 completed

23 October

I D 45
 (1.4.3.2.1)
 1 movement error at 1
 failed

I E 45
 1 movement error at 2
 failed
 1 movement error at 2
 failed
 1 movement error at 2
 failed
 1 movement error at 2
 failed
 1 movement error at 3
 self corrected
 1 movement error at 3
 failed

25 October

I E 90
 (1.2.3.4.1)
 1 movement error at 3
 failed
 1 movement error at 3
 failed
 1 movement error at 2
 failed

I E 45

1 movement error at 2
failed

1 movement error at 2
failed

1 movement error at 2
failed

border square A=90

(1.2..3.5.7.9.1)

1 movement error at 7
self corrected
completed

30 October

I D 90

(1.2.3.4.1)

1 movement error at 2
self corrected

1 movement error at 2
failed

I E 90

(1.2.3.4.1)

1 movement error at 4
failed

I D 45

(1.2.3.4.1)

1 movement error at 2
border limited error
completed

I E 45

(1.2.3.4.1)

1 movement error at 1
failed

I D 30

(1.2.3.4.1)

1 movement error at 2
failed

continued movement to close the figure

1 November

I D 30

(1.2.3.4.1)
1 movement error at 2
failed

(1.2.3.4.1)
1 movement error at 2
failed

I D 45

(1.2.3.4.1)
1 movement error at 2
border limited error
1 movement error at 3
border limited error
completed

I D 30

(1.2.3.4.1)
1 movement error at 2
failed

(1.2.3.4.1)
1 movement error at 2
failed

(1.2.3.4.1)
1 movement error at 2
failed

I D 45

(1.2.3.4.1)
1 movement error at 2
border limited error
1 movement error at 2
self corrected
2 movement errors at 2
failed

6 November

I E 90

(1.2.3.4.1)
1 movement error at 2
failed

(1.2.3.4.1)
 1 movement error at 2
 failed

8 November

I D 45

(1.2.3.4.1)
 1 movement error at 2
 border limited error
 1 movement error at 4
 failed

(1.2.3.4.1)
 1 movement error at 2
 border limited error
 1 movement error at 4
 failed

(1.2.3.4.1)
 1 movement error at 2
 border limited error
 1 movement error at 4
 failed

I E 90

(1.2.3.4.1)
 1 movement error at 2
 failed

** NOTE ** proceeded to draw a border square and stopped
 at the point of completion without erasing
 any of it

13 November

erase border square A=90
 4 movement errors at each vertex-perseveration of
 the "walk" key
 completed

draw border square A=90
 drew a square using top, left and bottom borders
 right edge of square was to the right of center
 failed a border square
 completed a square without using all four borders

I E 90
 (1.2.3.4.1)
 2 movement errors at 3
 failed

I D 90
 (1.2.3.4.1)
 1 movement error at 2
 border limited error
 completed

I E 90
 (1.2.3.4.1)
 1 movement error at 2
 border limited error
 1 movement error at 4
 failed

20 November (P)

I D 45
 1 movement error at 2
 border limited error
 1 movement error at 4
 failed
 attempted to close the figure-all 90
 degrees

 1 movement error at 4
 failed
 attempted to close

 1 movement error at 2
 failed
 attempted to close

I E 45
 1 movement error at 4
 failed

 1 movement error at 2
 failed

** NOTE ** above try repeated three more times with same
 error

27 November

I D 45 (P)

(1.8.9.2.1)

1 movement error at 8

border limited error

1 movement error at 2

failed

I D 90 (P)

(1.8.9.2.1)

1.8.9.3.5.6.1

1 movement error at 4

failed

closed figure

APPENDIX C

Activity Summary of Non-Autistic Subjects

Activity of S1

5 November

Would not come to the computer

27 November

Would not come to the computer

Activity of S2

29 October

I D 90

(123561)

1 border error at 2
7 rotational errors at 2
1 border error at 9
12 border errors at 3
3 rotational errors at 3
10 border errors at 5
1 rotational error at 5
failed

27 November

Would not come to the computer

Activity of S3

13 November

I D 90

(16541)

3 border errors at 2
4 rotational errors at 2
2 border errors at 6
5 rotational errors at 6
10 border errors at 6
failed

20 November

I D 90

(16781)

1 border error at 2
1 rotational error at 2
8 border errors at 6

12 border errors at 7
failed

Activity of S4

22 October

I D 90

(12341)
spontaneous activity
2 rotational errors at 4
completed

Activity if S5

23 October

I D 90

(12341)
14 border errors at 2
2 rotational errors at 2
13 border errors at 2
9 rotational errors at 2
failed

I E 90

(12341)
1 movement error at 1
1 border error at 8
1 rotational error at 8
4 border errors at 4
4 rotational errors at 4
3 border errors at 4
5 rotational errors at 4
failed

6 November

I D 90

(14321)
2 rotational errors at 1
1 border error at 3
6 rotational errors at 3
2 rotational errors at 2
completed

13 November

I D 90
(12341)
1 rotational error at 1
1 rotational error at 2
1 border error at 3
1 movement error at 4
failed

20 November

I D 90
(12981)
completed with out errors

I D 45
(12341)
1 movement error at 2
failed

27 November

I D 45
(12981)
completed without errors

I E 45
(12981)
1 movement error at 2
self corrected
1 movement error at 9
self corrected
completed

Activity of S6

13 November

I E 90
(14321)
1 movement error at 4
failed

I D 90
(14561)
completed without errors

20 November

I D 90

(14321)
1 movement error at 3
failed

(14321)
3 border errors at 4
1 movement error at 4
failed

Activity of S7

19 October

I D 90

(12981)
1 rotational error at 2
1 rotational error at 9
1 rotational error at 8
completed

26 October

I D 90

(12341)
1 rotational error at 2
1 rotational error at 3
1 rotational error at 4
completed

I D 45

(12341)
1 movement error at 1
self corrected
2 rotational errors at 1
1 movement error at 1
failed

(12341)
1 rotational error at 3
1 movement error at 3
failed

(12341)
1 rotational error at 1
completed

I D 30
 (12341)
 2 rotational errors at 2
 completed

I D 15
 (12341)
 completed without errors

9 November

I E 45
 (12341)
 1 movement error at 3
 failed

 (12341)
 completed without errors

16 November

I E 45
 (12341)
 completed without errors

I E 30
 (12341)
 completed without errors

I E 15
 (12341)
 1 movement error at 4
 failed

Activity of S8

Wanted to leave before attempting tasks on :
 23 October
 30 October
 6 November
 13 November
 20 November

Activity of S9

30 October

I E 90

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 1
self corrected
1 rotational error at 1
1 movement error at 2
failed

(12341)
1 movement error at 2
failed

6 November

I D 90

(14561)
1 border error at 5
4 rotational errors at 6
completed

I D 45

(14561)
2 rotational errors at 1
1 movement error at 6
failed

13 November

I D 45

(14561)
1 movement error at 6
failed

I D 30

(14561)
1 rotational error at 1
2 rotational errors at 5
1 movement error at 6
failed

20 November

I D 45

(14561)
3 rotational errors at 5
1 rotational error at 6
completed

(16541)
1 rotational error at 1
1 movement error at 6
failed

27 November

I D 30

(12341)
completed without errors

I E 30

(12341)
completed without errors

I D 30

(12341)
1 movement error at 2
failed

(14321)
1 movement error at 4
failed

(12341)
1 movement error at 2
failed

Activity of S10

19 October

I D 90

(14561)
3 rotational errors at 1
4 rotational errors at 4
10 border errors at 5
2 rotational errors at 5
2 rotational errors at 6
2 border errors at 6
failed

16 November

I D 90

(12981)
3 border errors at 2
1 rotational error at 2
5 border errors at 9
4 rotational errors at 9
completed

Activity of S11

6 November

I D 90

(14561)
4 rotational errors at 6
completed

I D 45

(14561)
1 movement error at 1
failed

I E 45

(12341)
completed without errors

I E 30

(12341)
1 rotational error at 4
completed

Activity of S12

9 November

I D 90

(14561)
3 border errors at 4
2 border errors at 5
1 rotational error at 6
completed

I D 45

(14561)
1 movement error at 1
failed

16 November

I D 45

(14561)
1 movement error at 1
failed

(12341)
1 movement error at 2
failed

I E 45

(12341)
1 movement error at 2
failed

Activity of S13

1 November

I D 90

(12981)
2 border errors at 2
3 border errors at 9
2 border errors at 8
2 border errors at 8
completed

I E 90

(12341)
1 rotational error at 1
1 movement error at 2
failed

8 November

I D 45

(14321)
1 movement error at 1
failed

I D 90

(14561)
completed without errors

15 November

I D 45

(12341)
1 movement error at 2
failed

I E 90

(12341)
1 movement error at 2
failed

Activity of S14

1 November

I D 90

(14561)
1 rotational error at 1
1 movement error at 1
self corrected
completed

(14561)
completed without errors

8 November

I D 90

(18921)
6 rotational errors at 4
failed

I E 90

(12341)
1 movement error at 2
failed

Activity of S15

18 October

I D 90

(12341)
completed without errors

(12341)
completed without errors

25 October

I E 45

(12341)
1 movement error at 1
failed

(14321)
1 movement error at 4
failed

(12341)
completed without errors

I E 30

(12341)
1 movement error at 1
failed

(12341)
1 movement error at 4
self corrected
1 rotational error at 4
completed

I E 15

(12341)
1 movement error at 3
self corrected
1 rotational error at 4
1 movement error at 4
failed

1 November

I D 30

(12981)
1 rotational error at 2
1 border error at 8
completed

I D 15

(18921)
1 movement error at 3
self corrected
1 movement error at 4
failed

(18921)
1 movement error at 2
failed

(18921)
1 movement error at 3
self corrected
1 movement error at 4
failed

(18921)
completed without errors

Activity of S16

29 October

I D 90

(12981)
1 rotational error at 9
completed

I D 45

(12981)
completed without errors

I D 30

(12981)
1 movement error at 8
self corrected
completed

I D 15

(12981)
completed without errors

5 November

I E 45

(12341)
1 rotational error at 3
completed

I E 30

(12341)
completed wwithout errors

I E 15

(12341)
1 rotational error at 2

1 movement error at 2
failed

Activity of S17

18 October

I D 90
(12341)
completed without errors

25 October

I D 45
(12341)
1 rotational error at 2
completed

I E 45
(12341)
1 movement error at 2
failed

(12341)
1 rotational error at 2
1 movement error at 2
failed

(12341)
1 movement error at 2
failed

1 November

I D 90
(12341)
1 rotational error at 3
3 rotational errors at 4
completed

I D 45
(12341)
completed without errors

I D 30
(12341)
1 movement error at 3
failed

(12341)
completed without errors

I D 15

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 3
failed

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 4
failed

Activity of S18

24 October

I D 90

(12341)
1 movement error at 4
failed

(12341)
completed without errors

I E 90

(12341)
1 movement error at 2
failed

(12341)
completed without errors

31 October

I D 90

(12341)
completed without errors

I E 90
 (12341)
 completed without errors

I D 45
 (12341)
 completed with out errors

I E 45
 (12341)
 1 movement error at 1
 self corrected
 1 movement error at 2
 failed

7 November

I E 30
 (12341)
 1 rotational error at 4
 completed

I D 30
 (12341)
 completed without errors

I E 15
 (12341)
 1 movement error at 2
 failed

 (12341)
 completed without errors

I D 15
 (12341)
 completed without errors

Activity of S19

18 October

I D 90
 (12341)
 completed without errors

I E 90
 (12341)
 completed without errors

25 October

I D 90

(14321)
1 rotational error at 4
1 rotational error at 2
completed

I E 90

(14321)
1 rotational error at 1
completed

I D 45

(14321)
1 movement error at 2
self corrected
1 rotational error at 3
1 movement error at 3
self corrected
completed

I E 45

(14321)
1 movement error at 3
self corrected
1 movement error at 3
self corrected
completed

I D 30

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 1
self corrected
completed

1 November

I D 30

(12341)
1 movement error at 1
failed

(12341)
1 rotational error at 1
completed

I E 30
 (12341)
 completed without errors

I D 15
 (12341)
 1 movement error at 1
 failed

(12341)
 1 movement error at 1
 failed

(12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 3
 self corrected
 completed

8 November

I E 15
 (12341)
 1 movement error at 2
 failed

(12341)
 1 movement error at 1
 failed

(12341)
1 movement error at 4
failed

Activity of S20

22 October

I D 45
(16781)
completed without errors

I E 45
(12341)
1 movement error at 2
failed

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 2
failed

(12341)
1 movement error at 4
failed

(12341)
1 movement error at 4
failed

(12341)
1 movement error at 4
failed

(12341)
completed without errors

29 October

I D 90
(12341)
completed without errors

I D 45
(12341)
completed without errors

APPENDIX D
The Software

FROST.ED TURTLES

What do I need?

In order to use these programs you need:

- 1) an APPLE II , II + , II e computer,
- 2) the computer must have a minimum of 64k RAM memory,
- 3) at least one APPLE DISK II diskette drive,
- 4) a copy of either Terrapin Logo or Krell Logo, and
- 5) a copy of FROST.ED TURTLES.

What do I do first?

- 1) The first thing you should do is make a backup copy of the programs. If you don't know how to do this, it is explained in the DOS manual from Apple. To be safe, you might ask the help of a friend.
- 2) Put the original away in a cool dry place and away from jelly coated fingers.
- 3) Use only the copy you have made when you want to run the program. This way you will always have the original in case of disaster.
- 4) Make sure you put the label provided on your copy. (It has the copyright notice).

How do I start Logo?

- 1) Place the Logo Language disk (from Krell or Terrapin) in your disk drive (drive 1 if you have two or more).
- 2) Turn on the computer.
- 3) After a while you will get a message "Welcome to Logo". A flashing cursor will appear to the right of a question mark.

How do I start the ABSOLUTE program?

- 1) Type READ "ABSOLUTE and then press the RETURN key.

Please note that there is a space between READ and "ABSOLUTE . Also note that there is a quotation mark only on the left side of ABSOLUTE.

- 2) Type START and then press the RETURN key
- 3) It will take the computer about a minute to load the program
- 4) The computer will stop with a display of program characteristics

CAUTION - When you stop the program:

to restart the same program:

follow the directions beginning at step 2 above.

to start a different program:

type GOODBYE and then

press the RETURN key

follow the directions for starting that program

How do I use the ABSOLUTE option?

- 1) you can use the program immediately without worrying about the screen full of information. Look at the bottom of the screen and you will see the message:

TYPE LETTER TO CHANGE CHARACTERISTICS
OR TYPE Q TO GO TO THE GRAPHICS SCREEN

Since you don't want to worry about the menu, type Q , the menu will disappear, and a graphics screen will take its place.

2) Now you will see a white screen with a black triangle (the turtle) in the center of the screen and pointing up.

3) Since you chose the ABSOLUTE program, you will be controlling turtle movement by pressing the I, J, K, and M keys.

I - will make the turtle move up.

J - will make the turtle move left.

K - will make the turtle move right.

M - will make the turtle move down.

Practice by pressing these keys to see if you can draw a box or any small picture. When you press these keys, the computer will act immediately (you don't have to hit return).

You may have found that if you try to move the turtle over a line that it has already drawn, the turtle will erase that part of the line which is traced.

4) The only keys that are active (cause something to happen) are I, J, K, and M.

There really is one more key that is active and that is the question mark. Hold down shift and press the question mark (just like a normal typewriter). Now you will see the graphics screen, the turtle and your drawing disappear only to be replaced by that menu of characteristics that had been on the screen a little while ago.

5) Other keys that the student may use, if they have been made accessible, are:

U - will cause the turtle's pen to be up and not leave a trail when it moves

D - will cause the turtle's pen to be down and leave a trail when it moves

! - will clear the screen and put the turtle in the center of the screen

How do I change the environment?

There are a number of characteristics of the program that you may control if you wish. You can make the length of the line the turtle draws either shorter or longer than what you just observed. You can either have the pen up so that it doesn't leave a trail or have the pen down so that it does leave a trail when the turtle moves. You can change the color of the background. You can change the color the turtle leaves on the screen as you move the turtle around. You can control which key(s) your child/student has access to when they are working on a task. You can even control a dynamic feature of the turtle where it can automatically execute any command to which your child has access.

The message at the bottom of the screen says "TYPE LETTER TO CHANGE CHARACTERISTICS". On the left edge of the screen you will find a column of letters each the first letter of a word that represents a characteristic that you may change. To change a characteristic you must type the corresponding letter and then follow the directions, again at the bottom of the screen. Sometimes a single keypress will alter the characteristic. At other times you will have to type a multidigit number or a word followed by return but the instructions will tell you when you have to press return. Sometimes you can even recover the original value before you started to make the change.

Changing the step

Start

press the letter S

Change

type the new step (number)

Finish

press the RETURN key to keep the change
press the ESC key to restore the old step value

Effect

pressing I, J, K, or M causes the turtle to move the turtle the number of units specified by Step.

Preset

the step is set to 20

Changing the pen condition (up/down)

Start
press the letter P

Change
change is automatic
no key press needed

Finish
no key press needed

Effect
if the pen is down, the pen is set to up (no trail).
if the pen is up, the pen is set to down (trail).

Preset
pen is set to down so that it will leave a trail

Changing the color of the pen

Start
press the letter C

Change
press either the left or right pointing arrow
(right side of the keyboard).

Finish
press the letter Q

Effect
changes the indicated color on the screen
actual color shown depends on background color

Preset
pen color is set to RV reverse

Changing the background color

Start
press the letter B

Change

press either the left or right pointing arrow
(right side of the keyboard)

Finish

press the letter Q

Effect

changes the indicated background color
may cause drawings to change color

Preset

background is set to WH white

Changing the student's access to keys on the keyboard**Start**

press the letter K

Change

press I, J, K, M, U, D, or ! to add or delete it
from student access

Finish

press the letter Q

Effect

if the command is highlighted (black letters on
white background) the key is accessible to the
student

if the command is normal (white letters on a
black background) the key is not accessible

pressing a key that is accessible will make it
inaccessible to the student

pressing a key that is inaccessible will make it
accessible to the student

Preset

I, J, K, and M are accessible
U, D, and ! are inaccessible

Changing the dynamic turtle operation

Start

press the letter T

Change

press I, J, K, M, U, D, or !

Finish

no key press needed

Effect

if the value of delay is less than 100 and the child has not pressed a key within a certain time period then the turtle will move or act dynamically according to which command has been selected

Preset

turtle operation is set to I (Move Up)

Changing the time delay for the dynamic turtle

Start

press the letter D

Change

type the new delay

Finish

press the RETURN key to keep the change
press the ESC key to restore the old delay value

Preset

delay is preset to 100 (turtle is not dynamic)

Running special Logo commands

Start

hold down SHIFT and press @

Change

type the Logo command you wish to have executed
and then press RETURN

Finish

press RETURN again

Effect

the computer will run your Logo command

WARNING - if the command is invalid then the program will stop prematurely and it may be necessary to restart the program by reading "MENU and selecting the desired program. It may be possible to restart the program by typing START and pressing the RETURN key.

save pictures of the graphics screen to the disk by typing SAVE "NAME and then pressing the RETURN key. NAME can be replaced by any name you choose.

read pictures off the disk to the graphics screen by typing READ "NAME and then pressing the RETURN key. NAME has to be the name of an existing picture file on the disk. If the NAME does not exist, the program will stop prematurely and will have to be restarted as described above.

Preset

none

Stop the program**Start**

hold down shift and press \$

Change

change is automatic
no key press needed

Finish

no key press needed

Effect

program is stopped
program is erased

MENU program is read
you may choose a new program

CAUTION - only use this command if you want to switch from the absolute program to the relative program and back. It is faster just to reset the values yourself. There is no problem if you wish to press \$ to restart the menu

Preset
none

How do I start the RELATIVE program?

1) Type READ "RELATIVE and then press the RETURN key.

Please note that there is a space between READ and "RELATIVE . Also note that there is a quotation mark only on the left side of RELATIVE.

2) Type START and then press the RETURN key

3) It will take the computer about a minute to load the program

4) The computer will stop with a display of program characteristics

CAUTION - When you stop the program:

to restart the same program:
follow the directions beginning at step 2 above.

to start a different program:

type GOODBYE and then

press the RETURN key

follow the directions for starting that program

How do I use the RELATIVE option?

1) you can use the program immediately without worrying about the screen full of information. Look at the bottom of the screen and you will see the message:

TYPE LETTER TO CHANGE CHARACTERISTICS
OR TYPE Q TO GO TO THE GRAPHICS SCREEN

Since you don't want to worry about the menu, type Q , the menu will disappear, and a graphics screen will take its place.

2) Now you will see a white screen with a black triangle (the turtle) in the center of the screen and pointing up.

3) Since you chose the RELATIVE program, you will be controlling turtle movement by pressing the F and L keys.

F - will make the turtle move forward.

L - will make the turtle rotate to the left.

Practice by pressing these keys to see if you can draw a box or any small picture. When you press these keys, the computer will act immediately (you don't have to hit return).

You may have found that if you try to move the turtle over a line that it has already drawn, the turtle will erase that part of the line which is traced.

4) The only keys that are active (cause something to happen) are F and L.

There really is one more key that is active and that is the question mark. Hold down shift and press the question mark (just like a normal typewriter). Now you will see the graphics screen, the turtle and your drawing disappear only to be replaced by that menu of characteristics that had been on the screen a little while ago.

5) Other keys that the student may use, if they have been made accessible, are:

B - will make the turtle move backward

R - will make the turtle rotate to the right

U - will set the turtle's pen to up and will not leave a trail

D - will set the turtle's pen to down and will leave a trail

! - will clear the screen and put the turtle in the center of the screen

