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EDITORS' INTRODUCTION TO THE SPECIAL ISSUE ON POSTFORMAL THOUGHT AND HIERARCHICAL COMPLEXITY

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We thank Alfonso Montouri and *World Futures* for inviting this special issue to highlight postformal thought and a range of work from the field of hierarchical complexity that defines it. Alfonso stressed that he wanted the issue to lay out the theory and postformal thought along with some of their respective applications and implications. Contributors to this issue have attempted to meet those expectations, for which we are grateful.

The Model of Hierarchical Complexity has a long history that only in very recent years resulted in its formal specification as a general theory. Our introduction to this special issue thus has three tasks to perform. It gives a synopsis of the Model's characteristics. Commons relates a brief history of the origins of the field of hierarchical complexity. He does this in order to identify with gratitude those who played key roles in influencing him and contributing to the Model's development over these many years. We then sketch the special issue's layout to suggest the story it is designed to tell.

THE MODEL OF HIERARCHICAL COMPLEXITY

There are two kinds of hierarchical complexity. The commonly recognized one refers to the ubiquitous linear hierarchies that are described in many fields of study. These are descriptive. By contrast, the Model of Hierarchical Complexity offers a standard method of examining the nonlinear activity of constructing the universal patterns of evolution and development. It accounts for evolution and development by recognizing their patterns are *comprised of tasks*, or actions, *performed* at specified *orders of* hierarchical complexity. Although the Model's unidimensional *measure* is linear, the *tasks* it measures are *nonlinear performances*, as this special issue conveys. The nonlinear activity of tasks is that of organizing, or coordinating,

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information. Hierarchical complexity applies to any events or occasions in which information is organized. The kinds of entities that organize information include humans and their biological systems as well as their social organizations, non-human organisms, and machines, including computers. The reason it applies so broadly is that it is a singular mathematical method of measuring tasks, and the tasks can contain any kind of information. Thus, its use of purely quantitative principles makes it universally applicable in any context. This enables a standard quantitative analysis of complexity in any setting, because it eliminates dependence on mentalistic, cultural, or other contextual explanations.

A BRIEF HISTORY OF THE MODEL OF HIERARCHICAL COMPLEXITY

In tracing the evolution of the Model of Hierarchical Complexity, there are four periods, each populated by different people and their contributions to its overall development. The two earliest periods were my pre-college then college and graduate school years. The next periods were from 1973 to 1983, and 1984 to present. The detailed history is in preparation for later publication. Highlights given here are selected to give credit where credit is due, without details that would flesh out the evolution of the general theory.

Pre-College Years

When I was 12, I read *Isaac Asimov*'s *Foundation 1*. From the strong impression I had about the math-psycho-historian character Mule, the idea of a mathematical psychology that could be used to predict history or at least understand it became a goal.

College and Graduate School Years

While at UCLA, *Albert Wohlstetter* (1958) was a key early influence. People met at his house to talk about decision making in Mutual Assured Destruction. He was a mathematical logician who became one of the world's leading nuclear and national security strategists. I suggested that his economic rational analysis was not the way people thought and that it might not be the best model. What about suicidal leaders like Hitler? I thought mathematics would shed light on thought, reasoning, and decision making because it was just such an activity. I became a mathematics major. I took a class from *John R. Myhill*, an Australian mathematical logician, on the completeness and incompleteness theorems of Gödel. Metamathematics had me hooked.

Donald A. Riley's class on animal thought clinched things and I knew that was the way. His class consolidated my idea of what human behavior was like. The precision I learned from *Donald M. Baer* in describing the contingencies gave me a way to view the world. *Edward Carterette's* course on thinking made clearer under what circumstances concepts were learned. But thought and action had to arise out of something less arbitrary than simple contingences of reinforcement and Hull-Spence mediated responses. What was it? Was it due to evolution, learning, and a combination? These questions would lead to my eventual focus on task complexity. In a class on personality, I wrote a paper comparing the basic assumptions of Freud, Skinner, and Lewin, showing that one could map many of the assumptions and characteristics of each from one theory to another. In retrospect, I realize I was doing Metasystematic stage 12 analyses at that point.

While at Columbia University, where I went to study with *Ralph Franklin Hefferline*, I met then–assistant professor *Deanna Kuhn*, with whom I would work later. My girl friend *Joan Borrison* complained about the *Bärbel Inhelder* and *Jean Piaget* (1958) book she was reading in a class with *Janellen Huttlocker*. It was a turning point for me when I read it. Its stage account was fascinating. I felt strongly that there was something about Piaget that was right. People were not crazy per se or irrational but rather, they simplified the world in an illusory fashion. I did not like the logic they used as a model but they had the right stages when the half stages were counted as stages. It also seemed it could be applied to all organisms' actions.

1973 to 1983

The effect of all the task analysis in behavior analysis and psychophysics, information processing theory, and five years of mathematics was to allow me to think about tasks in a very precise way. In 1975, when I saw *Deanna Kuhn* at the Society for Research in Child Development conference in Denver, I asked if I could work with her on some developmental research, and she agreed. We worked on the plant problem, the analog of Inhelder and Piaget's pendulum problem. Given my background in experimental science, I was trying to figure out how to have equal occurrences of each particular value of possible causes (e.g., lot or little water, leaf lotion or not, big or small pot of a plant) that would make a plant either healthy or sick. It became clear that there was no way to balance them in the plant problem she had developed because all single causes have the complement set of the other three variables as causes. That led me to think that the structure of the problem was where the constraints lay. Finite causal information will have the "causal" variables and their complements. Surely one had to have the physiology and the learning to attack the problem, but the problem was mathematical. It was a mathematical property of the task. I had reflected on the structure of the problem. I had identified a new stage. I was calling it the structural analytic, later to be named Metasystematic stage 12. That was one of the foundations of the Model of Hierarchical Complexity. *Janellen Huttenlocher,* who I knew from Columbia, agreed for me to come and give a talk on this structural analytic stage at the University of Chicago.

After coming to Harvard in the fall of 1977 as a postdoctoral fellow of Deanna Kuhn, I began to work with *Rick Richards* (Francis Asbury Richards). We wanted to develop a simpler problem than the one that the plant problem presented. We constructed the four-story problem and showed that it was an analog of Gödel's problem in the sense that systems of formal operations would be compared. Rick developed the V. P. Vanktesh story, Bad Bart the gambler, the Washing machine story, and the Richard Regan story. It was at that point we divided the "stage demands" of the task from the stage of performance, something that few people yet understand.

When I went to some of *Lawrence Kohlberg*'s scoring meetings in 1978 and 1979 and was confronted with his model and how they were trying to score items, I saw how much it needed the clarity of task analysis. I told him I thought he was right, but the way he went about it was wrong. I told him I would do it and write it up. I had already started working with Rick Richards, so we were ready to work on Larry's model. Straightening out Larry Kohlberg's stages was the biggest motivation for getting the precursor of the Model of Hierarchical complexity systematized as the stage generator it was.

At that time, there were no adequate means to decide whether or not something was a new stage. So in 1978, *Rick Richards* and I began to develop our first pass at the General Stage Model. We were ready for this because we had determined three aspects. The first was the stage sequence, which followed from our application of the second, our stage generator. We started with just three stages, the first being the Structural Analytic Stage. *Deanna Kuhn* suggested the name metasystematic around 1980. The second and third stages were from *Inhelder and Piaget* (1958). They were the formal operational and the concrete stage. The third was the separation of the hierarchical complexity of tasks from stage of performance.

We found out the first one to come up with postformal stages was *Patricia Arlin,* because of the support factor, which we only later understood. By 1980, we had learned about *Michael Basseches*'s theory. We were trying to understand how people understood systems and how they coordinated them. After we were successful, we needed to show that our four-story problem and the others measured a new stage of behavior. We had this done by late fall in 1977. I presented it at Western Psychological Association and gave a talk at *Judith Stevens-Long*'s class at California State University at Los Angeles shortly after. She later published an account of it in the first truly adult developmental text book, *Adult Life* (Stevens-Long, 1978). At the same time *Sternberg and Downing* (1982) developed postformal analogies problems.

During 1980, *Suzanne Benack, Rick Richards*, and I organized the first meeting of Adult Development. Our first meeting was called the *Beyond Formal Operational Symposium Held at Harvard*, March 31–April 1, 1981. We tried to locate everyone there was who had done work on postformal stages. As it turned out, this symposium founded the field of positive adult development. Networking began. In the process, I contacted *Kurt Fischer* and *Herb Koplowitz,* among others. They were extremely helpful.

Around this same time, *Deanna Kuhn* developed a transition notion that there were three transition steps: getting some causal variable correct but over generalizing; making no over generalizations but missing some actual causes; and then doing both correctly. *Robert A. Buhlman* and *Sharon Kantrowitz* came up with the idea of using signal redetection to score this transition. They also figured out the substeps of smash. The way we separated stimulus from response in those was really quite simple.

1984 to Present

As we were editing the *Beyond Formal Operations* (Commons and Richards, 1984a,) book**,** *Cheryl Armon, Francis Asbury Richards*, and I decided that it would make the new field of positive adult development more coherent if we had a comparative table of stage from the different postformal proposers. It was then that *Kurt W. Fischer* suggested we read his 1980 paper.

During and after the 1984 book, there were several breakthroughs. We used our stage generator understandings from Piaget and also Philip Cowan (1978), that higher stage actions are defined in terms of lower stage actions and organize them. That made the comparison possible. Our stage table was filled in with the help of the editors and *Kurt Fischer.* Specific stages came out of various discussions. In his chapter, *Herb Koplowitz* (1984) presented an unstaged example. As we discussed it, Herb's description made us all realize its coordinations gave rise to the new Systematic stage 11.

In 1981 and 1982, in our many phone calls with him when he was still at University of Denver, *Kurt W. Fischer* suggested the name for the abstract stage and made the suggestion for a possible sentential stage as set forth by Biggs and Collis (1982). What was strange is that for some reason, at that point neither Rick nor I were aware of *Fischer*'s (1980) seminal article in *Psychological Review* in which he laid out a good deal of the stage sequence. It would have saved us a lot of work. Yet we were coming up with almost the same stage sequences as his levels. We credited his work in our 1983 chapters, which had a copyright date of 1984. We differed in that later the Model had more stages: stage 0 for computers, stage 4 nominal, stage 13 paradigmatic, and stage 14 cross-paradigmatic. *Elena Jorum,* a graduate student at the Harvard Graduate School of Education, suggested the paradigmatic stage when she pointed out that if there was a cross-paradigmatic stage, there had to be a paradigmatic stage to cross.

The crucial insight that solved the major problem in our earlier version of the General Model of Hierarchical Complexity came when driving to Mexicali with *Roger Dunn* in 1984. We were on our way to meet with *Jesus Galaz* at Universidad Autónoma de Baja California. I wanted to collaborate on some research with Jesus on the existence of formal stage reasoning in non-literates. I was explaining to Roger our model. He asked how the organization of action was different from a chain of behavior. I said that in a chain, the organization of the subtask actions were arbitrary, whereas in the organization of lower stage tasks actions could not be arbitrary. This is because that organization usually has to work in the real world. We completed the conversation, agreeing on the nonarbitrary requirement, just as we crossed into Mexicali, Baja California. It was clear that higher order complexity tasks actions had to be defined in terms of lower order ones. We wrote this up in our chapters in the 1984 book. We showed our sequence and pointed out the similarity to *Fischer, Hand, and Russell* (1984) in the same volume.

In 1990, *Jonalu Johnstone*, *Jeremy B. Straughn*, *Maryellen Meaney*, *Julia H. Weaver*, *Erica Lichtenbaum*, *Sharon R. Krause*, with *Dorothy L. Danaher*, *Cheryl Armon*, *Suzanne Benack*, and *Dawn Schrader* wrote the first scoring manual, called Applying the General Stage Scoring System (GSSS). We also tested some of the assumptions of the model using Signal Detection scoring of responses to the Doctor–Patient problem and Laundry problems. It did not work well.

The development of instruments began with the plant problem and its paint and pendulum variants. Then Richards and I developed the multisystems (Four-Story task in 1978). *Peter Hallinan*, *Wilson Fong*, *Charles Ford*, and I developed the first sequence of tasks based on the Laundry problem. We wrote a computer program to test for the concrete, abstract, formal, and systematic stage in the early 1980s. We were indebted to Kurt W. Fischer for suggesting that there should be an item that measures each stage in a sequence.

Our present system for constructing instruments began with *Joseph Anthony Rodriguez* (1992). We adapted the stages for making the multisystems task to our new Doctor–Patient vignettes, (Commons and Rodriguez, 1993). *Theo Dawson* (now Dawson-Tunik) made a key contribution in 1996 when she said we should be using Rasch analysis instead of signal detection. That was major. She carried out a number of empirical validation and reliability studies, which are cited in this issue, *Trevor Bond* has been key to the empirical side, too, along with *Michael Linacre* who helped us run all these Rasch analyses.

After I took *Robert Duncan Luce*'s class on measurement theory in the late 1970s, I could start to formalize the theory to some degree. This had to be done in steps with *Rick Richards* at first, then with *Edward Trudeau*, and finally with *Alexander Pekker*, who cleaned up the mathematics and provided the combinatorial mathematics for the nonarbitary requirement. He also suggested that the equal spacing assumption should go.

The most extensive revision was completed in August of 2004. After working a year and a half with *R. Duncan Luce, Alexander Pekker* and I straightened out the formal mathematical theory. He systematized the meaning of non-arbitrary in a brilliant way, showing that not all combinations of behaviors were allowed. All this has profound implications. At the heart of our argument we used the mathematical notion of distribution to show the irreducibility of long multiplication to simple addition and multiplication. Luce told me and my son Lucas in the summer of 2003 that distribution was the core idea that made things work. Here, I had generalized distribution into the non-arbitrary organization of lower stage actions. This was general enough to fit all of thought and action, and yet powerful enough to generate stages. This also formed a new mathematics of complexity that was orthogonal to other forms. The only new thing I have done since then is to come up with the idea for the measurement of g (Commons, 2006; also see "Toward a Cross-Species Measure of General Intelligence", this issue). That proposal for cross-species measurement is a theoretical consequence of the Model.

After *Gerhard Sonnert*'s early work, *Sara Ross* has contributed the most accurate account of the social and political analyses using the Model, with more detail and accurate descriptions than Commons and Goodheart (1999, 2007). She is the one who pointed out that the Model is fractal because it shows by measuring any tasks that it is self-similar at all scales. She came up with the fractal characteristics of both the transition steps and within the smash sequence that is within the transitions. We are looking for people to help us develop the mathematics for all that. Now, we have to come up with a name for the new order 15 in the Model. This is the stage-generator characteristic of the Model's axioms in action: to reflect on the tasks of a given order, one has to be performing at the next highest order. To make a Cross-paradigmatic stage requires some glimpse of the 15th.

I think we made only one or two mistakes along the way. One was thinking for a short period that the orders were equally spaced. Another may be how much or whether to rely on signal detection. Two mistakes are not bad for a whole research program spread out over so many years.

THE HIERARCHICAL COMPLEXITY STORY IN THIS SPECIAL ISSUE

It is hoped that this special issue offers readers a solid introduction to the field of hierarchical complexity. To present its general theory of evolution and development, the foundations section of the issue includes a number of articles that address central concepts and evolutionary dynamics. These are inherent in, and consequences of, the theory. The foundations section is rounded out by inclusion of an article demonstrating a theoretical consequence of hierarchical complexity's universality.

Postformal thought is another consequence of the Model of Hierarchical Complexity, one given explicit focus throughout this special issue. Its emphasis indicates that it offers potentials to science and society that other stages of reasoning cannot. Throughout, contributions refer to subjects covered elsewhere in the issue. Such cross-referencing results in weaving the applications and implications of hierarchical complexity across content areas. We hope the result is a coherent story of hierarchical complexity and its ubiquitous role in the evolution of life, the living of life, and the continued existence of life in its many forms.

Once the theoretical foundations are laid, evolution's hierarchical complexity is illustrated from a number of angles. The hierarchical complexity view of evolution and history sets the context for the selection of articles that develop the theme for humans and their societies, past, present, and future. These are applications of the theory just as much as those included in the next section, labeled applications. Taken as a whole, this issue encompasses a breadth of applications.

Explicit attention to other implications of hierarchical complexity and postformal thought rounds out the issue. These contributions indicate that there are numerous cross-cutting implications for the future of human society and its evolution. These also suggest challenges ranging from how societies and their institutions are organized, to how postformal thought itself presents challenges, to illustrating why postformal thought and action are essential in our increasingly demanding world futures.

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