The Microgenetic Analysis of Early Learning in Language and Spatial Cognition

Research Purpose and Objectives

We propose the microgenetic interpretation of three years of an infant/ child study focused on learning about objects and space and on language development in the context of the family. This detailed corpus on one girl's learning, based on both naturalistic observation and weekly videotaped experiments, will permit the separate analysis of two streams of learning and the exploration of the extent to which and the ways in which they interact with each other. The thorough interpretation of this material is warranted on its own merits.

To advance the case study method, we will develop the corpus as a digital case study database or "datacase" to make accessible to other researchers and advanced students the materials, analyses, interpretations, theories and related computational models. These will permit discussion, criticism, emendation and alternative interpretations by others.

Rationale

The psychologist and linguist Katherine Nelson calls for studies which can serve as a ground for theory development in the domain of language learning:

> "Indeed we need more child study analogous to the natural history studies that formed the background of all modern science.... I believe we are now at a point in understanding aspects of human development that makes it feasible to construct more adequate theories if we turn our attention to the developmental process itself. This move requires viewing that process in its complexity. Thus we can understand a moment and a place in the child's development only if we understand where the child has been and what the forces are that are propelling her into the future...."
>
> Language in Cognitive Development (p.9)

Similarly, in the domain of Spatial Cognition, Newcombe and Huttenlocher argue:

> "...the key to a rich theory is close observation and domain specificity. In anthropology, Clifford Geertz has argued for 'thick description' of phenomena as a form of theoretical understanding. The same strategy may pay off for developmental psychology.... Such an approach does not mean abandoning thought about cross domain generalities, either at the specific level... or at a more abstract level.... However, at the present stage of development of our science, there is a strategic advantage to domain specificity and intensive investigation of particular problems...."
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> Making Space: The Development of Spatial Representation and Reasoning (p. 225)

Since learning comes from processes which take time, its understanding relates to a multitude of interactions between what is in the individual's mind and accidents of everyday experience. Lawler traced and recorded the development of one of his daughters from the time she was 18 weeks old through the sixth year of her life. This detailed developmental corpus, proceeding with weekly videotaped recording of her development for six years, is a unique resource. Call this corpus LC3 (Lawler's case number three). We will use the LC3 corpus to:

- explore language learning and its precursors within the family in the home,
- and explore the simultaneous development of object and space related knowledge by the child in interaction with objects and with others. [1]

We will develop the materials as a hypertext datacase for in-depth analysis through:

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[1] LC3 corpus development was guided to the dual focus on language and objects, with special attention to social interactions, by Professor Hermine Sinclair, "Piaget's linguist" during their long collaboration.

• digital presentation of text and media materials
• representation of those materials in explicit descriptions
• exhibition of processes of learning and development as seen in those materials
• modeling of states of knowledge and of processes that change those states.

We will make both the materials and interpretations of LC3 accessible to colleagues who study infant/child development. The intention is to encourage its "secondary analysis." Lawler wrote, in Case Study and Computing (P. 72):

> "The challenge of secondary analysis -- the use of data by someone other than the collector -- reaches its most acute form in the reinterpretation of individual life case study materials. The issue is critical for the field of psychology because many of our deepest theories of human nature have been rooted in exceptional studies of individuals. That raises these specific questions:
> • how can we make good use today of material collected by our predecessors ?
> • how can we prepare our materials for their best use by our successors ?
> • How can we introduce our intellectual heirs to an appreciation of the materials we inherit and are creating but avoid overwhelming them with the details they may not need to know ?
> ... Solving these three problems is essential for enhancing the credibility of case study analysis as a method. That is my goal as a scientist."

Making all materials available will enhance the credibility of the single case method.

The Research Plan: Development of the LC3 Corpus

The text materials, more than 820 vignettes, written mainly by Lawler, include observations of the child's language and other behaviors with analyses of their interrelations. The catalog of these vignettes is complete, as a computer spreadsheet, with entries ordered by serial day date in the child's life and indications of the general areas of development on which they bear. (Language, Social interactions, Sensori-motor Development, Cognitive Development, and others). Transcription of these vignettes as computer files is complete; they include extensible indexing of the observations.

The total LC3 video corpus numbers 240 half-hour videotapes over six years. The first three years of the corpus includes more than 130 videotapes designated by the initial, P, of the child's given name, Peggy, followed by the number of the week since her birth. The first tape is P18 and the last one in her third year is P157. The object-play segments form a continuing series designed to probe the child's developing object knowledge; this material relates to the Piagetian literature and is intended as a calibrating spine of the study. The other recorded segments are more varied, each depicting aspects of the child's behavior. A catalogue of videotaped materials in spreadsheet form (compatible with the vignette catalog) exists for the first three years, in a preliminary sense. Each tape typically shows three entries, falling roughly into the general categories of communication, socialization, and object play, with its own row in the spreadsheet. For example, the P44 segments are

A. Pointing Behavior
B. Mother plays with Peggy
C. Peggy playing with objects

Videotapes of the first three years, through P160, have been digitized to make LC3 portable.[2] As the videotapes are reformatted for computer accessibility, we will extend the videotape catalog to 157 weeks and somewhat beyond. As extensions to this catalog are made, we will also modify the vignette catalogue for compatibility, preserving the option

2 using a Pansonic DVD recorder, model DMR-E30. For use in a digital datacase, the video materials need be converted to a different format. The work also involves segmenting the contents into episodes, creating titles, etc.. Lawler is doing this with Macintosh IMovie software, creating output DVDs, in mpeg4 format, compressed to fit one segmented videotape image on each DVD. In this format, the LC3 corpus will fit on available high-speed, high capacity magnetic disk drives.

of their integration whenever that will be of benefit in supporting interpretation of the corpus.

Editing Digitized Videotapes into Files

One main objective of segmentation editing is to create digital files useful for analysis. The stream of behavior will be segmented into episodes by splitting the video files when the focus of the interactions changes. This editing will be done by Lawler. The grain of segmentation of the LC3 video corpus will determine both the content of the catalogue and its form. The finer the divisions of behavior into episodes, the more episode-rows will be needed in the catalogue. The more specific the categorization of behavior, the more "columns" will be needed to represent markers for relevant content.

Cycles of Interpretation

The information captured in the LC3 corpus can not simply be "coded" once and transcribed to text. The behaviors are as rich as life itself and what they "mean" will depend on the perspective of the observers. Different people will see different aspects of the corpus as salient. Understandings of learning will change as analysis of the richly documented developmental corpus of LC3 extends and deepens. Figure 1 exhibits a theory development cycle which the LC3 datacase will be designed to support. Partial, preliminary theories may filter out possibly critical information from analysis. Using updatable computer files, we can begin (with modifiable indices, partial transcriptions, descriptions of examples, pointers to delimited segments of video and models based on this information) to work around this impasse and to deepen and extend the examined and annotated corpus at need. Call this strategy variable depth analysis. As this analysis leads to improved theory, that improved theory will suggest the need for deeper analysis of other parts of the corpus and their more extended examination. The extended datacase will suggest enhancements of the theory. A positive feedback loop is established.

An example from a previous case study, LC2 (Lawler's case two, his daughter Miriam's learning at six)[3] is developed enough to illustrate the sorts of contents to be created for the bottom three layers of LC3. During the LC2 study, Miriam learned to play tic tac toe.[4] The corpus included her complete set of games during a period of several years, each dated and its relevant context noted. This collection of games represents a sequence of behavior examples. People usually mark cells with "noughts and crosses" to claim ownership. As the subject played, to record move sequences game moves were usually represented either by the digits one to five or the letters A through E, as in the games below (where "the letters" move first):

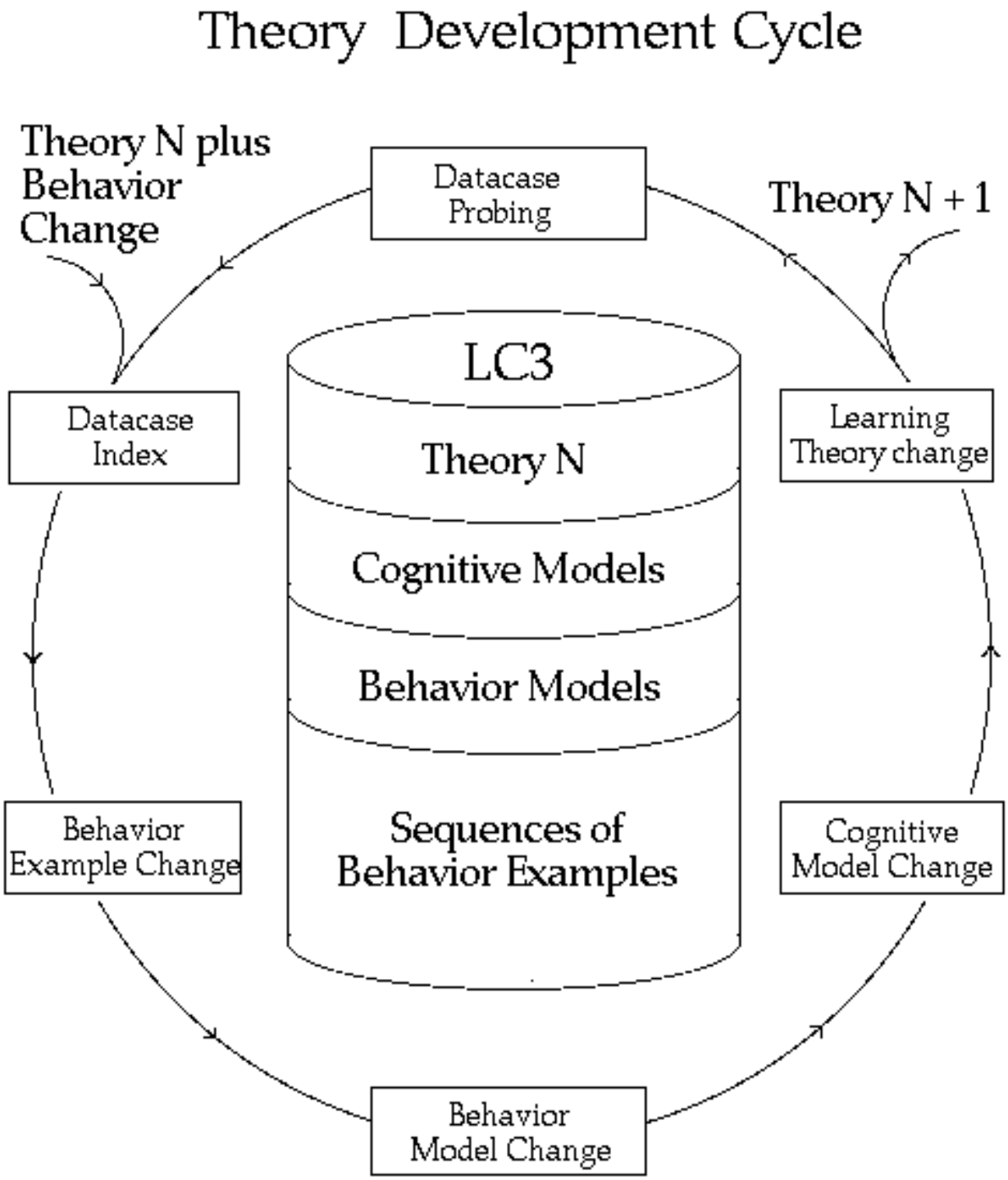
GAC 1			GOAL {1 3 9}			ACTION [1 9 3]			CONSTRAINT <[3 {2 5 8}]>		
1	2	3	A	3	C	A	2	C	A	C	3
4	5	6		1	D		1		4	1	E
7	8	9	2		B		3	B	D	2	B
cell numbers			win by plan			plan defeat			constrained draw		

When the complete set of games is all recoded to be represented in this regular way, they are models of behavior. When a representation is used to describe what is in a person's mind, one has elements for cognitive models, as above, where sequences of numbers,

3 For a selection of reviewers' comments on this work, see Appendix A.

4 This corpus of information and its analysis are reported in "The Articulation of Complementary Roles," Chapter 4 of Computer Experience and Cognitive Development, Lawler, 1985.

Figure 1 [5]



5 In this Figure, "Theory N" at any point of time represents the current state of our Learning Theory, always open to modification and change through the analysis of new material in the corpus or new ideas introduced by other analysts. "Theory N+1" could be as well the theory of another analyst undertaking a secondary analysis of the materials and ideas embodied in LC3.

indicating numbered cells of the game grid, represent goals (sets in curly braces), actions (ordered lists of moves in square brackets), or constraints on plans (in angle brackets, the structure [3 {2 5 8}] means "at the third move, check to see if one must block the opponent's win with the set of cells {2 5 8}."). Such elements are seen as data items in a structure which makes decisions about where to place the next token. Both elements and organization are important parts of cognitive models.[6]

The analyses of LC3 will be more richly specified and more thoroughly articulated, taking advantage of advances made by Minsky's creation of the Society Theory of Mind[7] and his developing work, The Emotion Machine. A more thorough analysis of cognitive structures relating to tic tac toe would have levels of description detailing reactive processes, deliberative processes, reflective processes, self-conscious processes, and even self-models and ideals.[8] We see cognitive structures as representing knowledge states of the subject. Instances of learning, then, are changes in those states; we aim to link such changes to specific behaviors and experiences as these are captured in the LC3 datacase. Theories of Learning are our reflections on instances of learning examined, analyzed and understood, from our perspective. Others could develop other theories covering the same material.

The Research Plan: Corpus Analysis

Corpus analysis will proceed through cycles of theory development, extending and deepening the description of events and modeling of learning with each cycle.[9] The most complete example of Lawler's methods and analyses remains "Computer Experience and Cognitive Development," (Lawler, 1985). That work is summarized in "Constructing Knowledge Through Interactions," (Lawler, 1990) and extended in "Consider the Particular Case" (Lawler, 1994).

Our theories will be based on thorough-going detailed descriptions of behavior, of states of knowledge, and of their changes. Our analytical strategy is:

- to use the observations and language theories of Katherine Nelson[10] as descriptions of knowledge and learning for a typical child aged three to six
- to seek predecessors of such behaviors and developments in the LC3 corpus for the period up to the subject's third birthday. This will lead Lawler to:
  > analyze language performances and their development
  > analyze object-manipulation behavior and its development
  > link selected instances of behavior in both these domains to explicit representations of knowledge ascribed to the infant's mind
  > link selected developmental courses to changes in content in the infant's mind
  > link selected developmental courses to changes in its organization of.
  > create a theory of these changes that relating internal knowledge construction to specific incidents exhibiting the interplay of social activity and learning.
  > create an empirically grounded theory of these developments in which the interplay of multiple interior knowledge representations explains and can be seen as driving the increasing complexity of organized knowledge in the mind.
- and thus, in sum, to explore how language and its precursors develop and how their development relates to cognitive development in another domain

6 These examples are from "Coadaptation and the Development of Cognitive Structures," Lawler 1987, in Advances in Artificial Intelligence, DuBoulay, Hogg, and Steels, Eds.

7 The Society Theory of Mind presents computational mini-theories of various aspects of the structure and function of mind and how various phenomena of mind might emerge from their interactions.

8 These are categories of processes proposed for consideration by Minsky in The Emotion Machine. These might include information relating to the subject's purposes and implicated values; for example, this could involve the notion that the objectives of playing tic tac toe would not be limited to winning each game, but could involve social aims, such as engaging with another person or reflective goals, such as trying to understand how the game works.

9 The basic method is described more extensively in chapter two, "Evolving Datacase Designs," of Case Study and Computing, Lawler and Carley, 1996.

10 As represented by Language in Cognitive Development (1996, Cambridge University Press).

Communication and Language

The general framework for analysis is taken from George Miller's "Language and Speech," specifically his noting (p.113) the separate development of vocalization and communication, and the centrality of sensory motor interactions to cognitive development, wherein these three separate streams join together rapidly at the time when true language begins. The LC3 videotape corpus is rich enough to capture the context of development of these three streams. Beginning at 18 weeks, and with weekly videotaped sessions starting at week 34, the corpus covers the periods when language begins and the predecessor behaviors are developing separately.

In 2001 Lawler presented to the annual Piaget Society Meeting a paper, "The Development of Indicative Pointing: details from an Infant Case Study."[11] That analysis is focused on pointing's development as a tool of indexical reference, one which becomes fully functional before language proper appears. It can represent **our method of analysis in miniature**, as summarized below:

- isolating a theoretically relevant type of behavior: pointing with the "pure point" (index finger alone extending in direction of target) to communicate reference.
- working backward in time from examples of mature performance to times where there was no such mature performance: in P50, the infant Peggy indicated reference to objects using the pure point; exhaustive review showed no such mature performance in earlier tapes; alternative forms of gestural reference or discountable, false positive examples of the pure point were seen.
- characterizing the course of development manifested within that period,
- inquiring what sorts of competence are required to exhibit mature performance
- defining the time of transition to mature performance and circumstances during the transition: transition occurred gradually between weeks 42 and 50.
- forming a theory about what developed or was learned: pointing develops from reaching by the learning the social convention of reference by the "pure point." This was a consequence both of being offered choices among foods or toys and the infant expressing great interest in wall-hung pictures of infants and children.
- fitting the particular learning mini-theory into the larger scheme of development: pointing is a proto-language form of indexical reference; understanding pointing provides guidance for the subsequent LC3 analysis of language development.

Our analysis will begin working backward from Katherine Nelson's characterizations of child language between three and six, searching for the roots of common later developments. In this search, we will depend heavily on Minsky's computational mini-theories in his Society Theory of Mind. We will also make use of classic developmental language studies for inspiration and comparison.[12] We will follow the strategy of the Theory Development Cycle, choosing materials of the corpus to render in coded form and emphasize for analysis. Of the 820 vignettes, 554 bear on language development. There are notes on vocabulary, grammatical issues, and early idiosyncrasies of vocalization; the independent importance of the prosodic contour in communication was noted at the beginning of the study. Thus, the text content of the vignettes, accessible from the vignette index, already provides significant pointers into the video corpus for their joint analysis.

In the analysis of LC3, we will trace these developments, among others:

- development of pre-linguistic communication (example: referential pointing)
- development of language production
- development of language comprehension

11 This report is undergoing revision before submission for publication.

12 Among those most obviously relevant are Bloom (1975, 1991). Brown (1973), the DeVilliers (1979), Halliday (1975), McNeill (1979), Miller (1981), Nelson (1989, 1996), and Sinclair (1989). We will count on the two consulting psychologists to this project, Professor Sheldon White of Harvard and Professor Jacques VonEche of Geneva to recommend to us other studies we have omitted from this short list.

< each of these will require traces of intonation, prosodic, verbal, and structural aspects of the infant's language

We will note and characterize the influence of family members on language development, as individuals and as a group, as well the impact of locations and behavioral. We will produce an authentic theory of the linguistic development of this one child, then compare and contrast this characterization and theory with those of others

Objects and Spatial Cognition

Our analysis of spatial understanding has its roots in Piagetian analyses focused on the extension of the object concept, specifically on the development of an appreciation of concavity and the interpenetrability of objects.[13] Our stance is similar to that of Newcombe and Huttenlocher, in focusing on learning through interaction without accepting the specific formulations proposed by Piaget half a century ago[14]. Their discussion of domain specificity and the interplay of spatial representations and language based descriptions[15] highlights the value of the LC3 corpus, designed to focus on these two domains of development in a single mind.

A second beginning point for the study of spatial cognition is the importance assigned to subject-object relations in the Society Theory of Mind.[16] The toys with which the child plays become the models by which the maturing mind understands the world. We will trace the development of knowledge about objects, such as:

- exploring the traditional Piagetian notion of object permanence
- development of an appreciation of varied object behaviors: objects with various shapes exhibit different forms of mobility (sliding, rolling, rotating)
- understanding objects with cavities and inter-object relations, specifically
  > juxtaposition (right-of, left-of, in front of, in back of, between, among)
  > superposition (on, under, on-top-of, supporting, supported by)
  > containment (containing others and being contained by others)
- understanding object sets with more complex inter-relationships, specifically
  > objects with relations of ordered nesting, stackability, and
  > objects in relations of one to one correspondence based on other properties, as balls of graduated sizes fit in cups and boxes of graduated sizes
  > appreciation of shape-based fit between various suites of holes and solids

Within the three year corpus, the infant proceeded from minimal object knowledge to an understanding demonstrated by her ability to easily and quickly insert solid pieces of various shapes into puzzle slots which fit each one alone. During that period of time, she played every week with a specific limited set of experimental objects which were otherwise not available for her use. In this sense, the LC3 video corpus is complete, although it is obvious that the subject had experiences with a world of objects "off-camera."

A third component of our exploratory approach comes from Lawler's analysis of the LC2 corpus. Chapter 5 "Cognitive Organization," proposes that development of coordination among disparate, experience-rooted schemata of different sensory systems is among the most important areas of development to explore. The LC3 video corpus makes salient the question of what different varieties of schemata may and must be considered to probe the development of knowledge about objects and space. We conceive of the infant as having a greater number of disparate "perceptual and experiential spaces" than is usually considered, such as:

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13 Specific thanks are due again to Professor H. Sinclair for her urging us to explore these possibilities by selecting sets of experimental objects for the infant to play with which would bring these issues to the fore in the infant's experiences. During this same period, she and colleagues at CRESAS in Paris were conducting the research of Sinclair and Stanback (1982), Babies and Things.

14 Piaget and Inhelder (1948), The Child's Conception of Space and Piaget (1954) The Construction of Reality in the Child.

15 in chapters 1, 7, and 8 of Making Space: The Development of Spatial Representation and Reasoning .

16 See the chapters 12 through 14,: "Learning Meaning," "Seeing is Believing," and "Reformulation."

• body parts spaces:
> oral space (lips, tongue, and oral cavity)
> capital space (face, neck and head entire)
> visual space (what can be seen but remains beyond contact)
> manual space (hands, arms and their reach)
> corporal space (trunk, back, and bottom)
> sitting space (space near the seated bottom and thighs)
• motile/horizontal spaces:
> belly anchored flailing space
> crawling on-the-belly space
> crawling on hands-and-knees space
• motile/vertical spaces
> the "carried infant" space
> the standing-in-place space
> the moving-in-rolling-walker space
> the dependence on movable objects space
> the transit among objects space
>the independent movement space
> the jumping/dancing space
> the running space

We will examine indications and search for evidence that such disparateness exists within schemata. This evidence may be ephemeral because the disparateness is destined to be eventually overcome by the integration of sensori-motor schemata as the infant constructs coherence through the progressive coordination of varied perceptual and experiential spaces. Our objective, as with the language study, will be the development of an authentic theory of the spatial development of this child. We will compare and contrast this characterization and theory with those of others.

Finally, we will compare the characterization and particular learning theories in these two related but distinct case studies with one another, asking:
• at what levels of description are they compatible and/or irreconcilable?
• how to understand the mutual influence of developments of each on the other?

Representation and Modeling

Functioning models are an expression of ideas and are most worthwhile in the latter stages of theory development, but the issue of how to express the results of our analyses in models will be ever present both as a goal and as a goad. Lawler's early studies were shaped by Minsky's statement of a goal for the field of Artificial Intelligence, the need for a better theory of the emergence of the control structure of the mind. Minsky's work[17] offers computational mini-theories of the structure, function, and development of mind. Lawler's first two detailed case studies, developed in Minsky's circle at the same time as the Society Theory of Mind, served to provide interpretation challenges and examples to think with about the nature of mind.[18] As in Lawler's earlier case study analyses, we will use computational ideas as tools to develop specific interpretations and theories of the nature of mind and learning. Since it appears that, especially for development in the domain of language, the role of communication is paramount, the mental representations advanced by Minsky's Society Theory of Mind and The Emotion Machine can be supplemented by the use of ideas derived from

17 This may be represented first by his popular book, "The Society Theory of Mind," but there is much more that is relevant. As a Visiting Professor at MIT invited by Minsky (1999-2000 and other times) Lawler read early and partial drafts of "The Emotion Machine," extensions to the Society of Mind Theory and discussed some of them with Minsky and his students.
18 The article "The Progressive Construction of Mind," Cognitive Science, 1981, is an early and accessible example of applying computational ideas to psychological and educational issues.

Piercean semiotics and their integration in attempts to make sense of how interaction with others affects the development of the mind in the individual infant. [19]

Evaluation Plan

With respect to the analysis of LC3 for its intrinsic merits, the evaluation of the research will be judged by the extent to which elements of the Research Plan (see Figure 2) are met. We expect this work to be done well and to win the approval of professional colleagues, based on the reception of past work. (See the comments in review of Lawler's book Computer Experience and Cognitive Development, attached here as appendix A). One major component of this research will involve feedback from the Advisory committee to the co-PIs about the ways in which this work compares and contrasts with traditional and current developmental and psychological studies. A second component will involve the interests in and the degree of acceptance accorded this work by relevant professional communities, i.e. communities of developmental psychologists, genetic epistemologists, linguists, and computational theorists of mind. Presentations will be prepared for societies such as the Society for Research in Child Development, the Jean Piaget Society, the Cognitive Science Society, the American Association for Artificial Intelligence and others. A file of reviews of those submissions will be kept as part of the project evaluation.

With respect to the use of the LC3 datacase by others, this research will have a widening circle of interest as analyses proceed.[20] First, students of Minsky at MIT will have access to the LC3 datacase, as will students of VonEche at Geneva and other communities where Lawler's studies are known. Following conference presentations, researchers will be encouraged to inquire about and discuss ways in which the LC3 datacase could serve as a resource to address questions relevant to their related but separate work. Scholars and students of Psychology and Education will be interested in the specimens of behavior, especially those focused on Child Development. Some will be more focused on related research, e.g. students of graduate seminars in Psychology on language or spatial cognition. There will be others who might like to pursue parallel lines of research using the LC3 datacase, or use it to develop interpretations at odds with ours. Lawler will consult with researchers on ways in which the LC3 datacase could be used to probe their issues. Papers produced by such seminars and research oriented groups will serve as an evaluation portfolio for this project.

During the second year of the project, we will select hypertext facilities for interlinking the components of the LC3 datacase to embody the ideas advocated in "Evolving Datacase Designs" (Lawler and Carley, 1996). We expect this to be in an XTML computational environment. The hypertext linked LC3 datacase will provide a tool for interrelating the four levels of elements in Figure 1 (behavior examples, behavior models, cognitive models, and learning theory). The evaluation of the hypertext LC3 datacase will be provided through its demonstration by the end of the project. We believe the usefulness of connecting ideas and models to evidence at various levels of description will be manifest and that accessibility to the LC3 datacase will invigorate and popularize case study as a psychological method.

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19 In this effort, Lawler have found very useful Terrence Deacon's "The Symbolic Species" (1997) and David McNeill's "The Conceptual Basis of Language." (1979).

20 The privacy issue is less critical in an infant/child developmental study than with more mature case study subjects, such as Robert White's Hartley Hale. The subject was Lawler's infant daughter and the family her mother and siblings. It will be his charge, as it is his charter, to protect their interests.

Figure 2
Planned Research Schedule

Datacase Development — During Year 1
- LC3 video corpus is minimally edited into computer accessible form
- LC3 video index reflects new segmentation based on video editing

Language Analysis
- characterization of language development for years 3 and 2
- definition of the set of behavior examples bearing on language

Spatial Cognition Analysis
- characterization of spatial cognition development for years 3, 2, and 1
- definition of the set of behavior examples bearing on spatial cognition

Expected Research Products
- first article from LC3 analysis of pointing prepared for publication
- introduction of LC3 datacase to students; first use by others

Datacase Development — During Year 2
- stabilized core of LC3 datacase with flexible extensions
- selection and implementation of hypertext linking facilities for LC3

Language Analysis
- grounding the subject's language meanings in her particular experience
- detailed analysis of selected language developmental strands

Spatial Cognition Analysis
- grounding the subject's spatial understanding in particular experiences
- detailed analysis of selected spatial cognition development strands

Expected Research Products
- presentation of first fruits of analyses at a research conference
- discussion of secondary analyses with interested colleagues
- preliminary grounded theory of domain knowledge interactions

Datacase Development — During Year 3
- consulting for others undertaking secondary analyses of LC3 datacase
- preparation of generally accessible LC3 datacase

Language Analysis
- detailed analysis of other language developmental strands
- detailed analysis of proto-language and pre-language development.

Spatial Cognition Analysis
- detailed analysis of other spatial cognition developmental strands
- detailed analysis of earliest understandings of object interactions

Expected Research Products
- presentation of language and space analyses at two research conferences
- articles prepared for publication on language, space, and cross domain knowledge interactions.

Project Staff and Management Plan

The project will be managed at the MIT Media Laboratory by the Principal Investigator Professor Selker. Co-PI MIT Professor Minsky will provide theoretical focus and guidance to the analytical work, which will be pursued by co-PI Professor Lawler, along with corpus development. Lawler has joined Minsky's Society of Mind class at MIT for the last three years, and will continue to do so, as will Selker when possible. Minsky's students will have access to the developing LC3 datacase for use in class projects, where they will have the opportunity to apply Society of Mind ideas for the interpretation of behavior and cognitive modeling of examples of learning. As researchers in other centers become interested in the secondary analysis of this corpus, Professor Lawler will provide support and guidance to them, both through communication channels and personal contact. MIT will remain the home base of the project even though Professor Lawler will be involved with other research communities over time.

Co-Principal Investigator, Professor Marvin Minsky has made many contributions to Artificial Intelligence, Cognitive Psychology, Mathematics, Computational Linguistics, Robotics, and Optics. His conception of human intellectual structure and function is presented in The Society of Mind (CDROM, book) which is also the title of the course he teaches at MIT. His research now focuses on how various phenomena of mind emerge from the interactions among many kinds of highly evolved brain mechanisms.

An inventor and scholar, Minsky holds many patents and is a member of the NAS, NAE and Argentine NAS. He has received the ACM Turing Award, the MIT Killian Award, the Japan Prize, the IJCAI Research Excellence Award, the Rank Prize and the Robert Wood Prize for Optoelectronics, and the Benjamin Franklin Medal. He will have primary responsibility for suggesting ways in which the Society theory of Mind can be applied in the interpretation the LC3 corpus and representation of the subject's inferred cognitive structures.

Co-Principal Investigator, Professor Robert Lawler, an International Fellow of the Archives Jean Piaget, is an analytical theorist who interprets case study materials to create models of developmental processes in specific cases. A list of insights and ideas he has introduced and advocated in the last 25 years includes these:

- bricolage (proposed by Levi-Strauss) can be a vision of cognitive self construction
- modality specific cognitive representations can be employed to represent forms of individuals' experience interpretation (assimilation)
- simultaneous agreement of disparate cognitive-structure outputs can be ascribed as occasions of insight (events of cognitive-structure accommodation).
- cross modality interaction can be argued to be a generator of significant advances in cognitive integration (augmentative accommodation)
  > the integration of disparate cognitive structures can be understood through situation-impelled conversion of discrimination links into relation links
  > co-adaptation can be seen as a primary mechanism of cognitive development; this includes the insight that redescription is a kind of proto-abstraction.
- adapting Feynman's "sum of histories" model that explanation requires examination of the paths of all possible histories and emerges from their sum can permit relating concrete learning through experience with more abstract and powerful forms on knowledge derived from cross-modality integrations.
- inverting the arrow of external indexical reference is the key to understanding the roots of reference and language comprehension in infants.

Lawler, retiring early from his tenured Purdue position as Professor of Education and Computing, recently has been Visiting Professor in Media Arts and Sciences at MIT and in Psychology and Genetic Epistemology at the University of Geneva. He will have primary responsibility for observing, selecting, tracing, analyzing and representing the knowledge developed by the subject of the LC3 corpus.

Project Advisory Board

Sheldon H. White, Professor of Psychology at Harvard University has had a long and distinguished career as a scholar and teacher at Harvard, where his interests included psychological theories of child development and the history of psychology. He has been President of the Society for Research in Child Development and a consultant to the National Research Council. Now completing a history of developmental psychology., he will provide guidance on relationships between analyses of the LC3 corpus and the history of developmental psychology

Jacques VonEche, Professor of Psychology and Genetic Epistemology at the University of Geneva, an internationally known theorist of child development, was a longtime colleague and collaborator of Piaget, Inhelder, and the case study analyst Howard Gruber, with whom he co-authored the definitive work, The Essential Piaget. VonEche is director of the Archives Piaget. He will provide guidance on relationships between analyses of the LC3 corpus and Piagetian psychology.

Research Sites

The MIT Media Laboratory provides a unique environment to explore basic research and applications, without regard to traditional divisions among disciplines. Each Media Laboratory faculty member leads a research group that includes a number of graduate student researchers and often involves undergraduate researchers. Areas of research are at the intersection of technological frontiers and human needs and opportunities

The Archives Jean Piaget is a private foundation within the University of Geneva initiated by Professor Bärbel Inhelder to collect writings of Piaget and the secondary literature inspired by his works. Other scientific activities take place at the Archives related to the ideas of Piaget and their further development. The Foundation is directed by a Jacques VonEche, Professor of Psychology.

Research Products and Dissemination

Intellect Books is planning on re-publishing the two books derived from Lawler's first two case studies (LC1 and LC2). Intellect is interested in publishing books that will report the outcomes of this research. As analyses, interpretations, and theories are developed, articles reporting these developments will be prepared for publication in archival journals including those of the Society for Research in Child Development, Cognitive Science, the Journal of Mathematical Behavior, Developmental Psychology, and journals of Artificial Intelligence studies.

The LC3 datacase materials will be made available for use by other scholars and students, first through academic channels and later through others. Depending on the needs of research users for extensive data, for speed of response, and for linkage creation, the form of availability may be secure, limited-access internet connection or, as needed, local, large capacity, high speed magnetic storage devices

Appendix A: comments in Review of Lawler's Second Case Study

Computer Experience & Cognitive Development

Sheldon White: Professor of Psychology, Harvard University
Dr. Lawler's MIT thesis was a case study of six months of his daughter Miriam's cognitive development. I believe it is the finest single study of children's learning we have, in care, in detail, in breadth and sensitivity of perspective.... The work of The Intimate Study stands as a model of the way a child's thinking should be examined.

Bärbel Inhelder: world's foremost Piagetian psychologist
The first highly convincing synthesis of cognition science and genetic psychology. An innovative study which highlights the computational approach to new understandings of the growth of mind.

Howard Gruber: world famous Case Study analyst
To know even one person as a mind alive is a rare and difficult thing, a child even more so. Lawler has had the penetration, the insight, the sympathy to do it. He shows us two minds at work -- the scientist's and the child's, both growing. In the long run, the prolonged and loving interaction between parent and child may be the most important story this case study has to tell.

Donald Norman: founder of the Cognitive Science Society
An important and unusual book. Bob Lawler provides a detailed ecological analysis of one child's growth. He examines the process of learning through interaction: Mind coupled with environment. The book lies at the intersection of cognitive science and Piaget's genetic epistemology. And very readable besides.

Guy Cellerier: leading European Cognitive Scientist
The psychological mechanisms that were solutions for Piaget's structuralist epistemology have become problems for today's procedurally oriented psychologist. Lawler's in depth study of a child's evolving mind is a theoretical, empirical, and methodological landmark in this new direction of research.

Marvin Minsky: founder of Artificial Intelligence
This is a uniquely detailed study of the development of knowledge and intelligence in one particular child. It has much to teach both to those concerned with how humans learn and too those involved in making machines that learn.

Seymour Papert: leading American Education Theorist
The most significant attempt since Piaget to obtain data rich enough for building a theory of how young children really learn.

Robert Davis: leading American in Mathematics Education
Lawler shows... that the true orderliness of human behavior becomes evident when one looks very carefully at extremely tiny details..... Lawler goes on to show how the analyses of Levi-Strauss, Goodman, Piaget, Minsky, and Papert begin to fit together into a new whole that gives us insight into how humans think and learn.

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