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THE EVALUATION AND CULTIVATION OF SPATIAL AND LINGUISTIC ABILITIES IN INDIVIDUALS WITH CEREBRAL PALSY

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Abstract

The work of the Cerebral Palsy project (members: Seymour Papert, Syvia Weir, Jose Valente and Gary Drescher) over the past eighteen months is summarised, and the next phase of activity is outlined. The issues to be addressed by the proposed research are as follows:

1. An investigation of computer-based techniques to maximise the acquisition of spatial and linguistic skills in severely Cerebral Palsied children, to serve the educational and therapeutic needs of this population.

2. Developing a set of computer-based diagnostic tools for use with physically handicapped persons which could contribute to the provision of a functional specification of subcategories of Cerebral Palsy.

3. Investigating the ways in which findings on Cerebral Palsy subjects can inform our theories of cognitive development and the adult functioning of normal individuals.

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I. INTRODUCTORY REMARKS AND MOTIVATION FOR PROPOSED RESEARCH

In drawing attention to the role which computers might play in the management of the physically handicapped, we have focussed (Papert and Weir, 1978) on several aspects of the situation:

> the evaluation and the cultivation of spatial cognition in this group;
>
> the study of linguistic structures in a language-deprived subgroup;
>
> and the improvement of career access in such a population.

To the extent that sensori-motor activity contributes to the full development of the cognitive structures underlying spatial understanding, it was argued that individuals with very severe motoric restrictions suffer from the lack of opportunity for such learning, since their lives contain little

> "explicit confrontation between the actions they perform and the consequences of such actions in the physical world" (Papert and Weir, 1978)

We suggested that such a confrontation can be made possible in the interactive graphics learning environment of our LOGO system, because it provides the opportunity for manipulating "objects" on the screen. We called this manipulation AS-IF actions, and proposed the introduction of LOGO activities such as those we had provided for non-handicapped children into the classroom work of the severely handicapped. In doing this, we are addressing three questions:

Question 1: Are the LOGO activities which have been developed for non-handicapped individuals suitable for use with Cerebral Palsy children, as judged by those in charge of supplying their educational needs? What modifications will be required to the existing system to cater for special needs.

Question 2: Does this LOGO experience yield quantifiable information about the state of a subject's spatial understanding?

Question 3: If pursued over a period of time, could this LOGO activity be a source of manipulation experience in 2D space, the effects of which could be looked for on other computer-based tasks?

Notice how placing motorically deprived individuals in an interactive graphics situation generates a significantly novel way of assessing such persons, in that the very element viz. motor handicap whose restrictions leads one to suspect the presence of a deficit in spatial cognition, renders the ascertainment of that deficit very difficult. Performance tests are notoriously difficult to administer to this group. And yet there is a theoretical as well as a practical educational interest in exploring the texture of the cognitive abilities, the patterns of disruption, displayed by persons with such unusual experiences. Is there a delay or a deviation in, or an absence of, development of specific capabilities? Are there dissociations which might yield insights into theories of brain function?

For example, do individuals in this population exhibit systematic patterns of spared and impaired competencies for different areas of mental activity, e.g. linguistic, spatial, deductive, which could provide evidence for the specificity/generality issue; i.e. to what extent is a particular type of computational process specific to a given faculty, and to what extent do common mechanisms support different areas of cognitive functioning.

Our world of AS-IF actions, it was postulated, gives us the possibility of carrying out selected, standardised AS-IF manipulative tasks on individuals with severe motor handicap, which we hoped might add to our understanding of these issues. So we add

Question 4: Can the computer be a useful tool for the assessment of cerebral palsy individuals, as judged by a comparison of performance on selected screen tasks by our population vs. a non-handicapped reference group?

Language deficits in Cerebral Palsy straddle a wide range, from the lack of any speech whatsoever, to severe through mild dysarthria, to the presence of substantial expressive oral language but no writing experience. Exactly parallel arguments were made about the theoretical and practical importance of providing a "writing" tool in the form of facilities for taking in, storing, and editing text, for use with the language-restricted subgroup of this population.

Question 5: Can the computer be a useful tool for psycholinguistic assessment of language-use in cerebral palsy subjects whose motor impairment has restricted the availability to such individuals of some of the normal expressive paths?

Finally we drew attention to the potentially important human and social consequences of this enterprise. We made the prediction that offering a disabled person the possibility of communicating with a computer, and thus the chance for <u>sustained</u>, <u>independent</u> activity and an immediate extension of the range of task complexity available to such an individual, would open up opportunities for increasing levels of intellectual achievement, of increasing opportunities for career access, enjoyment and a sense of personal fulfillment.

Our experience over the past sixteen months (the period during which we have held a B.E.H. grant for the exploration of these matters) has been most encouraging. It seems that the computer-based activities we have designed have considerable potential as research and educational tools for use with the physically handicapped. In this document we report our findings, in brief, and consider how we might choose which of many questions generated by our work we might most profitably pursue. In section 2, we present a summary of our findings with LOGO; in section 3, we summarise the screen task results; and in section 4 we give an analysis of their implications in relation to other work in the area. In particular, we raise the issue of how we might set about teasing out the relative roles of brain damage vs lack of manipulative experience in producing the deficits we are finding. Section 5 presents our preliminary findings on the linguistic aspects of the study. In the final section, we present a proposed plan of research for the 2-year period 1980-1982.

2. LOGO and CEREBRAL PALSY

<u>The viability of this activity as part of a school curriculum for Cerebral Palsy students</u>

We have worked with three age samples of Cerebral Palsy subjects

(a) three profoundly handicapped children aged 7-8 years
(b) three severely handicapped children aged 11-13 years
(c) three severely handicapped adolescents aged 17 years

In addition, two 18 year olds whose handicap arose after infancy (one post traumatic; one degenerative familial muscular dystrophy) have participated in LOGO activities. The children aged 11 years and over are pupils of the Cotting School for Handicapped Children; the younger ones are at the Kennedy Memorial Hospital for Children Day Program.

The answer to the question of the acceptability of LOGO in the classroom for the <u>oldest group</u> (question 1 above) is a resounding "YES".

--the LOGO curricular materials developed for nonhandicapped children (Papert et al, 1979) are suitable for use with this population. Next steps include further development of the physics material (see Appendix 1).

--the older the group the more obvious is the connection with other aspects of the curriculum. We detail this for Algebra and Trigonometry in Appendix 2.

--the use of the computer as a notebook-cum-scratchpad of ideas has replaced the need for "doing it all in the head" and has given a new lease to the intellectual life of these students. This can be summarised as the experience of sustained problem solving in learning to program, in the various parts of math which form a large part of LOGO activities and in the generating of their own notes.

--all these older children type, albeit slowly and by dint of a variety of ingenious props. The DELETE key is invaluable since they do hit unintended keys.

--the sheer fact of this whole new world of knowledge and of their own independent management of this, has had a profound effect. One subject has spent 6-9 hours a week at the computer since the onset of the project; has been brought to the LOGO laboratory weekly during vacations when the computer at the school is not available to him; lies in bed solving LOGO problems in his head, and has changed his career plans as a result of this experience. For an account of this subject see Valente(1979).

--the school at which we are working shares our enthusiasm. We have made a selfconscious effort to involve the teachers and the parents of these handicapped individuals in an integral way in the program in order to ensure that the activity will not end with the research grant. The math class teacher has spent upwards of 10 hours visiting the LOGO laboratory to work with a project member and the school is arranging for a part-time replacement so that this staff member can participate in the work of the project. The school authorities are also planning the acquisition of machines, both enterprises to be funded from their own resources.

The middle group has made slower, rather less spectacular progress, but rewarding enough to suggest that effort with this group should be expanded considerably. This group is especially interesting both because it allows us to use the work of the Brookline School sample of non-handicapped 11-year olds (Papert et al 1979) as a reference group, and because of the interesting findings on the screen tasks for this group (see section 3).

The youngest group is also the most profoundly handicapped we have tackled and progress is indeed very, very slow. Two of these (one mute quadriplegic; one non-cooperating dysarthric quadriplegic, both presenting problems of assessment of intellectual ability) had rather intrusive emotional problems and our attention was almost wholly taken up with these. The third was a charming, cooperative verbally fluent boy whose very limited counting skills and marked perceptual problems made the twenty sessions we had with him yield a lot of rather poignant excitement on his part, but rivetingly slow progress in acquiring LOGO primitives. It would seem that except for the isolated case, such profoundly handicapped individuals should not be worked with at present. Rather we should use the same in-depth approach, exploiting the versatility of the LOGO system, on individuals in the 11-14 year old group.

Using Logo activities as a way of assessing spatial abilities

The range of LOGO activities in which our handicapped students have engaged covers a much wider spectrum than has previously been encountered in non-handicapped populations. More than ever, each child is a law unto himself. Progress is invariably slow because of physical handicap. Special techniques have been introduced to lessen this effect eg. a button box (both hardware and software implemented), where each button represents a basic LOGO command, can significantly reduce the number of gestures required. (see Appendix 3).

Ranking LOGO activity which extends over such a wide range is not difficult, if one is content to make a rather coarse inventory of the stages reached. It is not clear how useful it would be to aim at too fine a rank ordering based on number of lessons before "x" or "y" facility is mastered, given the fact that there are often several different ways of doing similar LOGO tasks, each appealing to different work styles among children. It is clear that some subjects have special difficulty with the overtly spatial aspects of doing LOGO. Although the primitive TURN comands often give trouble to beginners, several of our subjects were quite unable to handle the right/left distinction and used trial-and-error to achieve their purposes. One young man found the problem of getting the turtle to a particular starting place within a figure quite beyond him, and it was our impression that this difficulty was quite outside the range we had previously experienced and had to do with a rather profound spatial defect, the details of which are currently being looked at.

Older handicapped subjects (17 year olds) are, for the most part, not at all stretched by the LOGO primitives, and thus for such a group, mastering these quickly is hardly evidence that no spatial deficit exists. Given this and the fact that LOGO engages abilities other than those connected with spatial concepts, and that these requirements interact in complex ways in the achievement of any LOGO task, it is our opinions that using LOGO to grade spatial ability (Question 2 above) would not be easy. Rather, it could be argued that a more promising approach would be to use LOGO as a source of experience in visiospatial problem solving whose effects can then be measured by other tasks. It would be necessary to remain on the alert for gross reversals in difficulty orderings.

In summary, then:

Our experience with LOGO and Cerebral Palsy leads us to recommend that the major advantages likely to be gained from LOGO work with this group lies first and foremost as a source of experience in visiospatial problem-solving activity, but also as a potentially valuable source of insights into the peculiar difficulties experienced by this population in the manipulation of visiospatial information. We suggest that other computer-based means should be developed for assessment purposes.

We have, of course, been engaged in preliminary explorations in the latter area as described in the next section.

3. DEVELOPMENT AND TESTING OF SCREEN TASKS.

A substantial programming effort has produced an efficient general purpose system for implementing a wide variety of tasks. New tasks can be added with relative ease. Features of the system include the provision of an automated record of the moves made by the subject complete with a time marker; and a facility for using this record to drive a rerun of the task for purposes of analysis. We report on two of the several screen tasks which have been implemented (see Appendix 4 for details).

A. A 2D version of Piaget's (1952) SERIATION task in which a cluster of randomly oriented "sticks" are required to be "carried", using a cursor, and arranged in serial order along a "table-top." After performing this screen version, subjects were asked to do the standard Piagetian task with wooden sticks.

Results

Non-handicapped children

All children 7 years or over could do the screen task, including the insertion step. Some 6 year olds and some five year olds could not do the insertion step in either the real or the screen task. Some 4 year olds cannot order the sticks in either version. We have as yet insufficient data to decide whether competence is exactly parallel in both versions of the task and are in the process of testing more of these very young children.

All Cerebral Palsy subjects had difficulty with some aspect of one of the tasks.

All 17 year-olds could perform the screen task except that one (Gti) needed considerably more trial and error than we anticipated. In addition to the expected motor difficulties, this latter was true of the wooden sticks version for all three in this group. (Gti) had to remove the two sticks being compared to a separate area.

Four 11-13 year olds were tested, viz. the three subjects who did LOGO and one other.
Only one subject (Amr) performed both the screen version of the task and the wooden sticks version. One subject (Jra) could seriate the sticks in the screen version but could not do the insertion step in that task, and could NOT do the real task with wooden sticks, even when only four sticks were used.
"I know it is not right, but I can't get it right!"

One subject (Kst) could not seriate on the screen (fig 1a), nor with wooden sticks. Even with four of these, she got them out of order, yet thought she had it right.
A fourth child (Msu), who is judged to be a very bright child, did the screen task as in fig 1b.; she was unable to seriate four wooden sticks

Comments

1. Seriation is a task in concrete reasoning (both versions) i.e. mental experiments carried out on physically present "objects". In fact the tasks also involve "a display in space" (Gillieron 1977), and for our task, the visiospatial issues arising include: comparative judgments of length, localization of objects in 2D, and perception of orientation of objects.

2. Piaget described a progression of stages in which the youngest could not order the sticks, at best producing a set of subseries (see our subjects Kst and Msu above); older children used a trial-and-error approach to reproduce the configuration, but could not insert extra sticks into the series (our subject Jra) a step which Piaget calls "reversibility" because it involves "undoing" the configuration in order to add the new stick. This is just what the oldest

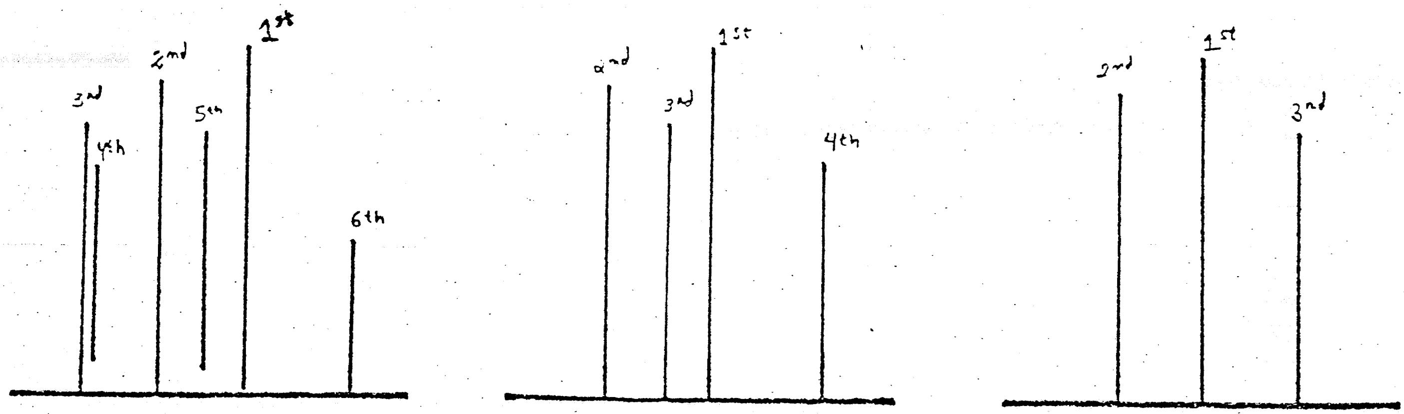


Fig. 1.a Screen Seriation of Kst.

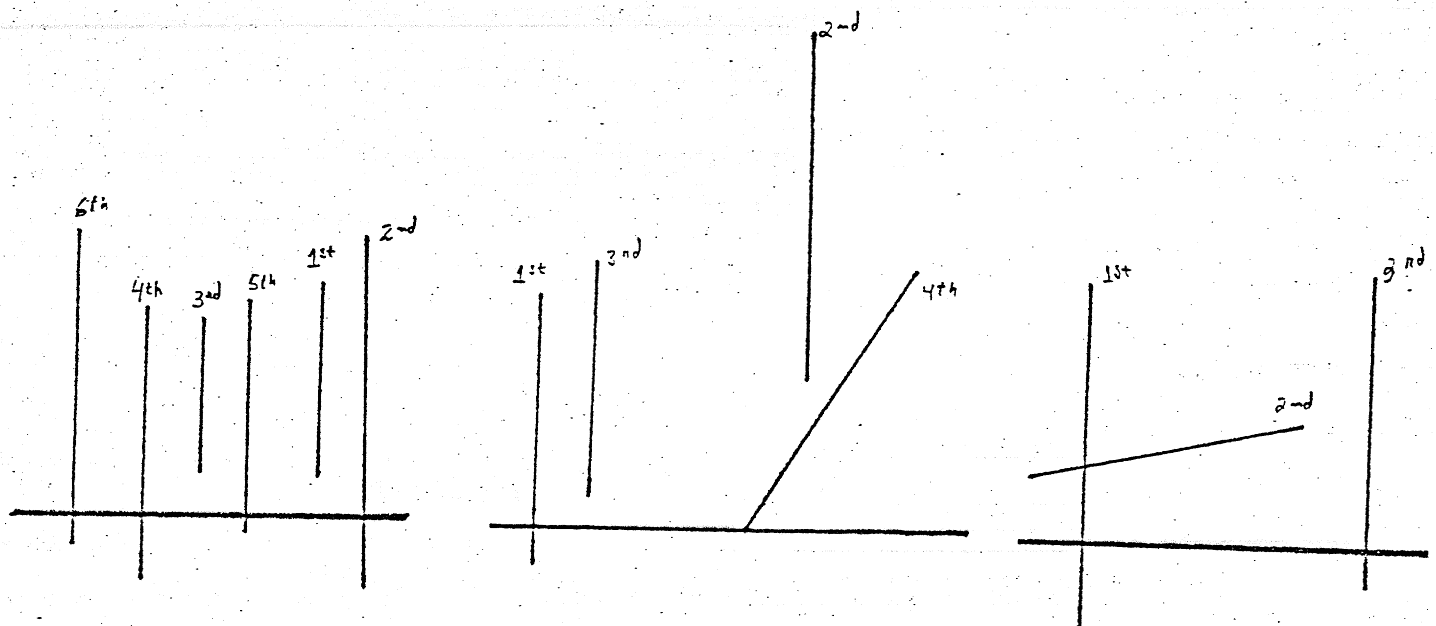


Fig. 1.b Screen Seriation of Msu.

Fig. 1

EXAMPLES OF SCREEN SERIATION

children (over 7 years of age) who are "operational" can do because they are able to consider a single stick as both longer than the sticks preceding it, yet shorter than those following it.

3. Closer scrutiny of the performance of the task shows that the order in which the sticks were picked up provides a way of ranking the performance of the subjects who failed to seriate.

One subject (Kst) picked up the sticks in the correct order except for one reversal in the 6- stick version. She put them down in the wrong place and made no attempt to correct her placement. One subject (Msu) selected her sticks in a random order, and made no attempt to adjust any of them once she had placed them.

Using the Newell and Simon "Production-systems" paradigm Young (1973) modelled the behaviour of his subjects as a series of rules and distinguished three components of a child's seriation skill.

(a) SELECTION: the block she chooses to work with next
(b) EVALUATION: her decision whether or not to accept a block as an addition to a line.
(c) PLACEMENT: whereabouts in the line she puts a new block; of which a major aspect is CORRECTION: what she does with a block once she realizes that its wrong.

Under (c) would come rules such as:

(i) if block not next in series then reject
(ii) if block not next in series then switch with neighbor
(iii) if block not next in series then insert into correct place

Our subjects Kst and Msu seem not to have any of these rules operating. These rules could all be described as "reacting to the consequences of one's actions".

4. The ability to insert sticks is regarded as evidence for the understanding of "logical reversibility" (as opposed to "foreseeing empirical return".)

Question 6: Do nonseriating CP subjects understand the reversibility of
left turn 45 degrees / right turn 45 degrees, and
forward 10 / back 10? Is this "logical reversibility"?

B. <u>Stereognostic recognition of shapes</u>

We have found this a particularly interesting area and have concentrated most of our attention here. Severely physically handicapped persons can enjoy the visual experience of shapes and spatial configurations to a much greater extent, usually, than they can indulge in the manipulation of objects in space. This latter manipulation involves a coordination of tactile information with proprioceptive information generated as the hands and fingers move with and over the objects, and with data from the motor component i.e. the coordinated instructions to muscle groups which correspond to particular movements. Haptic identification of objects develops more slowly than visual identification, and has been shown to be significantly impaired in brain damaged children (Rudel et al.,1974). A possible explanation for this is the fact that the various features of the palpated object are not available "all-at-once" as they are in the visual case. They have to be searched for and integrated over time.

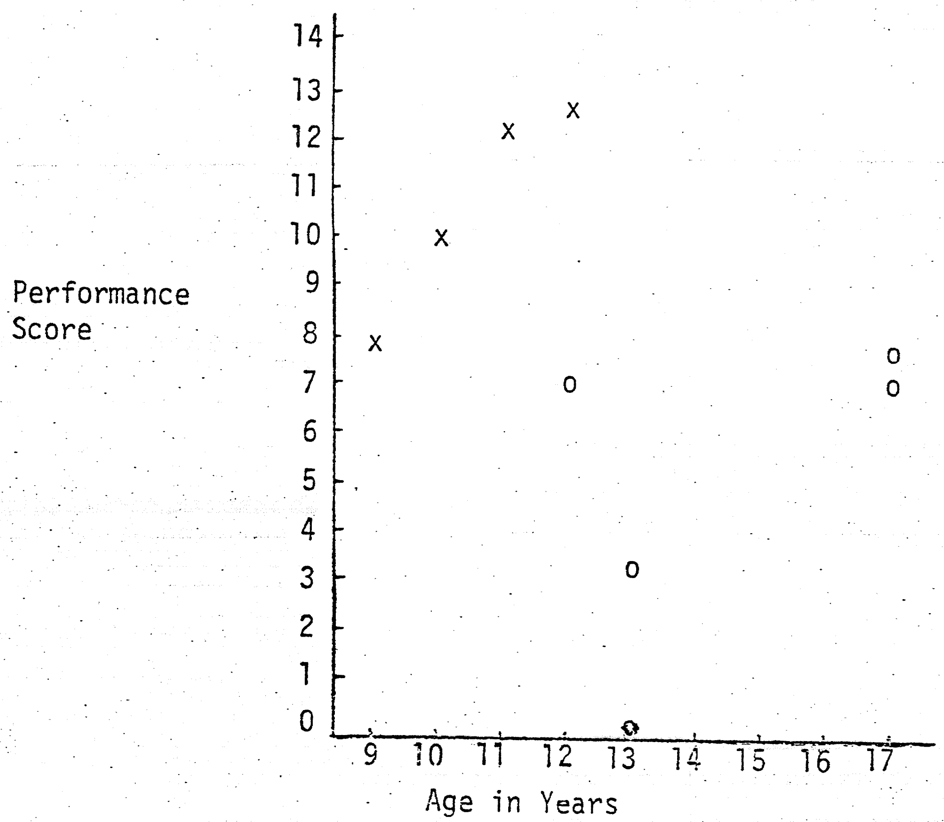
In an effort to replicate at least this last attribute, and because the standard palpation task clearly requires supplementing and modification for use in our population, we have invented a task we call "pseudopalpation". The game is to find a hidden figure on the screen by moving around a cursor which takes two forms, one when it is inside the boundary of the figure, and another when it is outside. The edge of the figure is detected by noting the change in shape of the cursor, and a small piece of the edge just crossed can be inspected by pushing the appropriate button. This allows the subject to accumulate evidence as to whether edges are curved, straight, horizontal, oblique, pointed, and so on. Exploration of edge shape at different parts of the hidden figure can lead to a recognition of the hidden shape. (See Appendix 4 for details of shapes used).

Results.

We have tested thirty non-handicapped children to give us data on which to base a grading of performance, and we are in the process of developing ways of quantifying the behaviour observed. In addition to using the tally of numbers of correct answers, we wish to use details of the subject's strategy of problem-solving. Our current algorithm takes account of features such as:

entertaining alternative hypotheses about what the figure can be,
searching for particular disambiguating features,
contour following or systematic exploration of extent of figure.

Figure 2 shows the distribution by age of patterns of performance on this task. Preliminary scrutiny of the performance of Cerebral Palsy individuals shows a deficit in level of achievement on both dimensions i.e. number of correct answers, and age appropriate strategies used. We are as yet unable to say whether this represents a delay or a deviation.



Legend:

x = mean score non-handicapped

o = individual score handicapped

Performance score = number of correct answers + $\frac{\text{strategy score}}{2}$

Figure 2 Performance on Pseudopalpation Task

4. DISCUSSION OF RELATED WORK

Of the several tasks involving spatial cognition for which screen version have been implemented on our system, the first two we have explored to any depth with our Cerebral Palsy subjects have demonstrated clear deficits. More work to confirm the robustness of these findings is proceeding. If we assume for the purposes of this discussion that our findings stand firm, we next need to consider their implications. Both our tasks have a high problem solving component and both have a high motor component i.e. the subject is not required simply to make relatively passive choices from among experimenter-determined responses. These two components are not independent. The tasks used in previous reports of deficits in visio-spatial functioning in Cerebral Palsy individuals can be examined with these components in mind.

Problem solving

1. Cerebral Palsy subjects perform better on perceptual discrimination (recognition) tasks (of simple geometric forms) than they do on perceptual analysis tasks (finding which of several figures the presented fragment was part of; and on perceptual synthesis tasks (which of several sets of lines could be used to construct a given figure). (Birch and Lefford, 1964)

2. Impaired figure-background discrimination in Cerebral Palsy subjects has been reported using masked and embedded figure tasks presented as a tactile task (Dolphin and Cruickshank 1952) or as a visual-perceptual task (Dolphin and Cruickshank(1951); Cobrinik(1959)). Cobrinik notes that handicapped and non handicapped groups perform about equally well on the simpler items, but that Cerebral Palsy children perform less adequately as the items become more difficult. Scrutiny of the tasks suggests that the increase in complexity amounts to a gradual increase in the puzzle or problem solving nature of the task.

Motor

1. Cerebral palsy children perform badly on the Goodenough draw-a-man test, commonly interpreted as evidence for their poor body image. However, they perform equally badly when the task involves copying very simple figures, suggesting a difficulty of drawing generally. (Abercrombie and Tyson 1966).

2. Measures of visual perception in Cerebral Palsy yield scores progressively lower as the motor component of the test used increases (Zeitschel et al 1979).

3. Cerebral palsy children who fail on the block-design reproduction task of the WISC, can succeed, most of the time, on a task which requires them to choose the one correct design out of three presented block designs (Bortner and Birch 1962).

4. The tactual figure-ground discrimination task (Dolphin and Cruickshank 1952) mentioned above involved exploring a surface with the hands and making a drawing of what had been perceived.

The lack of experience component

Can we infer that the common component in all this flows from the evident lack of experience which we described as a lack of explicit confrontation between actions performed and the consequences of such actions in the physical world?

> Sustained problem-solving involves using feedback from early steps: "that looks good.. lets see where this gets me", or "no that looks wrong". Instead, a handicapped child behaves like John Holt's (How children fail) kids: "shut your eyes, take a guess and pray that its right"

Support for the lack of experience thesis comes from an exploration by Wedell and his colleagues (1972) of the relationship between the amount of independent mobility experienced and the development of size constancy. The task requires subjects to match the height of an adjustable rod with standard rods at increasing distances away, and shows that under both monocular and binocular conditions of vision, children with the longest independent mobility (over 1 year) achieve a higher degree of size constancy at the greater distances than children with less experience of walking. This is not correlated with age at testing.

The brain damage component

An obvious possible alternative explanation for the deficits must be taken account of. All Cerebral Palsy subjects have brain damage and it is the fact that this damage affects their motor activity that puts them into the category under investigation. It is surely necessary to explore whether the visuospatial perception of an individual is disturbed as a consequence of that same brain damage which produced the motor deficit, or whether there has been additional damage to the neural substrate which directly supports such perceptual activity. Wedell et al (1972) consider that they have disarmed the possibility that their result reflects differences in degree of underlying brain damage, corresponding to degree of mobility restriction, by showing no covariance of size constancy judgements with performance on a vocabulary test. This would no longer seem to be a warranted conclusion in the light of a decade of work on hemispheric specialization. For an account of this endeavour see Kimura (1973) and Hecaen and Albert (1978). The same criticism applies to Cobrinik's (1959) conclusion that location of damage was not relevant to figure-ground discrimination deficit, since he too did not take account of the laterality issue.

Selecting the next tasks

Several questions arise.

Question 7: How would our subjects perform on a complex visual task
- (a) with no motor component
- (b) with no problem-solving in the usually understood sense
- (c) where there was unlikely to have been a lack of experience?

Should we find that our subjects are relatively unimpaired in their ability to perform such a task, we could feel more inclined to stress the lack of experience component as the largest contributing factor.

Question 8: How would our CP subjects perform on other visuo-spatial tasks which work on hemispheric specialization leads one to believe are mediated by the same area of the brain as the visuo-spatial tasks we have already tested?

Again, should we find no demonstrable deficit, we would be inclined to favour the lack of experience as the major causal factor.

It turns out that _face recognition_ tasks fulfill both of these sets of criteria. The factors concerned in the encoding of faces have been extensively explored in the past decade, (see Carey and Diamond, 1979 for a summary) and there is ample evidence that this is a complex visual task the execution of which depends on the integrity of the right hemisphere, as does most visio-spatial cognition. (See Hecaen and Albert, 1978 for a summary.) In addition there seems to be something rather special about the encoding of upright faces, eg. it is especially vulnerable to inversion as compared say to the encoding of houses.

> For a computational device to achieve this, it must have the ability to recognise objects under size, position and orientation invariance, so that it recognises that it is looking at a face; and, at the same time, have the ability to encode orientation-specific information on the basis of which it can recognise this particular face. It would not be surprising to find the two mechanisms located in different places in the brain, as the clinical evidence suggests.

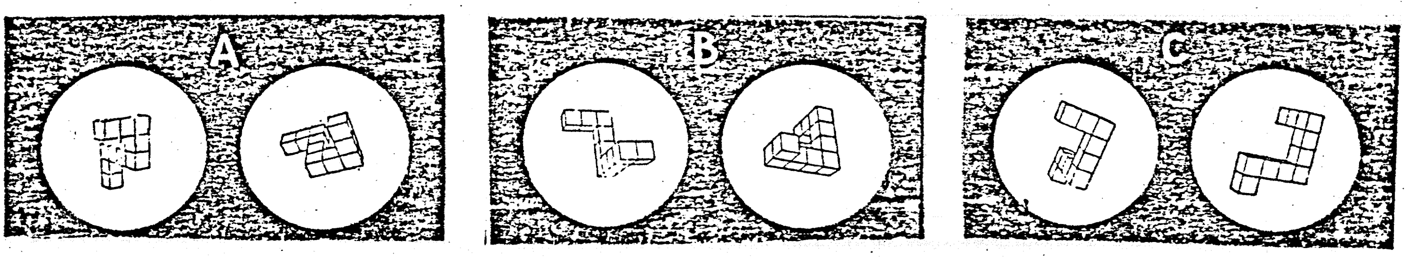
In contrast to normal adults, young children and patients with right posterior hemisphere lesions do not show this materials-by-orientation interaction i.e. inversion affects the encoding of faces no more than the encoding of houses. Our interest will be in whether those of our Cerebral Palsy subjects who show spatial deficits also show evidence of right hemisphere lesions as judged by their performance on face recognition tasks. We are also curious to see if individuals who habitually tilt the head to one side treat "vertically upright" as a less distinguished orientation. We need to know what the shape of the orientation tuning curve for faces looks like (Hinton 1979).

Next we consider other aspects of the ability to manipulate spatial information and to localise onesself in space, aspects which have a functionally distinct status from that involved in the recognition of form. We need to choose tasks which require the mobilisation of these abilities.

Possible candidates include:

<u>the topographical localisation task</u> of Piaget in which a subject is required to localize a "doll" in a miniature landscape depicted on the screen, in positions corresponding to those in which the examiner places the doll on a cardboard relief map version of the same landscape, which has been rotated 180

degrees; and the related three mountain task, in which the child is asked to pick the picture that the doll would see from various viewpoints; and the mental rotation task of Shepard and Metzler (1971), in which subjects are shown pairs of line drawings of 3D jointed cubes as in the figure, and asked whether or not they match under a rotation transformation.



The outstanding question we need to formulate is:

Question 9: What happens to the performance on these tasks as visio-spatial manipulation experience, in the form of LOGO classes, accumulates.

5. LINGUISTIC ASPECTS OF STUDY

Our focus of interest concerns the role that computer-based activity can play in extending the expressive possibilities available to Cerebral Palsy subjects with severe motor handicaps such that they have had no previous experience in generating written text. Typically a caretaker adult will write down what the subject says with an unknown amount of editing slipping in during the process. Now for the first time the spontaneous, uncensored productions of these individuals become available for their own and our scrutiny.

As with visuo-spatial activity, we conceive of this exercise as serving both diagnostic and educational roles. In some cases, the motor handicap includes a disturbance in the functioning of the apparatus of speech production i.e. dysarthria, severe enough to lead to some difficulty in assessing the linguistic competence of the individual. Making available an additional source of information in the form of "written" text is clearly of potential value. This would increase as the amount of existing oral expression decreases.

The prime concern of the school authorities is vocational placement and this implies a concentration on improving the communication skills of handicapped persons. The 17 year old student described in Valente (1979) hopes to go to college to train as a computer programmer, so the quality of his written text is of great importance.

(In order to protect the subjects privacy we do not quote his work.)

We do not have sufficient material yet for a detailed linguistic analysis, but some interesting points emerge based on our observation of his work. His text looks like written down "spoken English" rather than "written English". Some systematic errors are seen, for example, the "r"s that come before consonants are missing, as in "fist" for "first"; "lean" for "learn". We have consulted with our colleagues in the Linguistic Department, who have expressed an interest in seeing a larger corpus of data for analysis.

Again we ask the question

Question 10: What will be the effect of practice on the written work of individuals who have no previous experience of this activity?

PROPOSED PLAN OF RESEARCH

Using subjects from three schools for the physically handicapped viz. Cotting School, Kennedy Day School and Crotched Mountain

1. A group of twenty severely physically handicapped subjects aged 11-17 years will be studied with a view to obtaining performance profiles in the following selected task areas.
   a. Seriation, as already described (see section 3 and Appendix 4)
   b. Pseudo palpation as already described (see section 3 and Appendix 4
   c. Mental rotation task of Shepard and Metzler(1971) as described, briefly, in section 4.
   d. Topographical location as described, briefly, in section 4.
   e. Face recognition tasks, as provided by Professor Susan Carey.
   f. One other (verbal reasoning) task
   g. Locus of control. The Intellectual Achievement Responsibility test is currently being used in a LOGO study on Brookline children with learning difficulties, and we plan to use the same test on our Cerebral Palsy children.

Tasks will be administered in the first year and in the middle of the second year of funding.

2. Eight of the subjects will form the intensive core group with which we will work at LOGO activities during the entire period. These activities will include:
   Math (see Appendix 2),
   Physics (see Appendix 1),
   Creative Writing; an editor and a file-handling system enables each user to write his own stories, display them on the screen, store them in a notebook, and edit them at will, and
   Drawing, using a tablet (see Appendix 3).

3. The remaining twelve subjects will have two creative writing sessions a month. These will extend over several days, involve use of the editor, but not any turtle geometry or physics.

This will serve two purposes:

a. We will collect a corpus of data for linguistic analysis

b. We will give these subjects a computer experience, so that they can serve as an internal control.

Two points about the research design should be made.

1. The reason for having only eight subjects in the core group is that we have found this to be a manageable number given the extensive documentation involved.

2. Ideally, we need the following groups:

a. Handicapped Children: pre- and post-tested, with no special intervening activity.

b. Non-handicapped Children:
   - (a) pre- and post-tested, with creative writing experience
   - (b) pre- and post-tested, with LOGO experience
   - (c) pre- and post-tested, with no special intervening activity

However, as the point has been made many times in the past, it is not clear what group of non-handicapped persons would constitute an appropriate control. Further, we do not have the resources in staff and machines, nor are there sufficient suitable subjects available to us to enable us to pursue this research design, and we feel that the design we have chosen will yield the largest amount of information, whilst ensuring that each handicapped individual gets a valuable experience during the research period.

Machines

We will use the machines purchased under the grant we currently hold, for work at Cotting School i.e. two GENERAL TURTLE 3500 machines. In addition, we are requesting funds in this proposal for two "home" computers, either the TEXAS INSTRUMENTS or the APPLE version, and a printer, for use at Crotched Mountain for the creative writing part of the project.

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APPENDIX 1

DYNAMICS: LEARNING PHYSICS WITH A DYNATURTLE This is an abstract of the section written for the Final Report of the Brookline project by Andy diSessa

A dynaturtle, like the ordinary LOGO TURTLE, is a graphics entity which can be moved around on the computer display with commands typed at the keyboard. Like the geometry TURTLE, dynaturtle responds to commands, RIGHT or LEFT, by instantly turning in place. While motion for the geometry TURTLE is caused by the command FORWARD, a dynaturtle never changes position instantly, but can acquire a velocity with a KICK command which gives it an impulse in the direction the dynaturtle is currently facing. To effect real time control, one normally directs a dynaturtle with keystroke commands, R, L, and K which stand for RIGHT 30, LEFT 30 and KICK 30. Provisions are made to allow students to augment this small set of instant commands at their pleasure.

Two model games are provided for the students to begin with. One, called TARGET, has as its goal to direct a dynaturtle with K's, R's, and L's to hit a target, and to do so with a minimum speed at impact. A qualitative scoring together with impact speed is printed out when the target is reached. The initial configuration has the dynaturtle at rest aimed directly up the screen, and the target, as indicated in fig 1, positioned at a bearing of 45 degrees from the dynaturtle. A single K command would cause dynaturtle to travel the distance between initial position and target in about 15 seconds. The introduction to dynaturtle given to students is a brief description of commands together with an illustration, applying a few "kicks" to a tennis ball on a table using a small wooden mallet.

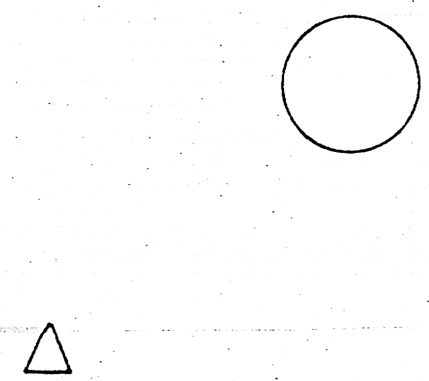


fig. 1
Initial Configuration of Target

Dynaturtle and the model games provided were designed with the intent of introducing the students to the Newtonian notion of controlling an object by changing its velocity. The fundamental principle is that an object has a velocity (both direction and magnitude) as part of its state, which is preserved until an interaction (KICK) changes the velocity. KICKs on the other hand act in a very simple way which can be described by vector addition (fig. 2): The old velocity is changed into a new one by adding a KICK vector whose length is the input to the KICK command and whose direction is the current heading of the turtle.

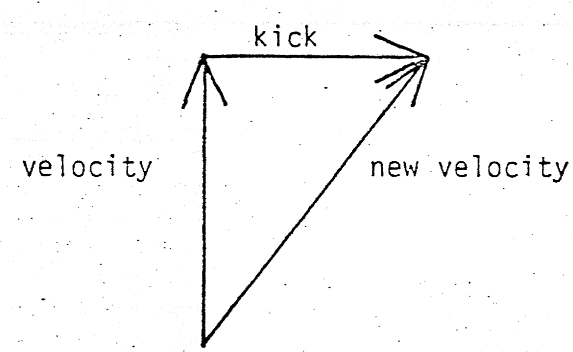
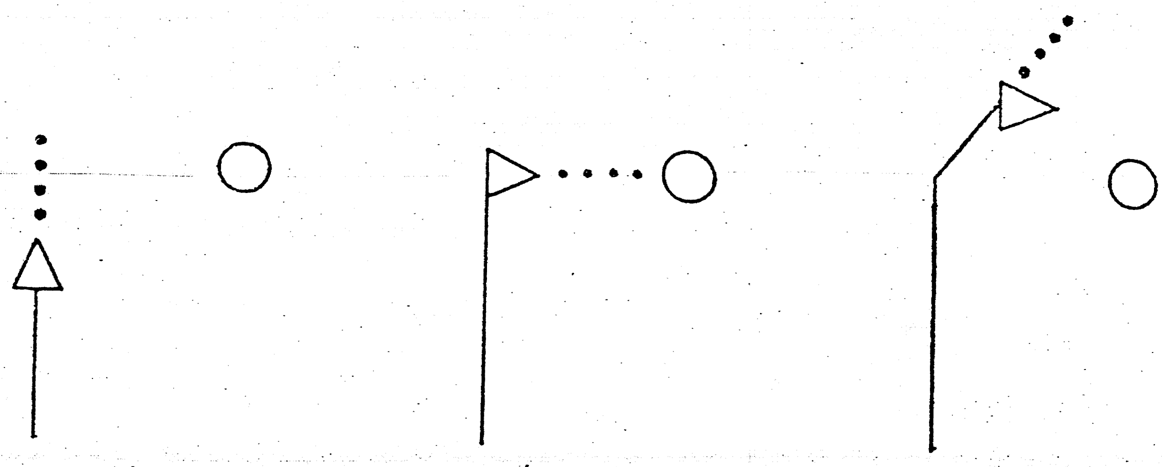


fig. 2
Vector Addition



Moving Upward

Expected Result
of a sideward kick

Actual Result

APPENDIX 2 This section was prepared by Jose Valente.

USING LOGO ACTIVITIES TO INTRODUCE BASIC CONCEPTS OF TRIGONOMETRY

Mike is an 18 year old boy with severe cerebral palsy of mixed type, enrolled as an 11th grade student in a special school for the handicapped. He has been using Logo for over a year now and has mastered the major LOGO ideas quite well.

In the beginning of his Logo activities, after several sessions exploring some of the LOGO ideas, he initiated a project whose task was to draw the background of Copley Square, a very well known landmark in Boston.

At one point in his drawing he had the church, the Hancock Tower, and intersection with a stop sign. The large street at the intersection represents Boylston Street and the smaller one represents Berkeley Street (see Figure 1.a).

When visitors came to see his work, he would show them this drawing and he found that the picture was not sufficiently representative to be recognized without some hints on his part. At other times the stop sign was even misread as a tree (due, perhaps, to its being out of proportion to the surrounding "buildings".) Mike would sarcastically reply: "a tree in downtown Boston!!" This was a topic for jokes, although Mike was not happy with it. To resolve the problem he proposed that his drawing be labelled with the word "stop" on the stop sig, and the name "Copley Square" written at the top of his drawing (see Figure 1.b).

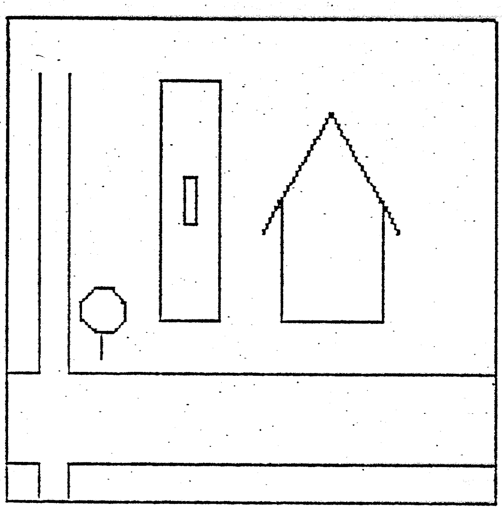
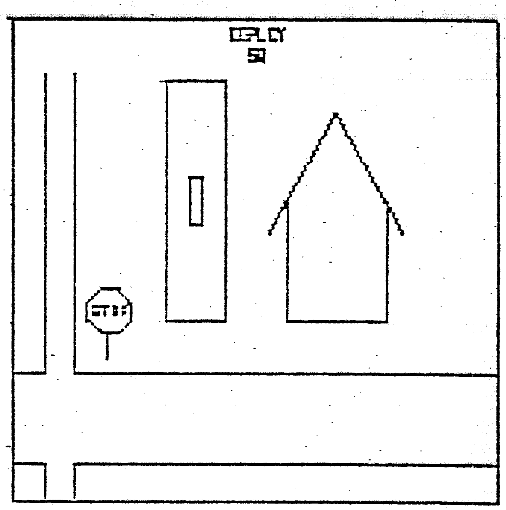


Figure 1a



Fiqure 1b

This new task gave Mike another idea. Since some letters in both words were the same -- eg. O, P, S -- and he needed them in different sizes, why not define procedures to draw the letters used in these two words so it would be possible to change their size? Moreover, why not have procedures like those to draw all the letters of the alphabet? From this point of departure, Mike worked on two projects simultaneously: background of Copley Square and the letters of the alphabet.

To draw letters of the alphabet with variable size, we can imagine each letter being drawn inside an invisible rectangular frame where height and width can be adjusted. If we make all the parts of the letter a function of these two variables, we can change the size of the letter by giving different values to them. Suppose we want to draw the letter G. The rectangular frame is defined as having height Y and width X (fig 2.a). Inside of this frame we can draw the letter G where the parts of it can be defined as shown in figure 2.b

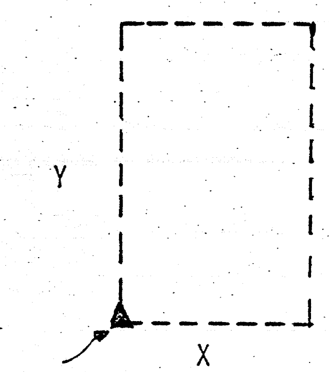


Figure 2a

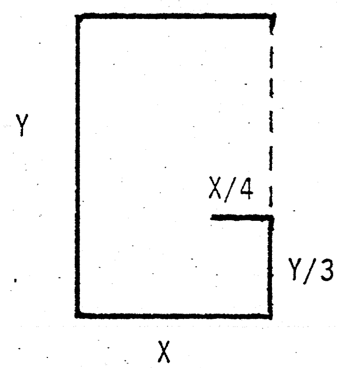


Figure 2b

```
TO G :X :Y :L
10 PENUP
20 FORWARD :Y
30 RIGHT 90
40 FORWARD :X
50 PENDOWN
60 RIGHT 180
70 FORWARD :X
80 LEFT 90
90 FORWARD :Y
100 LEFT 90
110 FORWARD :X
120 LEFT 90
130 FORWARD :Y / 3
135 LEFT 90
140 PENUP
150 FORWARD :X / 4
160 PENDOWN
170 RIGHT 180
180 FORWARD :X / 4
190 SUP :L :Y / 3
200 HIDETURTLE
END
```

Figure 2c

Therefore the procedure to draw the letter G has two variables X and Y (as size of the frame) and a variable L which indicates the distance between two letters. The Logo commands to draw it are shown in figure 2.c.

For those letters which can be drawn using only horizontal and vertical lines -- eg. L, T, E -- it is relatively straightforward to define procedures to draw them. Mike very rapidly mastered this. However, when the letter has slopes -- eg. R and K -- things are not quite as easy. The angle of the slope and its size change in some relation to the size of the frame. For example:

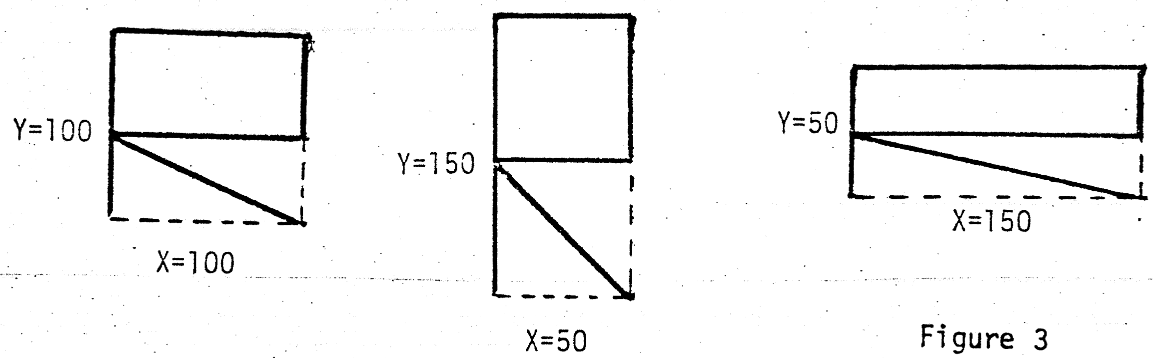


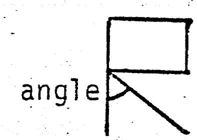
Figure 3

Mike's first attempt was to fix the angle at 45°. He found that this only worked for X=Y. For X not equal to Y we get poor results.

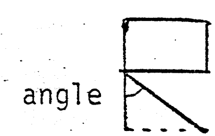
This provided a good chance to introduce Mike to the basic notions of trigonometry or what in the elementary text-books is called practical trigonometry.

These concepts were presented in the following form.

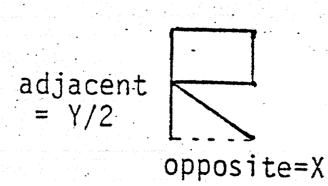
(a) identify the angle whose value you want to find



(b) define the rectangular triangle that has as one of its angles (different from 90°) the angle you identified in a.



(c) in this triangle identify the sides that are adjacent and opposite to the angle and find their values.



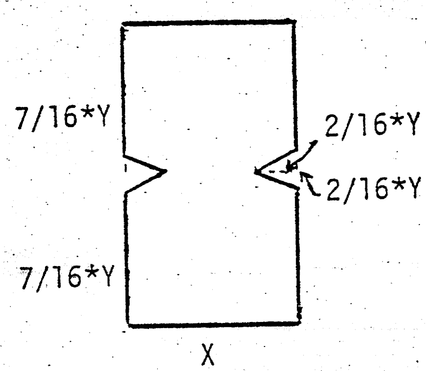
(d) the value of such an angle is give by:

$$\text{ANGLE} = \text{ARCTANGENT}\ \frac{\text{value of opposite side}}{\text{value of adjacent side}}$$

(e) the length of the biggest side of the triangle (hypotenuse) is given by:

$$Z = \frac{\text{value of adjacent side}}{\cos(\text{ANGLE})}$$

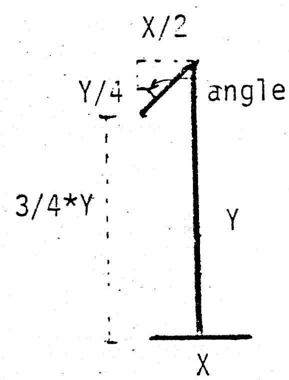
By following this procedure Mike was able to draw all the letters with slopes and show these ideas to his students. He was also able to deal with new details and slightly different problems which he solved in drawing the numbers from 0 to 9. For instance, in the number 8 shown below.




```
TO VIII :X :Y :L
10 FORWARD :Y / 16. * 7.
20 ANG :Y
30 FORWARD :Y / 16. * 7.
40 RIGHT 90
50 FORWARD :X
60 RIGHT 90
70 FORWARD :Y / 16. * 7.
80 ANG :Y
90 FORWARD :Y / 16. * 7.
100 LEFT 90
110 PENDOWN
120 BACK :X
130 PENUP
140 FORWARD :X
150 SUP 0 :L
END
TO ANG :Z
10 MAKE 'Z' :Z / 8.
20 MAKE 'ANG ARCTAN ( :Z' / ( :Z' / 2. ) )
30 MAKE 'H ( :Z' / 2. ) / COS :ANG
40 RIGHT :ANG
50 FORWARD :H
60 LEFT 2 * :ANG
70 FORWARD :H
80 RIGHT :ANG
END
```

Figure 4

These projects also gave Mike some good opportunities to operate algebraic expressions and fractions, and the more sophisticated syntax of these more powerful Logo procedures (for example, in drawing the number '1').




```
TO I. :X :Y :L
10 PENUP
20 FORWARD :Y / 4. * 3.
30 MAKE "ANG ARCTAN ( ( :X / 2. ) / ( :Y / 4. ) ) *
40 PENDOWN
45 RIGHT :ANG
50 FORWARD ( :Y / 4. ) / COS :ANG
70 RIGHT 180 - :ANG
80 FORWARD :Y
90 LEFT 90
100 PENUP
110 BACK :X / 2.
120 PENDOWN
130 FORWARD :X
140 SUP 0 :L
END
```

Figure 5

APPENDIX 3

DEVICES

For those whose typing skills are too limited by lack of fine motor control, and by and involuntary movements, to be useful, we have developed two supplementary devices, viz a button box and a tablet.

Button box

The principle here is to reduce the number of gestures required for any particular input. This is achieved by having fewer keys than the conventional keyboard, and having these keys larger and further apart from each other. Each larger key, called a BUTTON, can stand for an arbitrarily long string of alphanumerics, typically a LOGO command, for example: FD 10 (see fig. 1).

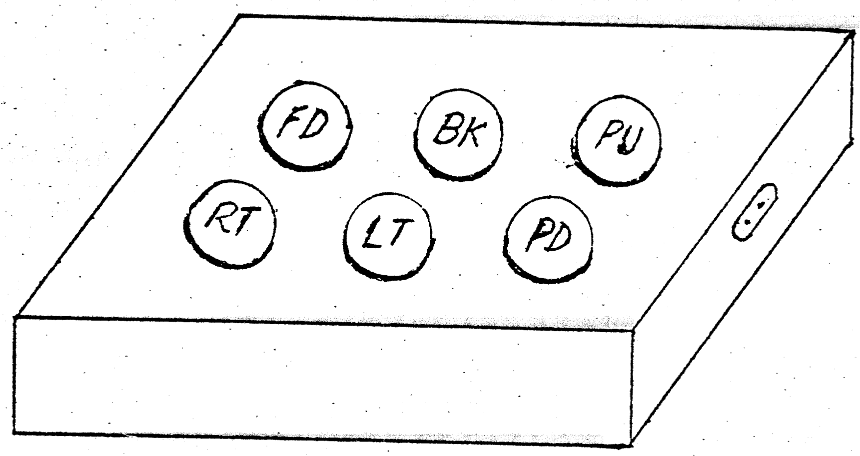


fig. 1

New commands can be added in a modular fashion by hooking up new boxes of buttons. This device was used by Perlman (1974) with 3 to 5 years old children and by Weir and Emanuel (1976) with an autistic child.

This same economy of gesture can be achieved by using software, and relabelling the alterated keys on a regular keyboard according to the activity the child is engaged in, for example manouvering the "hand" in the screen task (see Appendix 4).

Tablet

The tablet is an input device consisting of a flat metallic surface arranged so that the lightest contact pressure is registered. The affect of this is that any drawing made on the tablet (with a magnetic pen) is digitized, and can be stored or displayed on the screen.

The range of possible activities using this device includes tracing patterns, free drawing, and cursive script. We are in the preliminary stage of exploring the potential of this device for use with Cerebral Palsy.

APPENDIX 4

SCREEN TASKS

An efficient general purpose system for implementing a wide variety of tasks has been developed and programmed on the 3500 (in assembly code to achieve the necessary speed of response). New tasks can be added relatively easily. Features of the system include the prevision of an automated record of the moves made by the subject, complete with a time marker, and a facility for using this record to drive a rerun of the task for purpose of analysis.

The system consists of a collection of buttons including four which move the cursor around, two for rotation, and GRASP, DROP and PEEK buttons as described below.

Seriation

The first step is to allow the subject to become familiar with the buttons, using a two-stick display. To move a particular stick, the subject must direct the cursor, called "hand", using the four directional buttons (in a northerly, southerly, easterly, or westerly direction), until the "hand" touches the stick. At this point, pushing the GRASP button causes the stick to be "grasped" by the "hand". Now pushing the directional buttons moves both the "hand" and the stick; pressing a rotational button can rotate the stick counter or clockwise. When the stick has been moved to the desired position it can be dropped by pressing the DROP button.

The subject is now ready to do a 6-stick, a 4-stick or a 3-stick seriation task, depending on the circumstances of the task. A demonstration of the completed task, ie. a proper seriation, can be called up on the screen at will. Finally, extra sticks can be presented to test the ability the subject to do the insertion step.

Pseudo-palpation

In this task there is a hidden figure on the screen whose identity has to be established by moving around a cursor which takes two forms, one when it is inside the boundary of the figure, and another when it is outside. The edge of the figure is detected by noting the change in shape of the cursor, and a small piece of the edge just crossed can be inspected by pushing the appropriate button. This allows the subject to accumulate evidence as to whether edges are curved, straight, horizontal, oblique, pointed, and so on. Exploration of edge shape at different parts of the hidden figure can lead to a recognition of the hidden shape. The same set of directional buttons are used for moving the cursor around in this task as were used in the seriation task. In addition, there is a button which allows the user to take a PEEK at the configuration of the edge which has just been crossed.

The set of possible shapes was taken from Laurendeau and Pinard (1970), who used wooden versions of these shapes to investigate haptic perception in 2-12 year-olds. A board displaying the 12 shapes (as in fig. 1) was available for scrutiny during performance of the task. Seven of these were chosen as the test figures, viz. square, triangle, trapezoid, circle, maltese cross, diamond, and 4-star, and presented in that order.

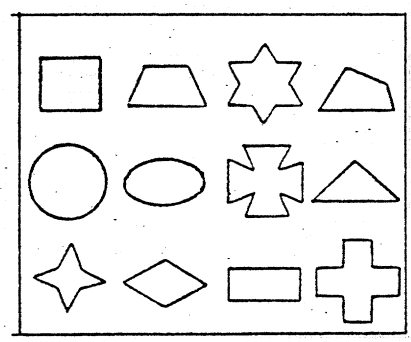


fig. 1