LOCO AS AN INFORMATION PROSTHETIC FOR COMMUNICATION AND CONTROL

Sylvia Weir
LOGO Group
Massachusetts Institute of Technology
Cambridge, Ma 02139

ABSTRACT

When used with physically handicapped and learning disabled children, computer-based LOGO activities can serve diagnostic and therapeutic purposes, as well as provide insights into theories of knowledge representation and cognitive functioning in general. The impact of LOGO flows from the active role taken by the students in initiating and controlling their activities; from the specifically spatial geometric emphasis of these activities: from the ready availability of problem-solution paths for scrutiny by the. student and by the teacher, and from the prosthetic value of the computer in providing a means for the expression of otherwise trapped intelligence in this population.

1. INTRODUCTION

The LOGO learning environment [I] provides a versatile tool for diagnostic, instructional and remedial use with children who have special educational needs [II 14 16 17 18). Weir [18] has described the successful use of LOGO with severely physically handicapped but mentally alert cerebral palsy' adolescents at the Cotting School for Handicapped Children. The educational impact has been substantial. It is our belief that the flavor of the work has been influenced by the A.I. setting which spawned it. Themes which arise include an emphasis on process rather than product: a concern for the varjety of types of knowledge involved in solving a problem; the learner as model builder: and the specificity/generality issue - how specific are the computational mechanisms underlying cognitive processes?

Observing children with disabilities offers a magnified and slowed down view of familiar processes. Although we do not know how many unusual and deviant. mechanisms have been invoked in these children, it is instructive to explore their behavior as a source of evidence for *possible* cognitive mechanisms

II. MODELS AND PROCESSES

To the extent that sensorimotor activity contributes to the full development of the cognitive structures underlying spatial understanding, individuals with severe motoric restrictions suffer from a reduced opportunity for such learning. Hence they are at risk in regard to the development of a *deficit in spatial competence* as a result of the restricted manipulatory experience available to them. An exposure to LOGO has provided a source of *spatial manipulatory activities* for these individuals. The LOGO theme of the "learner as model builder" takes on a poignant significance, since lines on the graphics screen can become models of objects (AS-IF objects), and producing an effect on such graphics objects can become highly significant actions for a severely handicapped person. This has had a dramatic effect on the cerebral palsy victims with whom we have worked, both on their academic progress and on the level of self confidence they demonstrate (see section VI).

Performance tests are notoriously difficult to administer to this group. The very motor handicap that leads us to suspect a deficit in spatial cognition, renders the ascertainment of that deficit very difficult. Measures of visual perception in Cerebral Palsy yield progressively lower scores as the motor component of the test used increases [20]. Cerebral palsy children who fail on the block-design reproduction task of the Wechsler Intelligence Scale for Children, can succeed, most of the time, on a task which requires them to choose the one correct design out of three presented block designs [2] However, turning assessment tasks into a multiple choice format in this way gives a somewhat impoverished setting, since all information on *how* the task is performed is lost.

In contrast, exploiting the possibilities of an interactive graphics situation can generate a significantly novel way of assessing motorically restricted persons. We have developed an extension of the standard LOGO system which allows the use of *screen versions of assessment tasks,* thus reducing the motor component of the task to a minimum. "Using these, we have found deficits in spatial reasoning in some cerebral palsied subjects when they are asked to perform tasks involving ordering by length, shape recognition, spatial localization and mental rotation [7 14 18).

The computer places constraints on the execution of a task that emphasizes the intermediate steps of the task. This results in a wealth of detail in the protocols of both handicapped and non-handicapped controls. We recommend a more widespread use of this approach as an adjunct to more standard recognition, sorting and copying tasks, where end results tend to predominate over evidence of the problem-solving process. It is of Course possible to emphasize process without a computer, but the computer does facilitate this, and provides all kinds of other perks like automatic records of the actions performed and automatic timing.

I. Cerebral palsy is a disorder of movement and posture resulting from • permanent, non-progressive defect or lesion in the brain occurring before the end of the first year of life.

HI. SPECIFICITY OF COMPUTATIONAL MECHANISMS

There is a theoretical as well as a practical interest in exploring the patterns of disruption displayed by persons with these unusual experiences. Are "there *dissociations* - a pattern of spared and impaired competencies such as spatial excellence coupled with marked language deficits? This would lend support to the view, gaining ground among cognitive scientists, that some computational mechanisms at least are quite specific to the domain and level of processing involved in the particular problem being solved.

It is difficult to obtain good data on subjects with gross limitation of expressive power -- restricted or absent speech, and/or Inability to write or Derform other manipulations. Text-editinc facilities provide a way for motorically restricted intellectuals to keep *notes in the form of computer files,* and to engage in problem-solving at a high level without having to do it alt in the head, by using the *computer as a scratchpad*

Combining information from a variety of LOGO activities provides a powerful way of making fine-grain analyses of performance in spatial, numerical and writing domains. Very clear dissociations are exhibited.

Dissociation in an fourteen year old quadriplegic

Ja's favorite project was the production of a newspaper, in which he showed his ability to plan his activity. He first generated the section headings, and then went back to fill in details, taking each section heading and expanding it, beginning with the easiest and not with the first -- an example of top-down planning. In contrast, his spatial ability was very poor. He programmed a simple drawing of a car step-by-step and painfully slowly. He failed on a mental rotation task [7 9] that five year-olds can do. He could not seriate six Micks -- neither using real sticks (12 14). nor in the graphics screen version of the Piagetian task [18]. He could seriate four screen "sticks" but not four real sticks. He could not insert new sticks into an ordered row of four sticks, graphic or real.

Hi* performance on Piaget's village (topographical) task [8] was revealing. In this task, the child and the experimenter each have identical drawings of a scene. The experimenter places a doll successively at different locations in the drawing, and, for each placement of the doll, the child is required to place his doll in the same positions on his own drawing. The first time round, the drawings of experimenter and subject are in the same north-south orientation. Then the experimenter's drawing is rotated 180 degrees while the child's drawing is left at the same upright orientation. In our version of the task, each of these parts is done first with physical models of the scene, and then with the child's scene drawn on the screen, using the cursor as doll. Ja's strategy in the "real" task was to copy the physical movement of the experimenter, thus getting the wrong placements, (score 3/9). In the computer task he began *describing the position of the doll in words* and achieved a score of 8/9 correct placements. He succeeded in turning the computer version of the task into a linguistic task which he could do. When he performed the "real" task, the underdeveloped state of his place-finding skill led him to use a less successful copying strategy.

Ja.'s work with numbers was far below age-level, and idiosyncratic. There are many places in his work with Turtle Geometry where he started with 14, which is his age, as the argument for a turtle command, and then continued along the number sequence regardless of whether he was instructing the turtle to turn right, to go forward or .to go back, and regardless of the needs of the problem.

The contrast between Ja's skill in the linguistic domain and his weakness in spatial and number-handling areas leads us to reject the proposal that he has a "general sequencing" problem, as suggested by his clinicians, since he can order letters very skillfully. Instead we hypothesize a *domain-specific problem involving inadequate development of appropriate mental representations for spatial Knowledge*(datastructures and operations on them; spatial metaknowledge).

IV. VARIETIES OF KNOWLEDGE

Many of our subjects give the impression of having small local packets of knowledge, without the appropriate procedural metaknowledge regarding how to fit these into any particular solution path. This is illustrated by their behavior in the missile game. To give Ja. and other students a sense of a number as a quantity, in this case as something which does a particular amount of work, we set up a target game, in which the student was required to estimate the number needed to move the missile to the target - a hit was rewarded with an explosion. A second cerebral palsy subject, Kst, the same age and with similarly poor spatial ability and good verbal skills as Ja, showed an even stronger tendency to step through the number sequence when playing this target game. She went (12 II 10 9 8 7) to hit the first target at 7; (6 5 4 3 2) to get the next target at 2, and so on. Her use of the successor function was without error, but inappropriately inflexible for a fourteen-vear old.

Her problem would appear to be not so much that she did not have a given schema, but that she did not know when to activate it or how to choose the most useful of several possible schemata - she did not have the flexibility which accompanies efficient metaknowledge. This is illustrated further by her performance when required to face the turtle in particular direction, and drive it to a given destination.. She always stopped short, and made no midcourse correction even though the wrong direction she had taken took her way past the locality involved. The experimenter found that if he took the driver's seat and asked the appropriate questions after each step --"Is the turtle facing the right way?" -- this was sufficient, most of the time, for her to "solve" the problem. When the appropriate invocation of schemata was facilitated by embedding the game in a linguistic context -- driving the turtle around the screen was expressed as successive visits to depicted characters in a story -- her aim became more accurate, and she readily made appropriate mid-course direction corrections without any prompting. When the problem took the form of a linguistic task, she showed appropriate invocation of schemata.

A detour; Spatial Giftedncss

Dissociation between the development of spatial and linguistic ability can go the other way - *spatial excellence in the presence of linguistic deficits.* Evidence is accumulating for the existence of a group of children who in fact are spatially gifted. Such children turn up in the *specific learning disability* category of school-children whose reading skills are below expected level. They have difficulty with language use. and since schools do not provide an opportunity for them to display their superior spatial skill in any formal way, they lose out. We have begun working with such children and find the predicted excellence at LOGO [17 19). For example, one eleven-year-old dyslexic boy at a local school for the learning disabled demonstrated more skill at LOGO Turtle Geometry in the first half hour than any other child of that age we have encountered: and it was easy to detect the clever heuristics he adopted spontaneously, e.g., constructing his own "unit" and "yardstick" appropriate to his needs. Our explanation is that his success rests on highly developed metaknowledge in the spatial domain. Stories about such children have accumulated in the LOGO community [6 17 19), and there is independent neuropsychological evidence for the existence of such a category among learning disabled children (5).

The question arises as to whether one can do anything with this finding in practical terms, i.e., how it can affect decisions about the education of such children. Research on individual differences in aptitude in relation to instructional variables has shown that aptitude-treatment interactions do occur, but that these relate more to general mental ability rather than to the contrast between verbal and non-verbal ability (4). Inconsistent results are reported on the use of pictorial materials to enhance the learning of those students who score high on the visualization dimension. However, the figural enhancements of instructional materials used up till now have taken the form of graphs and diagrams -- a rather static form. Notice the assumption that learning consists of the acquisition of facts - a diagram is a perfectly appropriate visual enhancement of factual acquisition. This approach does not take account of the need to know when and how to deploy a fact in a problem-solving situation - crucial procedural components of metaknowledge.

Using a computer, it is now possible to introduce a more dynamic approach by making a substantial proportion of the formal school subjects available in spatial mode on a graphics screen. Most importantly from a pedagogic point of view, we can arrange for *computer-based spatial learning to be procedural and constructive in nature,* as is the case with LOGO, with all the advantages which flow from this.

Providing an opportunity for spatial problem-solving *in a formal setting,* in addition to the more usual places like the playing fields and the artist's drawing board is essential to the healthy academic growth of some people - future engineers, computer programmers -- allowing them to exploit their spatial facility to acauire *academic skills.*

The excellence we have been talking about has been shown to have a physiological counterpart, in that it is related to maturational rate [15]. Neuro-anatomical issues arise when interpreting the significance of the finding of a spatial deficit in cerebral palsy subjects. We return to the main topic of physically handicapped children and their spatial deficits.

V. AN AMBIGUITY. BRAIN DAMAGE VS LACK OF EXPERIENCE

While there has undoubtedly been a restriction in motor activity, there has also undoubtedly been brain damage in these subjects. Although motor dysfunction is the predominant, defining characteristic of this group, the various etiological agents of cerebral palsy do not as a rule recognize functional boundaries; a pure motor disorder is rare. In particular, the original insult, be it vascular, mechanical, infectious or whatever, can affect those areas in the brain which recent research has shown to be concerned with spatial understanding (reviewed in [5]). Thus, in any particular case, the spatial deficit in question may have resulted either from *direct* damage to the neural substrate which supports such activity in the undamaged brain, or *indirectly* from damage to motor areas, the dysfunctional consequences of which, namely, restricted manipulatory experience, have led to the spatial defect under consideration.

We hope to cast some light on the matter by observing the effect of intensive spatial problem-solving on the degree of spatial deficit shown by our subjects. To the extent that we can produce an improvement in performance so would we be inclined to attribute the deficit to the lack of experience.

An Example from the Linguistic Domain

Disambiguating brain damage and lack of experience arises in the area of language production. We have not yet worked with non-vocal individuals, but some of our students have never before written anything whatsoever, because their handicap is severe enough to prevent them from holding and using a pencil. The standard procedure here is for an adult to act as scribe, and in the process, insert all those "minor", trivial" markers etc., whose presence or absence is of such interest.

If severely handicapped individuals are to hold down a job, the quality *of* their writing is important. For many *o(* these students, this is the first opportunity to generate their own text, without the intervention of an adult. Their output can be used in *diagnostic* mode, to establish patterns of expressive language disability, and, where required, as a *remedial* tool for language re-education.

We show such a sample of writing produced by Ma., a quadriplegic cerebral palsied student. He was 17 years old when he started LOGO, and his programming and math achievements have confirmed his high intelligence. He has now been admitted to the University of Massachusetts Boston campus as a computer science student. This is the first piece of writing he produced.

> "I ment Dr. Sileva Where, Jose Valente and Gary Drescher on October 5, 1978 at 9 : 32 : 47 AM. which the computer I was so excized it like being it a waitting & maternace room at a hospiltal whiting to fine if oot's a boy or a grail.
> We had a and we whont you to do it fist for us I am LOGO number " I " ginny pig. When they get a new idse they say to hel, michalel we had a and we whont you to do it fist for us
> like a nice guy I do if I wont to or not. I do and then I give my por and con on the idse. I tell them why I came up for a allturative. Why you mite ask? Becose I know how the person on the arther end feel. Becose I am the middle man betwee M.I.T. and handcap people.
> I also teach five stundts. No tow lean at rate. Some ask then I know they are intered in leaning about logo. Then the one that take for granted. I can tell.
>
> When 1 teach I lean form my standt. as well or bedter then form a book. I call that on the job training.
> My fist and every day e.xperreance with the compuer when it cash and it lost but it keep on losting all that I have tort it but keep no teaching it overy and overy agian when I bring back to live"

This looks like spoken English which has been written down. There i» much phonetic spelling, omission of words and letters, as well 85 letter reversals and a curious construction for present tense verbs. How much is this due to lack of experience and how much to damage to the relevant brain area? Are the errors random, resulting from inaccurate typing, thinking faster than he is able to type, lack of spelling experience, and the like? Or is there tvidence for particular patterns seen in patients with known lesions, e.g. the type of disturbance associated with a lesion in the anterior portion of the dominant hemisphere (Broca's expressive aphasia). In this type of lesion, inflectional markers for plurals, possessives. and third person singular /s/ are affected differentially [3]

We can see errors with tense markers in the above passage:

"feel" (feels); "handicap" (handicapped); "take* (takes); "cash" (crashed); "keep" (kept).

However, these errors could conceivably be due to his misperception of the spoken words, upon which he is basing his spelling (notice fine" instead of "find"). Misperception could cover the instances of letter omissions which occur, especially "f" before a consonant, which is not sounded:

"fist" (first); "lean" (learn).

Either haste and/or lack of experience, or brain lesion, could conceivably account for the numerous omission of words:

it [was] like being in; we had a [idea): No tow lean at [same] rate.

and the reversal of letter order:

"grail" (girl); "idse' (idea); "por" (pro); "stundts" (students); "tow" (two); "form" (from): "no" (on).

In order to investigate and treat this problem we have set up a *focal remedial program.* All his English lessons take place in the computer room, using the text editor, instead of a scribe whose activities were masking the true situation. He writes his own book reviews, essays and the like, on the computer; in addition, and, in collaboration with his English teacher, we have instituted a series of remedial writing sessions involving specific exercises based on weaknesses shown in his writing, in order to assess how much Improvement we can achieve. Early indications are that a great deal of improvement can be achieved, a very necessary step for his college career. He recently wrote this letter in response to a query about LOGO from another victim of cerebral palsy.

107 Second Street
Medford, Mass. 02155
February 6, 1981

Mr. Neville Anderson
Bush Farm
2400 Acacia Rd
Greenfield, N.C. 27405

Dear Nick,

My name is Michael Murphy. I am the person whom your mother saw on "I'M Magazine". I attend the Cotting School in Boston mass. I have been work with the compuers for about two and a half years. The name of the system is "LOGO". It has open many new doors for me. Now I can draw picture on a cheen ane write letter like this one.

I was the first C.P. person in the U.S. to tired the "LOGO" system. Enclose I will send some of my work.

Sincerely Yours,
Michael J. Murphy Jr.

P.S. I would be greatful if you could send me a piece of your art.

VI. SOCIO AFFECTIVE ISSUES: EFFECT OF PARTICIPATION IN THE PROCESS

Severely handicapped persons cannot engage in the motor activities which ordinarily support the acquisition of cognitive structures. What is missing from their lives is the explicit confrontation between the actions they perform and the consequences of such actions in the physical world, an experience taken for granted in normal development.

This LOGO experience is often the first in which these students have had an opportunity to participate in the process of tackling problems where they are required to initiate solutions, try them out, decide when to change track and when to persist, respond to feedback - all those things which tend not to happen in the usual dependent, adult-dominated situations which characterize their lives.

It is characteristic of the LOGO system to seek to promote a close association between a child's cognitive development and an environment where he or she takes the active role in his or her learning. This aspect becomes especially important in work with special needs children, e.g., with an autistic child [16]; with the learning-disabled child [17 19): and, most poignantly, with the cerebral palsy child, where a particularly debilitating consequence of the gross physical handicap is the dependent, passive role it imposes on its victims. A profound lesson has to be learned, one which is taken for granted in "normal" development. *A handicapped individual has to learn to believe that an action he takes can have an effect on his environment.* The uncompromising way in which LOGO places initiative and control in the hands pf the, user and gives the user a chance to know what she knows, means that she may now engage in sustained, independent activity and be her own critic. The resulting enjoyment and sense of personal fulfillment can greatly enhance their general sense of personal worth and competence, and could have important effects on the members of this disadvantaged section of society, not the least of which is the creation of a high degree of motivation which can then form the basis for significant learning in formal subjects.

There is much evidence of *increased motivation* among the participants, as reflected in an intense competition for the use of machines -- coming in an hour before school and skipping half the lunch break to work on the computer, - and the frequency of animated discussion about various computer projects represents a new experience for the school. The school authorities have been so impressed by all this that they have raised S27.000 to equip a computer center. Computer programming has become an integral part of the school curriculum and 41 out of 50 senior students have opted to take computing. All 5 of the seniors involved in our project have changed their career plans to computer programming. Three of these have been accepted into the computer science course at University of Massachusetts Boston campus. Increased, vocational access -• the possibility of independent living - is *the* great advantage accruing from the computer activities.

The versatility of the system supports a wide range of cognitive styles and levels of ability [10]. allowing a student to carve out an area in which he feels comfortable - a microworld -- in which to work. The teacher can aim for a balance between working with strengths and exercizing weaknesses. Individual case studies reveal the range of reactions to the introduction to LOGO, the preferred activities of different students, differences in styles of debugging, styles of working, amount of risk-taking, response to the anxiety of a new subject and so on.

As an illustrative example, we quote the subject who handled the devastation of failure by denial. Ja. was always ready to change his purpose to fit his latest error. It was a great step forward when he learned to tolerate making an error and allowed himself to benefit from the process of debugging that error. Another subject, aged seventeen, was so uncertain, shy and lacking in self confidence that she had the reputation of making no intellectual progress whatsoever. The virtues of LOGO applied particularly to her, and she has moved from a totally dependent situation, where she made no move on her own. and looked for reassurance after each command she typed, to one in which she works on her own for long periods of time and initiates her own quite sophisticated projects.

We believe that a major element in the improvement we see in motivation and in the positive affect generated by LOGO activity has to do with issues of who is in control of the activity. We have only scratched the surface *of* what is possible.

ACKNOWLEDGEMENTS

The work reported here was supported by the Bureau of Education of the Handicapped under grant number CFDA 13-443. It was carried out with the cooperation and support of Seymour Papert, the director of the LOGO laboratory, by the members of the Cerebral Palsy project: Syvia Weir, Jose Valente, Gary Drescher. and Linda Laatsch.

REFERENCES

(1) Abelson H. and diSessa A. Turtle Geometry. MIT Press. Cambridge, Massachusetts.

[2] Bortner.M. and Birch, H.G. (1962) Perceptual and Perceptual Motor Dissociation in Cerebral Palsied Children. J. of Nerv. and Ment. Pis. 134(2): 103-108

(3) Caramazzo, A. and Berndt, R.S. (1978). Semantic and Syntactic Processes in Aphasia:. A Review of the Literature. Psychological Bulletin 85 (4): 898-918.

[4) Cronbach, L.J. and Snow, R.E. (1977) Aptitudes and Instructional Methods A Handbook for Research on Interactions New York

[5] Denckla. MB.. Rudel, R.G.. and Broman M. (1980). The Development of a Spatial Orientation Skill in Normal, Learning Disabled, and Neurological!)' Impaired Children. In Biological Studies of Mental Processes. Ed. D. Caplan. MIT Press.

[6] Howe, J.A.M. and 0'Shea, T. (1978) Computational Metaphors for Children in Artificial and Natural Intelligence ed. F. Klix Deutsche Verlag

[7] Laatsch. L. K. (1981) The Ability of Cerebral Palsied Students to Mentally Rotate. Unpublished *MS*. Dissertation MIT.

(8] Laurendeau, M. and Pinard, A. (1970). The Development of the Concept of Space in the Child. International University Press. New York.

[9] Marmor. G.S. (1975) Development of Kinetic: When Dow the Child First Represent Movement in Mental Images? Cogn. Psychol. 7: 548 559

[10] Papert. S.. Watt. D.. diSessa, A., and Weir.S. (1979). Final Report of the Brookline LOGO Project. LOGO Memos 53 and 54.

(I1) Papert. S. and Weir, S. (1978). Information Prosthetics for the Handicapped. Artificial Intelligence Laboratory Memo 496 (Logo Memo 51). MIT. Cambridge. Mass.

[12] Piaget. J. (1952). The Child's Concept of Number. Humanities Press. New York.

[13] Rudel, R. G.. Teuber, H-L. and Twitchell, T. E. (|974). Levels of Impairment of Sensori-motor Functions in Children with Early Brain Damage. Neuropsychologia 12: 95-108.

[14] Valente. J. (1981) Senation in Cerebral Palsied Children: a 2D Graphic Version of the Seriation Task Forthcoming

[15] Waber, D.P. (1980) Maturation: Thoughts on Renewing an Old Acquaintanceship, in Biological Studies of Mental Processes, ed. D. Caplan MIT press Cambridge, Mass.

[16] Weir, S. and Emanuel, R. (1976). Using LOGO to Catalyse Communication in an Autistic Child. D.A.I. Research Report #15 Department of Artificial Intelligence, Edinburgh University.

[17] Weir, S. and Watt, D. (1981) LOGO: A Computer Environment for Learning-Disabled Students. The Computer Teacher 8(5):I117

[18] Weir, S. (1981) LOGO as an Information Prosthetic for the Handicapped. Working Paper #9, Division for Study and Research in Education. MIT Cambrdge Mass

[19] Weir, S. (|981) Spatial Giftedness, Maturational Rate and the Learning Disabled Child: Why Doesn't He Learn? Forthcoming.

[20] Zeitschel, K. A., Kalish, R. A., and Colarrusso, R. (1979). Visual Perception Tests Used with Physically Handicapped Children. Acad. Ther. 14: 565-576