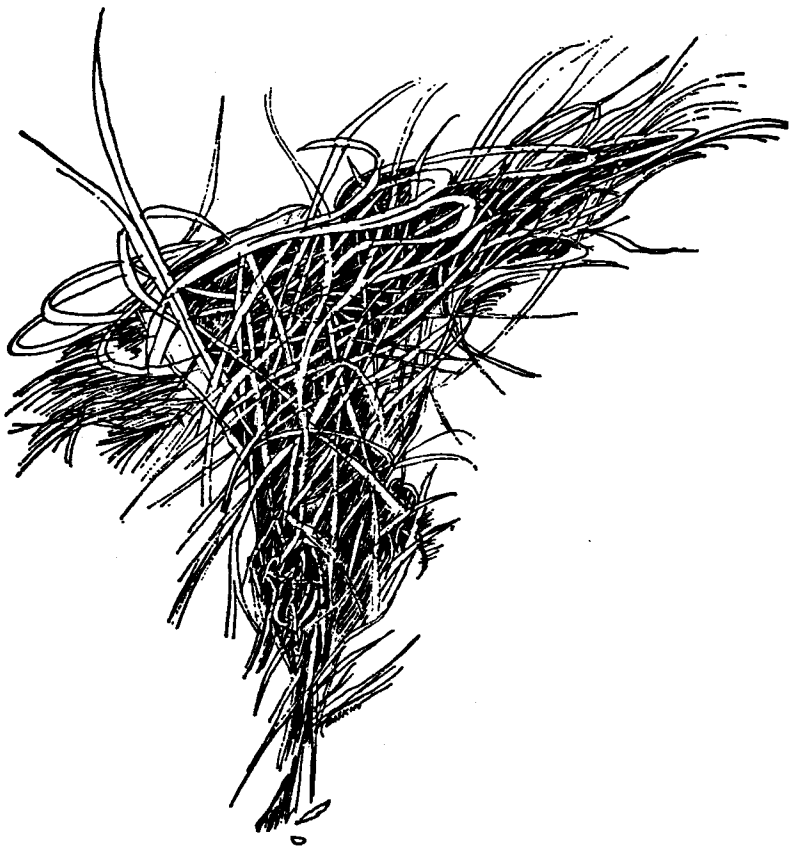
Contemporary Implications of Vygotsky and Luria

Michael Cole and James V. Wertsch



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THE HEINZ WERNER LECTURE SERIES

This is the twenty first of the Heinz Werner Lecture Series. This series is designed to provide a forum for outstanding scholars who are known for their contributions to the developmental analysis of biological, psychological and/or sociocultural phenomena. This series is sponsored by the Heinz Werner Institute for Developmental Analysis.

Heinz Werner (1890-1964) was one of the leading psychologists of the past half century. Deeply impressed by processes of organic formation and ordered change in various domains of the life sciences, he sought to apply developmental conceptualization and developmental analysis to all aspects of existence in which mentality is manifested. Convinced that developmental psychology is not merely a subject matter but is, rather, a manner of conceptualizing all psychological phenomena, Werner sought to encompass animal behavior, ontogenesis, pathological phenomena, products of collective activity, and behavior evoked in experimental situations, within a comprehensive system--a general psychology, grounded in the fundamental concept of development. In accord with Werner's philosophy, the Heinz Werner Institute is devoted to the application of developmental analysis to all psycho-biological and psycho-cultural phenomena. It seeks to fulfill Werner's vision by promoting research and teaching at graduate and post-graduate levels which will serve to integrate the various life sciences without collapsing their distinctiveness in method and subject matter.

Bernard Kaplan

Clark University

Seymour Wapner

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From Moscow To the Fifth Dimension: An Exploration in Romantic Science

Michael Cole[1]

It is a special pleasure for me to be able to speak in this forum which is so evocative of the history of psychology in general and developmental psychology in particular. My assigned topic at this meeting is to talk about the work of Lev S. Vygotsky, a Russian psychologist who was Werner's contemporary. Like Joe Glick (1983, 1993), I believe that there are important convergences between the two thinkers that appear to involve their shared commitment to both organicism and development. I offer my remarks as a possible contribution to the task of finding points of synergism between Werner and Vygotsky that will enrich the current discussions between their students and admirers about the path to a more inclusive and powerful theory of development.

Departing, perhaps, from what my hosts anticipated, I will not spend much time directly discussing Vygotsky or Werner, although I will mention both. It is not indifference that motivates this choice. The fact of the matter is that I never had the opportunity to interact directly with either Vygotsky or Werner as a student or colleague. Instead it was Alexander Luria who provided the interpretive frame for understanding Vygotsky.

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[1] This work was carried out collaboratively with many of my colleagues at the Laboratory of Comparative Human Cognition over the last decade. I am particularly grateful to Scott Woodbridge and Amy Olt who have provided invaluable assistance not only in the design and implementation of the activities, but in developing means for analysis of student field notes as data. This work was supported by a grant from the Andrew Mellon and Spencer Foundation.

And it was primarily through Vygotsky that I came to appreciate Werner. So, in this chapter I will seek to make a virtue out of necessity, and use Luria's ideas as a prism through which to think about commonalities between the ideas of Vygotsky's cultural-historical school and those of Heinz Werner and his students. I begin by noting some key points of obvious commonality between the two. I then turn to the way in which Luria used these ideas in his research, particularly with respect to remediation of brain injuries. Toward the end of his life, Luria proposed the idea of a "romantic science" that was his resolution of the classic dualisms of idiographic-nomothetic, or natural-cultural. I will give an example of a methodology in the romantic science mode that, I will argue, provides an excellent medium for comparing different-but-similar theoretical claims. I called it a "mesogenetic" method.

Encountering Werner

I owe my introduction to Werner's ideas to Joe Glick who bears no responsibility for the unevenness with which I have assimilated what he has tried to teach me. As colleagues at Yale University , Joe and I participated in a project with Bill Kessen to evaluate the workings of "Man, a course of study" in live classrooms. As a side interest we conducted an experimental study of the development of concept discrimination. This work was done within an "experimental child development" methodological framework (Cole, Glick, Kessen, & Sharp, 1968).

At this same period I was just beginning my work in West Africa and it seemed to me obvious that to understand cultural differences in thinking one needed to adopt a developmental perspective and its methods. The ethos of the times strongly biased young academic psychologists to apply methods of study borrowed from the experimental study of learning on the model of the white rat/college sophomore. Choice of rat or sophomore was more or less irrelevant, although the work with rats generally had higher prestige. A similar, stimulus-response

learning theory was believed to apply to representatives of both species, with suitable adjustment of parameters.

This milieu was not fertile ground for introducing a Wernerian organismic developmental perspective. However, Joe and I found common ground in our work in Liberia to which he brought a strong bias toward externalizing the process of change and appreciating the fact that qualitative differences between quantitatively similar performances offer privileged sites for learning something about development-as-process.

In general, at that period, I knew only Werner's (1957) *Comparative Psychology of Mental Development* which I assimilated to my distaste for those theories of culture and cognition that assume strong developmental parallels between cultural, cognitive, and historical change. To me such ideas looked suspiciously similar to 19th Century evolutionary anthropological theories. I did not like that kind of thinking in the work of the Russian cultural-historical psychologists, and I did not like it in its American, German, French, or English varieties any better. I saw in it a common grounding in early 20th Century cultural-historical theories, one prominent branch of which was German Romanticism.

Focusing on Genesis

My next encounter with Werner came via the Russians. In the chapter on problems of method reprinted in *Mind in Society*, Vygotsky (1978) identifies Werner as a thinker whose methodology is adequate to the study development-as-process because it provides "a dynamic display of the main points making up the processes' history " (p. 61). His characterization of microgenesis is pure Werner:

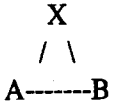
> Any psychological process, whether the development of thought or voluntary behavior, is a process undergoing changes right before one's eyes. The development in question can be limited to only a few seconds, or even fractions of seconds (as is the case with normal perception).

> It can also (as in the case of complex mental processes) last many days and even weeks. Under certain conditions it becomes possible to trace this development. Werner's work furnishes one example of how a developmental viewpoint may be applied to experimental research (Vygotsky, 1978, p. 61).

The Method of Dual Stimulation

Vygotsky (1978) and his students applied this idea with particular success in their studies of the "method of dual stimulation." This method serves as one model of the basic unit of psychological analysis from the cultural-historical perspective promoted by Vygotsky and his students because it included the cultural mediation as a central focus and served as a juncture where natural and cultural processes are joined to create specifically human forms of action.

This juncture point is in the mediated act. Vygotsky (1929) wrote that the mediated act (A -X- B) consists of two simple reflexes, A-X and X-B. These elements are, he argued, entirely natural processes. The uniqueness of the mediated act is in the quality that emerges when they are combined. To capture this quality he depicted the familiar triangle:



A is an action on B that incorporates X as its means. Mediated action mixes the natural and the artifactual; the relations of its parts are explainable in natural science terms, but the emergent property of their combination is not. It is a qualitatively unique form of thought and action, a hybrid of phylogeny and culture.

It is this line of reasoning that underpins the iconic Vygotskian experiment in which a child tries to get cookies that are out of her reach (this work was directly modeled on Köhler's research with chimpanzees). As described by R.E. Levina who carried out this research under Vygotsky's supervision, a young

child is asked to achieve a goal (reach a piece of candy) that is beyond her reach on a cupboard (Levina, 1981). There is a stick hanging on the wall. At first the child attempts to reach the candy *directly* by climbing on a nearby couch and reaching. She next says that perhaps she should call for help from someone taller than herself, but then begins to use the stick, commenting all the while on her progress. Vygotsky (1978, p. 59) referred to this kind of mediated behavior in the memorable comment that human beings are able to "control their behavior from the outside." Another example is provided by Luria's (1929/1978) research on prewriting actions of preschool children. Luria observed that the sophistication of the written marks that children make on paper to help them remember a set of objects goes through a microgenetic sequence from iconic mimicry toward abstract summary even before the children know the conventions of written language.

The influence of the idea of microgenetic research is also illustrated in the later chapters of my work with Sylvia Scribner on Vai literacy and the subsequent research of her laboratory on cognition and adult work (Scribner & Cole, 1981; Scribner, 1984). More recently it can be seen in the work of Geoffrey Saxe (1994) who explains his approach to be a combination of ideas from Luria, Werner and Kaplan.

In this paper I describe my current approach to studying development as "a process undergoing changes right before one's eyes." However, I will not be focusing on the second by second or minute by minute processes of change. Rather, I will be considering change over an intermediate length of time measured in days, weeks, and even months. In order to motivate the empirical research to be described later in the talk, I need to take a small detour to explain the idea of romantic science and the way that Luria and others have implemented it. Then I will describe my own implementation of the idea.

Luria's Conception of a Romantic Science

Luria (1979) begins his autobiography with a discussion

of the science of psychology he inherited in the second decade of the 20th century. His story begins in the latter part of the 19th Century when the "new psychology" came into being. Like many of his generation, Luria saw psychology as composed of two, apparently irreconcilable, ways of knowing. In Cahan and White's (1992) terms, the origins of the discipline of psychology really contained two psychologies. The First Psychology chose the path of experimentation and quantification in seeking explanatory laws of universal applicability. The Second psychology sought to understand human nature as a hybrid of organic and cultural features that had to be studied in the process of change, "genetically." The Second Psychology also privileged research that can be considered ecologically valid, that is, based upon forms of interactions that are not constructed primarily for purposes of psychological analysis. Luria characterized this way of doing science as "descriptive. "

Like many of his generation, Luria (1979) sought a resolution of the problem of two psychologies. Cultural-historical psychology is an effort to forge such a resolution in theory and methodology. Romantic Science seeks unity of the two sciences by resolving them in practice. In arguing for a resolution through practice, Luria was following in the footsteps of Vygotsky and Hugo Münsterberg (upon whom Vygotsky draws explicitly). However, he went a step further than either Münsterberg or Vygotsky. In his autobiography he focuses on another of the dichotomies that haunts discussions of the two psychologists, the dichotomy between an idiographic approach, that accounts for individual cases and a nomothetic approach based on aggregations of individuals. His way of synthesizing the two psychologies seeks to prove the utility of theoretical principles arrived at through the experimental study of groups of people by showing how they are relevant to *understanding and changing* the concrete life circumstances of an individual human being. It is this synthetic approach that he called romantic science.

Luria (1979) contrasted romantic science with what he

called classical science:

> Classical scholars are those who look upon events in terms of their constituent parts. Step by step they single out important units and elements until they can formulate abstract, general laws. . . Romantics in science want neither to split living reality into its elementary components nor to represent the wealth of life's concrete events as abstract models that lose the properties of the phenomena themselves. (p. 174)

In writing about romantic science, Luria quoted a line from Goethe's (1988) *Faust* in which Mephistopheles tells an eager student, "Grey is every theory, ever green the tree of life," expressing his skepticism for the golden promises of theory and his desire to deal with the process of life itself. Elsewhere in the same scene, Mephistopheles advises the student on his future career, describing the consequences of following the path of science. The images he uses capture perfectly the difference between classical and romantic science.

The conversation begins with Mephistopheles admiring the work of weavers, who create patterns, a process in which "A single treadle governs many a thread, And at a stroke a thousand strands are wed." Quite different is the scientist's approach, and quite different the result. In light of my discussion to this point, it would not be amiss to think of the scientist as a psychologist who pursues the First psychology.

> And so philosophers step in
> To weave a proof that things begin,
> Past question, with an origin.
> With first and second well rehearsed,
> Our third and forth can be deduced.
> And if no second were or first,
> No third or fourth could be produced.
> As weavers though, they don't amount to much.
> To docket living things past any doubt

You cancel first the living spirit out;
The parts lie in the hollow of your hand,
You only lack the living link you banned.
(Goethe, 1988, p.95)

Luria illustrated his concept of romantic science in two longitudinal case studies involving people for whom ordinary ways of mediating action in the world are impossible (Luria, 1968, 1972). One was a man with a superb, but unusually organized memory. The other was a man who had suffered unusual disorganization of memory owing to massive destruction of the left-posterior part of his brain. In each case Luria combined information from experimental studies of large groups of subjects with the peculiarities of the individual case. His ideas about how the two kinds of knowledge, nomothetic and idiographic, should be combined was evaluated through the success or failure of the therapeutic regimes he prescribed.

In recent years the major champion of Romantic Science has been Oliver Sachs, whose deep involvement with his patients over a period of time is strongly reminiscent of Luria's approach and adds importantly to the range of abnormal brain-behavior relationships that can be used to develop a more powerful theory of mind and development (Sachs, 1987; 1995). According to Sachs, a central characteristic of Romantic Science is that it treats analytic science and synthetic biography of the individual case as essentially complementary, "the dream of a novelist and a scientist combined" (Sachs, 1987, p. xii). Equally important in my view is that both Luria and Sachs are therapists who engaged their patients as human beings and attempt to demonstrate through practical amelioration of suffering the truth of the basic premisses of their theories.

Alexander Romanovich and I never discussed his ideas about Romantic Science, which I encountered first in editing his autobiography, although he had apparently been thinking about the idea for some time (Sachs, 1987). Our mutual topic was

culture in mind viewed in terms of a classical science approach using experimental methods to cross-cultural research. At the time of his death, I had only begun down the path that would lead me to the practice of Romantic Science.

I do not have the space here to recount the ensuing journey. Interested readers can find partial accounts in various publications (Cole, 1996; LCHC, 1982; Nicolopolou & Cole, 1993). In general terms, my research on culture and development since the early 1980's has involved constructing, analyzing, and seeking to sustain model activity systems. A key feature of this work has been the effort to implement a central idea of the cultural-historical approach to psychology proposed by Vygotsky, Luria, and Leontiev--the need for a multi-level analysis of developmental change that includes several genetic domains (for discussion of this issue, see Scribner (1985) and Wertsch (1985). Consequently, my version of romantic science goes beyond the study of individual adults to a form of research and theorizing which includes micro-analysis of change in adult-child interaction over periods ranging from minutes to weeks, analysis of ontogenetic change over periods ranging up to a few years, and the development of the system of activity which serves as the medium for the developments being analyzed. Because it serves as the general context for all of the work, I begin by describing the system of activity, which we call *The 5thDimension.*

The 5thDimension as a Medium for Romantic Science

The 5thD is designed to be run during afterschool hours in community institutions, such as the Y, Boys and Girls Clubs, churches, and libraries, which take responsibility for supervising children in the hours between the bureaucratized life of school and the family setting. The applied goal of the program is to increase children's involvement in activities that will promote cognitive and social development. The basic research goal is to elaborate and critically evaluate a cultural-historical theory of human development of the sort proposed by Vygotsky, Luria, and their colleagues.

Figure 1 provides a schematic overview of the 5thD in one of its institutional settings. The basic structure of these core elements has remained relatively constant across generations, so I will treat it as a generic case. The central coordinating artifact at the heart of the 5thD is a maze divided into twenty-one "rooms" each of which (symbolically) contains two activities.

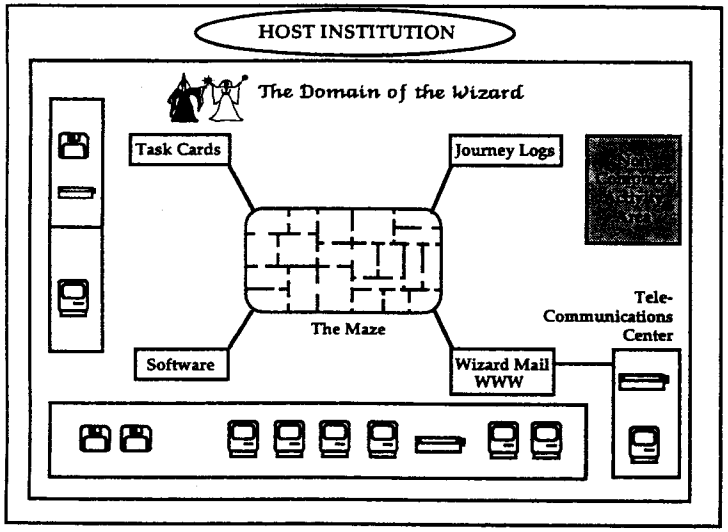


Figure 1. A schematic representation of the main elements of the 5thDimension activity system in its institutional setting.

The actual maze is usually constructed of cardboard and is about 1 square meter in width and 3 inches in height. Most, but not all, of the activities are instantiated on microcomputers as educational games; the remainder include arcade-style games, telecommunication activities (e.g., a treasure hunt on the World Wide Web); arts and crafts, and physical exercise.

The 5thD includes a variety of other standard artifacts in addition to computers and computer games. These include

- A constitution with all of the rules printed on it.
- A box containing record keeping folders for each child

- A constitution with all of the rules printed on it.
- A box containing record keeping folders for each child
- At least one computer linked to a modem to enable children to communicate with distant places
- Task cards that specify what one has to do to pass various levels of the game and give hints about ways to proceed
- A consequence chart that specifies "next rooms" which children can enter when they complete an activity at a specified level of expertise
- Tokens called "cruddy creatures" with children's names attached which are moved from room to room to mark the children's progress
- A "hints book" where good tips and strategies about playing the games are stored for others to consult.
- A 20 sided die used to make decisions about what room to go to in some circumstances.
- An elusive Wizard/Wizardess available only through email and live chats on the computer.

These artifacts by themselves do not, of course, constitute the 5thD. Rather, they are resources that adults and children can draw upon in order to reconstitute the sociocultural system of the 5thD, which can be productively thought of as a collective process that must be performed by children and adults on each occasion of its coming into being.

According to the rules of the 5thD (contained in its constitution) the children make progress through the maze by completing the tasks associated with each game. In addition to the local goals of completing each task at one of its three levels, the 5thD provides for a variety of other goals, designed to appeal to a variety of children. For example, by traversing a path that takes them in one entrance and out another, they may "transform their cruddy creature" and obtain a more desirable figurine. They may choose to follow a path that will get them to a favorite game or allow them to play alongside a particular friend. Children who

display a high level of expertise by completing half the games at the excellent level and the other half at the good level are rewarded with a special t-shirt, often a party, and ascent to the status of Young Wizard's Assistant, which entails greater access to telecommunications and complex games as well as new duties and responsibilities for assisting novice members.

An important design feature of the 5thD is that undergraduates enrolled in a practicum class participate with the children as older, more knowledgeable peers. We refer to the undergraduates as "Wizard's Assistants" because of their proven educational achievement and greater general knowledge relevant to a lot of the games. This role assignment seems to work well and it is routine for friendships to develop between undergraduates and child members of the 5thD.

At UCSD, which divides its academic year into three 10-week quarters, the 5thDimension goes through three 8-week sessions which children attend from 1-4 days a week, depending upon local circumstances. Undergraduates are allowed to take the practicum course as many as three times and children are allowed to attend year after year. Graduate students, post-doctoral fellows, and project staff all participate from time to time in the 5thD. Consequently, at any given time, participants include a mix of child, undergraduate, graduate, and researcher "old timers" and "newcomers" with varying amounts of experience and knowledge about the activities.

One interesting feature of this arrangement is that cultural knowledge and age are not tightly linked: very often the children have more knowledge about the computers, games, and norms of the 5thDimension than the undergraduates. This situation creates enormous heterogeneity of knowledge and authority, which helps to re-order every day power relations with important consequences for the dynamics of the interactions that take place.

A second interesting outcome of these arrangements is variation in the timing of participation. Undergraduate participants move in and out of the system on a University schedule every 10 weeks, except for the summer time. Children move in and out of the system in many different time segments: they may come for only part of a session, or only part of a week, or once a week, or daily for a while after which they turn their attention to soccer or piano lessons. A few children attend the 5thD over a period of several years. This large number of different temporal patterns characterizing different participants makes for an unusual degree of heterochrony which amplifies the already considerable heterogeneity of synchronic activities.

These circumstances make the 5thD a rich medium for studying developmental change on several time scales simultaneously: the microgenesis of joint problem solving measured in several seconds or minutes, microgenesis that spans several days of work on a single complex task, the ontogenesis of the participants, and the cultural-historical genesis of the system of activity itself.

Evaluating learning and development in a 5thD activity system

Although my description has been brief in the extreme, I hope it is enough to allow you to picture an afterschool activity in a Boys and Girls club where 8-12 children, 5 or 6 undergraduates, and one or two researchers gather to participate in an activity system designed to mix play, education, peer interaction, and attachment. Central to this play-world is a system of rules which participants come to partially share, and modify, in the course of their participation. A typical session of the 5thD can be pretty confusing to a newcomer. Small clusters of children and undergraduates are grouped around computers, or drawing at a table, or examining a maze, or inspecting a log of recent achievements. There is a lot of cross talk, not a little arguing over strategies and obligations, and a good deal of coming and going for reasons that are hard to discern.

At first glance this sort of hurley burley might seem an unlikely place to be able to document processes of learning and development. By and large, the activity is *joint, collective* activity. This is how it should be according to a Vygotskian perspective; individual accomplishment is the precipitate of joint activity. But it poses severe problems for any psychologist who wishes to document learning and development as individual achievements.

In so far as one follows the path of the explanatory, nomothetic, First Psychology, the problems of evaluating learning and development in the Fifth Dimension seem insuperable. One such problem is that of attributing performance to individual children. After all, the rule of thumb in the Fifth Dimension requires the undergraduates to help out whenever they think it is necessary to provide the right sense of joint responsibility. The children know that they are college students, "big kids" who know a lot. Were the undergraduates to "hold out" on the children and display an interest in testing them, the dynamics of the joint activity would be destroyed. But how are we, as analysts, to parse any given performance by the child? How much of the product is really the responsibility of the child, and how much of the adult?

One seemingly simple way around this problem is to set up an experimental group of children that attend the Fifth Dimension and compare their performances on a set of criterion tasks with children who have not participated. There are two major problems with this straightforward approach.

First, the Fifth Dimension, by virtue of its fundamental organizing principles, is ***voluntary*** activity. The children not only self-select for participation in general, they self-select on a minute-by-minute basis. If they get bored, or frustrated, or have a soccer match to go to, or their best friend wants to play ping pong in another room, off they go.

Second, even if self selection was not a problem, and even if we could arrange for plausible control groups, and even

if we demonstrated that the Fifth Dimension produces measurable cognitive consequences "beyond the 5% level," we would face the inevitable question: what features of the Fifth Dimension are crucial to its effects?" Is it the participation in computer games? Is it interaction with the undergraduates? And so on. If we were to take such questions seriously, it would involve us in creating a variety of "almost Fifth Dimensions" with one or another hypothetically important feature removed to see if it made a difference. While this might seem like a feasible enterprise to some readers, my own experience with the vagaries of the Fifth Dimension renders me totally uninterested in such a snark hunt.

This is not to say that I have not worked at such evaluations and even scored some limited successes. Moreover, colleagues currently working with me in a multi-site implementation of the Fifth Dimension are engaged in just such analyses. However, I have become more interested in another possibility: that through a description of the interactions of children and undergraduates over time, it might be possible to document the process of change in such a way that the conclusion of cognitive benefits from participation in the Fifth Dimension can be firmly established.

Consequently, in my own work, and in the remainder of this paper, I concentrate on another possibility that implements an insight shared by Vygotsky, Luria, and Werner: it should be possible to evaluate the process of development with evidence about the genesis and transformation of problem solving abilities in the actual process of interactions among participants. Treat the process of developmental change as the product (Rogoff, 1995; Stone & Wertsch, 1984).

When Luria conducted research in the style he called romantic science, his data documenting the process of change consisted largely of clinical descriptions of what his subjects did and said, with a few more or less standardized test procedures included in order to gain deeper insight into specific processes.

Our data consist of a combination of detailed field notes written by undergraduates and other adults shortly after their participation in a 5thD session, unobtrusive tests that are embedded in the tasks that the children carry out as part of the games, and videotaped recordings. In the remainder of this article, I will concentrate my remarks on the description of change in the undergraduate field notes. These data are of particular interest to me because they both approximate most closely the main kind of evidence presented by Luria and provide a remarkable source of evidence about the process of microgenetic change, the level of development where the convergence between Werner and cultural-historical psychology is clearest.

Estimation Using Cartesian Coordinates.

My first example describes an occasion when Brian, ages nine, plays the game, *Shark*.[2] Shark was designed to provide children with deep experience in mediating their behavior through representations of the number line. According to the First Psychology, a well-developed representation of the number line is essential to the process called "long division," which is introduced to American children around the fourth grade. Children who have shaky knowledge of the number line experience inordinate difficulties in long division (Pettito, 1985). Consequently, evidence that the children who acquire a rich representation of the number line as a consequence of playing the Shark game often would be of both theoretical and practical interest. Figure 2 provides the display confronting children when they reach the third level of *Shark* (on the first level, only the abscissa, labeled "aim" is presented; on the second level, only the ordinate, labeled "distance" is presented). The field notes were written by Emily Rubin. Emily's description documents Brian's acquisition of knowledge about this important cultural tool.

[2] This game was written by Jim Levin

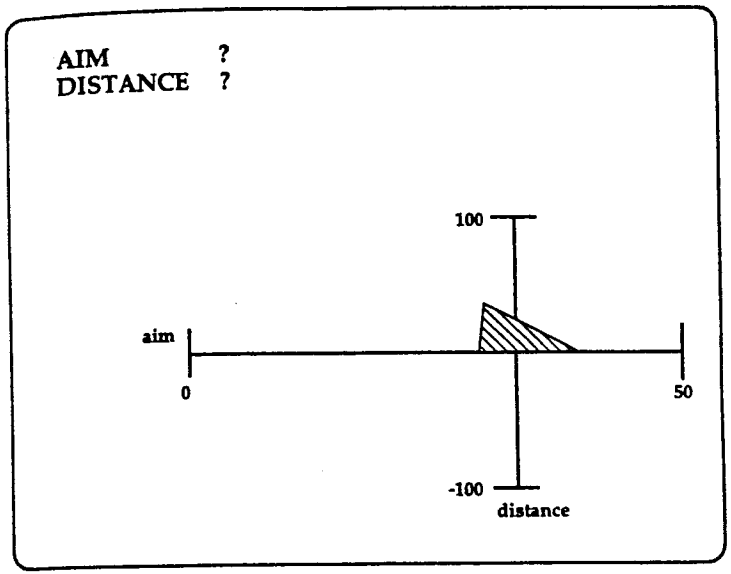


Figure 2. An example of a display of the Shark game, in which children must estimate the location of the shark on the horizontal and vertical number lines.

Emily writes:

I found the task card and joined Brian at the computer...I told him that I had only briefly played this game, so we should probably read the directions on the task card.

I read the description of the game from the task card. Before I had finished, he had begun the first level. For the first five levels or so, I used the task card to keep track of the guesses he made at harpooning the shark. He wasn't very aware that I was doing this until I told him that he had only made 2, 3, 2 and 1 misses and he was well on the way to becoming an expert at this game. He then began paying attention to what I was writing down. Every now and then he even asked me what his last guess had been.

During the first level of Shark, he was fumbling with the concept of the number line. He had not grasped the concepts of

"aim" and "distance" yet, rather he was just filling in the numbers which he felt corresponded to the lines on the screen. The first level was just an "aiming" level. He noted the numbers on either end of the number line and said, "This is huge!", referring to the distance between 0 and 50. He did much of his thinking out loud. "I'm gonna put..." he mumbled out loud, "I'll put 45". I would explain to him how his shot was too far to the right and he needed a lower number. He quickly shot the shark within two tries.

The second level was more difficult. It included distance as well as aim. He typed in a number for the first line and pushed return. He sat back in his chair expecting the harpoon to fly, but instead the computer read, "Type a number?". "Type a number!!!???", he read aloud. "I just did..." I told him that he would have to guess the distance as well. I motioned to the second number line on the screen. "You not only have to type where the shark is, but how high to shoot the harpoon," I said. He guessed the distance incorrectly. He was about to guess the second distance lower than the first when the shot had been too low. I remarked, "Remember last time? You guessed 33..." He quickly changed his input to 35 and harpooned the shark within three tries.

By the third level, he was prepared to enter both aim and distance. His first shot, which he made without my assistance, he exclaimed was "Too high!!!" (Referring to the distance number line). He began making the observations that I had previously made in the first two levels. On his next shot, he commented, "It was too high again! and too far that way!!" These directional comments were similar to the ones I had made on the previous levels.

As we made our way through the next few levels, he became more independent when making the decisions. For instance, when we were narrowing down a shot, I suggested that the aim should be 17, but he quickly responded by saying, "No,

I'll do something...(He was thinking of what to type)...I'll do 16" He was right on the dot with the aim, but the distance was still off. "So, I'll change the distance... " This was the first time I had heard him refer to the number line by saying "the distance," rather than pointing to the line and guessing.

Commentary on the Number Line Example.

Although I have truncated the exposition, this example provides an account of how the child comes to master the increasingly complex sub-tasks that the game sequence presents as part and parcel of his interactions with his undergraduate companion. (The fact that the child spontaneously talks aloud is an important resource for analysis of this example). Several moments stand out in this account:

- Initially the child takes no note of the adult keeping a record of progress, but then he starts to use the adult's contribution to mark his progress. Here we see the first of many examples of how new goals arise as the child comes to master new cognitive forms as a part of the joint activity with the undergraduate.
- As the game progresses, the child overtly appropriates the special pointers and adult verbal formulaic speech patterns, illustrating early stages in the acquisition of socio-cultural knowledge central to mastery of the number line and a Vygotskian account of development.
- There is an intimate link between the child's increasing ability to engage the game and the growth of excitement and satisfaction. In reality, if not in cognitive science, cognition and emotion are different aspects of a single process. As coparticipants in the joint activity, the undergraduates appear unable to give an account of learning and development in interaction except as they are fused with emotion.

Microgenesis Over Multiple Sessions

Although Vygotsky asserts that the process of microgenesis can take place over a number of days and even weeks, it is

primarily change within a single interactional session that has been analyzed in these terms. The 5thD, however, routinely provides evidence about the process of change over days and weeks, as the next example illustrates (See also Siegler & Crowley, 1991).

The set of field notes for this analysis was written by two UCSD undergraduate psychology students enrolled in the practicum course, Daisy, and Julie. Daisy's field notes cover 8 separate interactions over a one month period during which she worked with a 10 year-old girl named Vivian. Julie's notes are from one interaction with Vivian shortly after she had mastered the game she was playing with Daisy. The object they are working on is a computer game called *Island Survivors*.

Island Survivors is an ecology game that was intended as part of the *Voyage of the Mini* television project designed for educational purposes. The players are challenged to support an ecosystem by maintaining the life of all animal, plant and human inhabitants of the island over a period of many months. The core concept of the game is ecological balance which depends upon the construction and interaction of food chains. Activities on the island involve collecting firewood, building shelter for protection, and obtaining food by hunting, gathering and fishing. The human inhabitants, who are stranded for a year, can also suffer setbacks from sickness. Feedback on population size is given by graphs illustrating the status of each species for each month of the survival period (See Figure 3).

The basic cognitive challenges of the game include estimating and taking account of life cycles, food supply, weather, and health conditions The players must be able to interpret the graphs, work within time limits, and appreciate the factors that interact in the natural ecological system. It is also important that one be able to manipulate the keyboard effectively to move one of the survivors about the island to gather food. This aspect of the game is arcade-like; it requires practice and

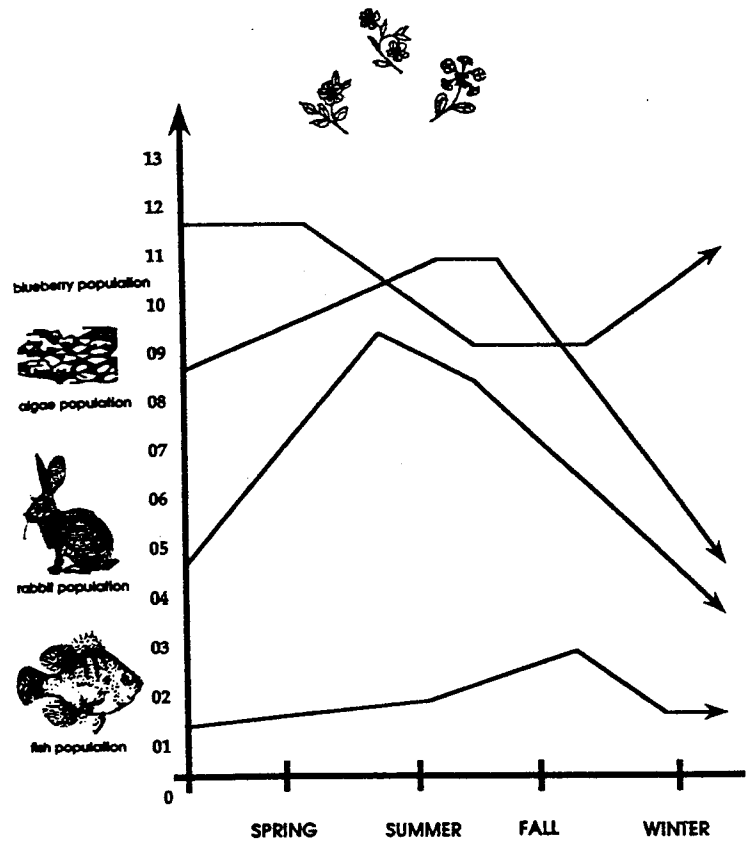


Figure 3. Sample screen from *Island Survivors* in which children must interpret graphic representation of population levels over time.

dexterity. If these activities are not carefully balanced or mastered, the human inhabitants risk starvation.

In our use of Island Survivors, the children initially play games that have been partially structured to insure that they