Revelator Game of Inquiry: A Peircean Challenge for Conceptual Structures in Application and Evolution

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Abstract. In unpublished manuscripts from Peirce's last decade, he emphasizes his dialogic and interactive view of logic-as-semeotic, exemplified by the Existential Graphs. Recently published research of these manuscripts solidly supports the project of creating a game for instituting his pragmatic methodology to demonstrate his full semeotic logic. Revelator is my conception of that game, to pursue Peirce's ideas for *improving the economy of inquiry*. Revelator's design somewhat resembles many well-known games, such as bridge, chess, crossword puzzles, and even poker, but its core purpose is to reveal complex relations among the conditional propositions, by which players represent their conjectures as plays in the game. The game design invites the application and evolution of Conceptual Structures technology to aggregate, integrate, and display the *complex logical behavior* of these propositions. Plays are treated as rule-defined agents that can adapt in complex conceptual environments to form multi-agents, promoting the emergence of collaboratively formulated and selected models of possible knowledge (or robust hypotheses). Peirce's full vision of a dynamic logic continues to challenge Conceptual Structures to become an engine of inquiry.

1 Introduction

Successful inquiry is a complex phenomenon, an experience that requires imagination in conjecturing, in devising ways of gathering and checking the evidence as exhaustively as possible, and in avoiding potential sources of error. Good inquirers are careful, skillful and persistent in collecting relevant evidence and discovering new evidence, with the intellectual honesty to avoid temptation to discount unfavorable evidence that threatens to undermine their conjectures. They need both rigorous reasoning, to predict the consequences of their conjectures, and good judgment, for assessing the significance of the evidence and guarding against the tendency of wishful thinking. Because of these demands, even scientific inquiry progresses in a "ragged and uneven way," as Susan Haack describes it, and yet still finds "new truths, better instruments, better vocabulary, etc., and ways to build on them; so that over the centuries the sciences have built a great edifice of well-warranted claims and theories (even though, to be

U. Priss, S. Polovina, and R. Hill (Eds.): ICCS 2007, LNAI 4604, pp. 443–459, 2007.

sure, the trash-heap of discarded concepts and theories is larger by far)" [Haack (2003: 338; see 340-41].

Particularly in 21st century science, explains C. Dyke, the necessary increase of multi-disciplinary inquiry requires that "everyone is fully, self-consciously, aware of the 'rules and regulations' governing serious contribution, both in the home discipline and in the more extended one" [Dyke (1988): 3-4]. He invokes Warren Weaver's manifesto delineating the evolution of inquiry in science leading to its current imperative.

> [T]he science of the enlightenment taught us how to deal with organized simplicity. Nineteenth century science (Boltzmann, etc.) taught us to deal with disorganized complexity. The challenge for twentieth century science is to learn how to deal with organized complexity (without, I would add, pretending that it is simply conjunctive simplicity). ... Not only are the phenomena to be studied complex, but scientific practice itself is a phenomenon of organized complexity. The complexity of investigation must be studied along with the complexities investigated. The old positivist philosophy of science was a canon of simplicity, providing no room for a clear understanding of complexity. Insofar as working scientists (and social scientists) continue to understand their own activity in a positivist way (as many do), they will not find the space to meet Weaver's challenge. [Dyke: 5]

Although Dyke concurs that inquiry needs, in place of the positivist explanatory framework of simplicity and linearity, a new framework for dealing with organized complexity, he insists that it be capable of accommodating "the firm results obtained by the sciences of organized simplicity and disorganized complexity." These stand as foundations upon which to build a new integrated approach, he says, if we pursue strategies that: "(a) are consistent with and legitimated by our earlier successful practice; (b) take full advantage of the resources and the models we have at our disposal; (c) do not foreclose any legitimate options that we might want reopened at a later stage; and (d) do not leave us with a tangled mess of hypotheses incapable of being integrated or even compared" [11].

Ahti-Veikko Pietarinen finds plentiful evidence in Peirce's late manuscripts that his work on logic, semeotic [his preferred spelling (see *CP* 8.377, 1909)], and Existential Graphs (EGs) was pointed toward what in the 20th century became game theory and model theory, on the way to a new framework for scientific inquiry. Pietarinen maintains: "Understanding of Peirce's logic is only just evolving. This is mainly due to unavailability of published material from his last and very prolific epoch. ... I believe that the connections between, say, the emergence of existential assumptions in quantification, the reduction thesis concerning relational notions, the dialogical approaches to semantics, the tenet of constructivism, and the theory of modalities are all destined to find solid logical home in Peirce's overall semeiotic programme." [Pietarinen: 181]. He concludes, "Much more is to be expected from applying and eventually injecting Peirce's ideas into the modern theories of games and rational behaviour than is currently realised" [462]. Revelator is my attempt to apply Peirce's ideas in a game context toward creating a framework for 21st-century inquiry that can integrate successes of the previous frameworks [see Keeler (2000, 2003-2006); *CP* 7.328-335] (1873); *CP* 1.372 MS 909, 1887-88; MS 298 (c. 1905); MS 318 (c. 1907)].

2 Revelator: Game of Inquiry

Revelator is conceived as a game for improving Inquiry. We conduct inquiry when we confront a puzzling situation and attempt to resolve the puzzle by constructing hypotheses. Hypotheses formulate our conjectures about what we anticipate might solve the puzzling situation. Hypotheses are "educated guesses" that may become firmer when they improve our anticipation: when certain conditions are fulfilled as we guessed, to produce the consequence we expect. A hypothesis formulates an answer to the pragmatic question: Under what (specified) circumstances would my belief (about something) be true?

In playing Revelator, players make their conjectures explicit by formulating them in terms of conditional propositions that attempt to answer puzzling questions. For a very simple example, if you saw some unfamiliar animals, you might conjecture that they are birds and make the claim: "Those animals are birds, because they can fly." Any conjecture may serve as an explicit hypothesis, if it is formulated in a conditional proposition whose antecedent specifies a course of action to be performed and whose consequent describes certain consequences to be expected. The primary rule of this game of inquiry is that players must use the conditional form to relate claims and reasons supporting them in the explicit form of hypotheses; for example: "If I observe those animals flying, then they are birds." Notice that the claim and reason above can be easily reformulated into this "if ... then" form.

The Revelator Game of Inquiry is to be played among a group of inquirers, who confront a puzzling situation and want to construct hypotheses collaboratively. Although not played collaboratively, the US television game "Jeopardy" may begin to suggest the format of this game. Several Jeopardy contestants compete by formulating questions in response to answers displayed in a matrix of answers categorized under topics. Instead of Jeopardy's arbitrary format requiring questions from contestants to match answers posed in topical order, Revelator requires players to use the format of a conditional proposition, composed of a claim and a reason for that claim, as a legal play in the game. Plays in this logical form can serve as inferences to be related to and articulated with other players' claims and reasons contributed as conditional propositions in the progress of the game.

Through inquiry, we gain knowledge of which conjectures are justified to be considered candidate hypotheses. In expressing a conjecture as a claim, we assert a real possibility of an event we can imagine, which would be realized under certain describable conditions. Descriptions of these conditions are reasons that might justify our claims as contributions to the process of inquiry, by referring to evidence that can be checked to support the claims [see Keeler (2004); (2005)].

Peirce explains that although any claim that pretends to disclose a new fact without basing it on new evidence cannot possibly be correct; that observation cannot serve alone. "[F]or if it did the only active part which we should have to play in this method of inquiry would be simply the willingness to observe, and there would be no distinction of a wrong method and a right method of investigation." There must also be "*an elaborative process of thought by which the ideas given by observation produce others in the mind*" [my emphasis]. Furthermore, observations widely vary and are never exactly repeated or reproduced. Not only can no one make another's observations, or reproduce them; but no one can make at one time those observations which that same person makes at another time. "They belong to the particular situation of the observer, and the particular instant of time. ... Since, therefore, the likeness of these thoughts consists entirely in the result of comparison, and comparison is not observation, it follows that observations are not alike except so far as there is a possibility of some mental process besides observation" [*CP* 7.329-33 (c. 1873)].

Especially in collaborative inquiry, interpretations of evidence and the inferences relating them can quickly become complex. How can participants efficiently construct the evidentially soundest and inferentially most fruitful hypotheses from the countless possible conjectures asserted by all? How can participants "put their heads together" in collaboration, combining their individual "best guesses," to construct hypotheses that incorporate possibly all their conjectures? What logical augmentation tools might facilitate that aggregation and integration process? And what self-corrective habits in their interactions might participants cultivate by engaging in such a process? Revelator's purpose is to address these questions in the spirit of Peirce's "economy of research" [see *CP* 1.122 (1896), 7.158-61 (1902), 7.83 (1902), 7.219 (1901)]. The ultimate research question will be: Can Conceptual Structures technology augment the process of aggregating and integrating inferences to reveal collaborative hypotheses, to improve the process of inquiry?

3 The Economics of Inquiry

According to Peirce's theory of inquiry, while deduction can discover the hidden complexities of our concepts and induction is "the sole court of last resort in every case," only by abductive reasoning can inquirers originate a proposition. He maintains that although even careless abduction will eventually suggest a true hypothesis, "The whole service of logic to science ... is of the nature of an economy. ... it follows that the rules of scientific abduction ought to be based exclusively upon the economy of research" [*CP* 3.363 (1885); 4.581 (1906); 7.220 (1901); Keeler (2006); see Note 1; also see Tursman]. Instructed by Peirce's ideas, a pragmatic game for improving the economy of collaborative inquiry would induce players to find the most promising initial and strongest unifying claims, consider new and provocative evidence, foster the requisite technical skills (including those for effective expression). Broadly, its purpose would be to promote awareness of the patience, time, and persistence needed to add inference to inference for steady advancement and to encourage players to remain on the lookout for techniques to cope with these factors more effectively. Overall, the game must help investigators routinely self-correct — that is, to form habits that minimize error. Finding and reducing errors (both in interpreting evidence and in constructing inferences) is crucial in constructing good hypotheses for the economy of inquiry [see Weiner: 178; and *CP* 1.120 (1896), see Note 2].

Inquiry has many possible sources of error that cannot be completely captured by any proper logical model for finding the truth. The work of investigation is difficult and inquirers are fallible, sometimes because of prejudices or entrenched and unexamined commitments to poorly warranted background beliefs, such as in stereotypical thinking. Inquiry, unlike advocacy, is an attempt to discover the truth of some question, whatever that truth may be — but without expecting omniscience to reveal the complete truth. In advocacy, people negotiate about whose perspective should prevail. Advocates attempt to make a case for some opinion, by selecting and emphasizing whatever evidence favors that opinion and ignoring or playing down any that does not. Inquirers must do their best to discover some truth about the puzzles that concern them, regardless of whether that truth advances any personal interests. They must seek out and assess the worth of relevant evidence by a process in which they understand that their claims are fallible, revisable, and seldom impartial, because the social context of their work can affect even what questions are considered worthy of investigation and what solutions occur to them [see Haack (2003): 338-41; *CP* 1.43-49 (1896)].

When we as inquirers make our beliefs explicit in the conditional form of claims and reasons, we consciously distinguish between the possibility that something is in fact true and *how we think we know it is true*. The result of inquiry, accordingly, is not that our belief becomes true, but that we gain knowledge of how justified the belief is. In other words, inquiry requires us to distinguish between *identification* and *classification*: no two things are in fact identical, but we may be justified in classifying our representations of them as being related in some way that can be explicitly expressed. A particular hypothesis can be judged correct, then, to the extent that we have perceived and effectively represented a correspondence between a description of some consequence of our classification and the identified actual occurrence of that expected consequence. Our knowledge is built of these justified relations among our *representations of* described and classified *experiences* of what we call "facts" [see Keeler (2006): 319-20].

Whatever relations we claim to be among things we observe, and call "facts," are conditionally dependent on how we perceive and conceive them. Because hypotheses explicitly express this conditional dependency, when you as an inquirer assert a hypothesis you become responsible for its claims, as though you had placed a wager on it [see *CP* 5.543 (1903)]. If in the process of inquiry these claims are found to be correct, you win the wager; but just as with plays in the game of poker, the significance of those claims together with other justified claims, as knowledge, must wait to be *revealed* in the evolution of further inquiry. Since none of us is omniscient, the more other inquirers engage in contributing and evaluating claims and reasons, and building justified relations among them, the greater our chances of constructing strong hypotheses and reliable knowledge based on more experience. At the same time, the complexity of conceived claims and reasons represented in collaborative inquiry makes economy an even greater challenge.

4 Inquiry's Intricate Forms of Inference

Peirce explains three qualities, "Caution, Breadth, and Incomplexity," as the economic considerations in the intricate evaluation among hypotheses.

> In respect to caution, the game of twenty questions is instructive. ... The secret of the business lies in the caution which breaks a hypothesis up into its smallest logical components, and only risks one of them at a time. What a world of futile controversy and of confused experimentation might have been saved if this principle had guided investigations into the theory of light! Correlative to the quality of caution is that of breadth. For when we break the hypothesis into elementary parts, we may, and should, inquire how far the same explanation accounts for the same phenomenon when it appears in other subjects. [*CP* 7.220-21 (1901)]

He further explains how an incomplex and even rough hypothesis can be more robust and do what a more elaborate one would fail to do [see *CP* 7.222 (1901)]. And he often identifies incomplexity with the dialogic purpose of his EGs in "the central problem of logic, [which is] to say whether one given thought is truly, i.e., is adapted to be, a development of a given other or not" [*CP* 4.9 (1906)].

To avoid advocacy, inquiry should proceed only from claims that can be subjected to careful scrutiny of their reasons (as evidence), and inquirers should rely on a "multitude and variety" of many claims and reasons that can be *conceptually articulated*, rather than the apparent conclusiveness of any one claim. As Peirce explains, reasoning in inquiry should not form a "chain of inferences" (which is no stronger than its weakest link) but rather a *cable*, "whose fibers may be ever so slender, provided they are sufficiently numerous and intimately connected" [*CP* 5.3 (1902)]. The minutest details formulated as claims and reasons can collectively turn out to be crucial contributions in constructing strong arguments. Although this process of inquiry cannot be fully automated, technology can perform functions of representation, bookkeeping, and logical articulation that are tedious and error-prone for humans, to clarify and reveal hidden conceptual complexities.

To grasp or understand a concept is to have practical mastery of inferences in a network involving that concept—and *evolving* its application. Fully grasping complex inferential networks of conditional relations is a significant challenge for inquirers, especially in collaborative inquiry. Asserting a responsible claim requires understanding at least some of its consequences, and realizing what other claims it relates to and what other evidence relates to it. In a game of inquiry, players' develop research strategies in making plays that can justify other plays, can be justified by still other plays, and that close off or precludes still further plays. Players in the game need logical augmentation to help them develop the practical mastery of inferential articulation for this conceptual content [see Keeler (2004); and (2005) for a scenario of players].

5 Play of the Game

Scoring the plays in Revelator involves keeping track of each player's properly contributed conjectures (each asserted conditional proposition increases a player's score by one point). Strategy in the game involves learning to evaluate all contributions. A player must be able to keep track "upstream," to find what other claims may have implied or justified any claim in question, and also "downstream," to keep track of what else any claim in question implies or justifies as consequences. Overall, players must keep track of the interactions of claims and reasons, especially those that are inferentially or interpretationally incompatible, indicating that more investigation is needed.

Unlike many "normal-form" games identified by game theory, in which each player chooses a strategy once and for all, Revelator is an "extensive-form game," in which new strategies are developed *as more general claims and reasons*, calculated to incorporate or select other players' claims and reasons. Pietarinen explains that in the traditional theory of games (formulated in von Neumann & Morgenstern (1944), strategic interaction is static and that "the truly dynamic theory of games is still under intense development" [448]. He points out in Peirce's terms, "strategies are instructions that evaluate actions, and hence are species of thirdness. They indicate what the actions of a player or an agent ought to be in an inventive manner. In their capacity of providing functions that evaluate individual choices, they also provide a route by which one might hope to be able to understand how intelligence emerges, namely through the constant evaluation of individual action, and with the aid of the associated notions of learning and recognition of new concepts as implied by these actions" [442].

Since conditional propositions are the counters that increase a player's score, each counter must be linked to its player's identification, and appear in a collection of that player's conjectures in the game. Strategically, any conjecture is a player's agent, and should provide motivation for what else is or might be claimed. The play of the game reveals the possible "strategies" of "conjecture-agents" (that is, the logical consequences of their combined implications) among all "agents" (or plays) in the game. A form of "controlled English" can be used to accomplish the translation of the "if ... then" form of plays into formal logical expressions (See example: <www.ifi.unizh.ch/attempto>). In the operation of a real game of inquiry, relations among the plays would become complex. In the earlier example, "If those animals can fly, they might be birds," the reason "those animals can fly" would be articulated with other reasons related to claims that an animal is a bird, and also to any other claims that are justified with the capability to fly expressed in a reason.

In imposing constraints on the linguistic form of plays, Revelator is somewhat like the game of bridge, as Dyke analyzes that challenge: "to accept the lean vocabulary with its rigid constraints, and to shape and manage it so that it gains the capacity to do its limited job elegantly and precisely" [Dyke: 80]. Dyke compares playing bridge to a laboratory experiment in which experts carry out a dialogic, goal directed, and limited but intellectually complex activity [see Dyke: 74]. His concept of *information space* conceptualizes the constraints and limitations on the legitimate discourse of the bridge auction [Dyke: 83]. The matrix used to represent the calls in a bridge auction can be used to trace the path through the information space leading to a final contract, which makes the game seem like the perfect place to evaluate the rationality of paths [see Dyke: 89]. However, he explains, as in many cases of evolutionary ecology or the genetic code:

> [m]any possible pathways are adequate for particular hands, and particular pathways are adequate for many possible hands. (Brooks and Wiley [1986] remark that evolution is not the survival of the fittest, but the survival of the adequate.) No management of the limited information space is possible which univocally matches bidding matrices with hands. There are, however, ways of grouping hands and matrices to provide criteria for *reasonable* matchings. Were this not so, bidding skillfully and choosing a bidding system would be impossible. Determinism is absent here, so skill finds an essential role. [Dyke: 90]

Skilled inquirers evaluate each conjecture for: what it implies, what other conjectures are consistent with it, what others are inconsistent, and how it stands up to the evidence (that is, what consequences should follow from its truth, to what degree it is confirmed by any consequences that do follow, how it is false if the consequences do not follow). Whether we are investigative journalists, detectives, historians, house inspectors, dog breeders, theater set designers, or just making our way through life, we use such skill more or less explicitly. Formal inquiry is conducted to improve the skill of ordinary everyday inquiry, by overcoming our sensory and cognitive limitations and our fragility of commitment to finding out. Science has been remarkably successful because of the steady evolution in its enhancements of imagination aids, of sensory and reasoning capabilities, and of evidence-sharing and intellectual honesty, which are intricately related in the operation of its inquiry [see Haack (2003): 341]. Revelator is intended to reveal these multi-dimensional complexities.

6 Complexities of Inquiry in Operation

Haack uses the analogy of a crossword puzzle to represent the nonlinear character of inquiry, its "weaving of interconnected threads" making mutual support among conjectures possible, without vicious circularity [see Haack 1993, 2003]. Determining progress in a game of inquiry is more like determining the reasonableness of entries in a crossword puzzle with their pervasive mutual support, than like judging the soundness of an essentially one-directional mathematical proof.

Crossword clues are analogous to inquirers' reasons for believing based on experiential evidence, and any already filled-in entries are analogous to claims already established with some certainty. Although the clues don't depend on the entries, the entries are somewhat interdependent. Relations among clues and entries are also analogous to the *asymmetries* between experiential evidence and asserted claims that must be based upon that evidence. Confidence in the correctness of any entry in a crossword puzzle depends on: how much support the clue gives that entry, along with support from any intersecting entries that have already been filled in; confidence that those intersecting entries are correct, independent of the entry in question; and the extent to which intersecting entries have been filled in. Justifying an entry or a play in the game then must be partly *causal* (requiring evidential verifiability) and partly *evaluative* (requiring logical validity), and the crossword analogy illustrates how the "explanatory integration" of these two parts depends on how favorable, how secure, and how comprehensive any supporting evidence is [see Haack (1993): 81-82].

An especially successful play in the game of inquiry then would be like completing a long central entry in a crossword, making other entries significantly easier to fill-in: a substantial contribution to the *explanatory integration* of "a web of conjectures." At the same time, such a play also scores well with *experiential anchoring*: a conjecture is more justified the better it is anchored in experience and supported by other conjectures that are integrated components of an explanatory story and also anchored in experience. Such a "breakthrough" may even make further breakthroughs feasible, consolidating or generalizing over many dependent conjectures. Conversely, discovering a wrong crossword entry resembles what might be called a "breakdown" in the game of inquiry, when a key claim turns out to be confirmed invalid by all players.

Figuring out how reasonable our confidence in some crossword entry is, comes down to not only how well some entry is supported by others, but how well it is supported by its clue. Analogously, appraisal of how justified a particular conjecture is depends on both how justified are other conjectures that it depends on (how dependently supported it is), but also on how justified the reasons are for that conjecture (how independently secure it is). Justification for conjectures cannot be proclaimed categorically, but must be ascertained in degrees.

Furthermore, both degree of support and degree of independent security are not sufficient to determine the degree of justification. Eventually the appraisal reaches a point where the issue is not how well some conjecture is supported by others, but how well it is supported by experiential evidence. Devastating evidence, such as demonstrating that an initial, foundational conjecture was based on an illusory observation, can "wipe-out" an entire construct of conjectures. The comprehensiveness of the evidence for (or against) a conjecture must also be taken into account in determining its justification. This would include failures to take relevant evidence into account (including to look closely enough, to check from different angle, etc.). So a conjecture is more justified, the more supported and the more independently secure it is, and also the more comprehensively relevant evidence is taken into account. Distinguishing the error- and ignorance-related aspects of our fallibility, through explicit inquiry, reveals that they are pervasively interdependent and complex [see Haack 2003].

The crossword and other game analogies only begin to show the intricacies and complexities of formal inquiry. Without that formality and responsible conduct, our everyday careless inquiry often becomes what Haack [2003] calls "pseudo-inquiry." These are really forms of advocacy that are ubiquitous in academe, politics, and elsewhere, they include "sham reasoning" (when we make a case for the truth of beliefs to which we are already steadfastly committed) and "fake reasoning" (when we make a case for the truth of beliefs to which we are indifferent but believe will benefit us). Sham and fake reasoning show how inquiry can be perverted to give beliefs support and security, without comprehensive evidence for their justification. Such pursuits reduce knowledge to a sort of "map" for the "virtual territory" of limited purposes and advocate that *representation* as all there is to knowledge. Inquiry then becomes the sort of "game" in which we "mistake the map for the territory." In genuine inquiry, we understand the role of such "map-making" as the construction of coherent accounts or models to carry out exploratory, conceptual investigations.

7 Inquiry as a Complex Adaptive System

Players in the Revelator game would construct these model representations, by which to "prune, filter, and select" among all the contributed claims and reasons, toward formulation of collaboratively constructed hypotheses (or robust models). Its game format would serve as an effective method for inquiry in several ways that resemble the skills-building features of familiar games. First, the game would formalize the strategic process of inquiry, explicitly and sportively. Second, it would encourage collaborators to engage in the conceptual discipline of formulating model hypotheses. Third, it would induce responsible conduct among players by requiring explicit reasons for their claims, and to encourage competition within a stable pattern of cooperation [see Axelrod (1984)]. Revelator leaves the burden of constructing and checking intricate logical relations among contributed claims and reasons to automated conceptual processing, which would keep score and track individual contributions, identifying each with its originating player, to create an automatic credit system that promotes fair competition among inquiring players.

Since inquiry's purpose is to construct hypotheses that are reliable enough to serve as stable strategies in the evolution of further inquiry, within Revelator's game context competing claims and reasons could behave as players' agents in complex adaptive systems (*cas*) [see Holland 1995, 1998]. The building blocks for evolving the stable strategies in *cas* are interacting agents, described in terms of rules (expressed as "if ... then" statements). In *cas*, any agent must adapt to other adaptive agents as part of its adaptation to an environment, just as a player's contributed conjecture (expressed in "if ... then" form) must adapt to others contributed in the game. Agents adapt their behavior by changing their rules as experience accumulates; in the same way, hypotheses must change claims and reasons as evaluations and evidence accumulate.

Analogous to the children's game of building blocks, the game of inquiry has propositional "building blocks," with logical constraints rather than physical ones. These conditional-proposition agents (as "if ... then" rules) establish the "dimensions," in place of the dimensions of physical blocks. Geometrical and gravitational (forceful) constraints are replaced with inferential and evidential (factual). These conditionally-related building blocks must "behave" as complex systems adapting to a conceptual "environment," in which fallibility would serve as gravity does in physical systems, within the "dynamics" of conjectures. Players could explore future possibilities and continually bring the state of the model up to date as new claims are contributed, to improve the *faithfulness* of the model they construct. Revelator is *explicitly* a game of inquiry, so players remain aware that: "uncertainty lies in the model's *interpretation*, the mapping between the model and the world" [Holland (1998): 44-48].

At the beginning of Peirce's last decade, in a series of lectures at Harvard, he struggled to explain thought (or Thirdness) as an active factor in the real world, against the common assumption that the inviolable laws of dynamics determine all motion, and explain whatever happens in material universe, leaving no room for the influence of thought. He stressed that the laws of dynamics are different from such laws as gravitation and elasticity, and may even be precisely like logical principles: "They only say how bodies will move after you have said what the forces are. They permit any forces, and therefore any motions." Finally, he asked how anyone can be certain that we have sufficient knowledge of these laws to be reasonably confident that they are so absolutely eternal and immutable that they escape the "great law of evolution"?

> Each hereditary character is a law, but it is subject to development and to decay. Each habit of an individual is a law; but these laws are modified so easily by the operation of self-control, that it is one of the most patent of facts that ideals and thought generally have a very great influence on human conduct. That truth and justice are great powers in the world is no figure of speech, but a plain fact to which theories must accommodate themselves. [*CP* 1.348 (1903)]

In Pietarinen's view, these *easily modified* habits are evolutionary strategies that include: "rules, responses, guides, customs, dispositions, cognitive conceptions, generalisations, and institutions that have influenced [conduct] through evolutionary time." *Interpretation* is the evolutionary strategy by which Peirce "attempted to illustrate the emergence of experience as dialogical action between the inner and the outer, or the potential and the actual" [442, 191]. Without this *evaluative* function, complex adaptive systems cannot bridge the gap between rule-governed habits and truly inventive habits (between Secondness and Thirdness, in Peirce's terms). John Holland concludes: "we will not truly understand complex adaptive systems until we understand the emergent phenomena that attend them" [(1998): 242].

8 Holland's Explanatory Framework

Researchers in collaborative inquiry often jointly uncover possibilities unsuspected by any one participant, as do players in a game. And like regular players of a game, investigators begin to recognize certain kinds of patterns that become "building blocks" for longer-term, subtle strategies (something like "forks," "pins," and "discovered attacks" in chess). Holland identifies this "getting more out than you put in" as a ubiquitous "emergent" feature in the world around us: in rules of thumb for farming, ant colonies, networks of neurons, the immune system, the Internet, and in our understanding of the physical world, which has emerged from a small corpus of equations originated by Newton and Maxwell. Holland's work investigates the enigma of this feature: "how can the interactions of agents produce an aggregate entity that is more flexible and adaptive than its component agents" [(1998): 215, 248]?

Holland began in the 1970s to develop his "framework for understanding many important facets of learning in organisms and machines, ranging in complexity from conditioning in rats to scientific discovery." He collaborated with philosophers, cognitive scientists, and AI researchers in the attempt to integrate the ideas of several disciplines and construct a systematic approach to the study of induction: "all inferential processes that expand knowledge in the face of uncertainty." The basis for his framework was derived from his earlier *classifier systems* [1978]. "Classifier systems are a kind of rule-based system with general mechanisms for processing rules in parallel, for adaptive generation of new rules, and for testing the effectiveness of existing rules. These mechanisms make possible performance and learning without the 'brittleness' characteristic of most expert systems in AI." The resulting "pragmatic framework" denied the sufficiency of purely syntactic accounts of equivalence between inferences, and insisted that "sensible inferential rules take into account the kinds of things being reasoned about" [(1986): 1-6].

His more recent, simulation work demonstrates that a small number of rules or laws can generate systems of surprising complexity—but not just of random patterns. These "emergent systems" have recognizable features, a dynamic flux of patterns, and perpetual novelty. Emergent phenomena are recognizable and recurring, or *regular*, although not easily recognized or explained. If the origin of these regularities and their relations to one another can be understood, Holland thinks we might hope to comprehend emergent phenomena in complex systems. "The crucial step is to extract the regularities from incidental and irrelevant details" [(1998): 4]. Knowing that it took centuries of study to recognize the patterns of play in the game of chess, we should not expect to find the patterns of emergent systems simply by discovering underpinning laws of dynamics. Holland reminds us, however, that mathematical descriptions in a modeling process can help in discerning patterns and that a well-conceived model makes possible prediction and planning, to *reveal* new possibilities. Games and maps are historical antecedents of modeling, and computers make possible even more complex and dynamic models [see (1998): 28-52].

Holland's framework for the study of emergence from complexity specifies mechanisms and procedures for combining them. His use of "mechanism" extends beyond overtly mechanical to mean something like an elementary particle in physics for mediating interactions. Mechanisms provide a precise way of describing the elements (the agents, rules, and interactions) for defining complex systems, a common way (across disciplines) of describing the diverse rule-governed systems that exhibit emergence. In particular, mechanisms for recombination of elementary "building blocks" play a critical role. These interacting component mechanisms, called "constraint generating procedures" (*cgp*'s), have no central control, which increases the flexibility of their interactions, which then rapidly increases the possibilities for emergence [see Ibid (1998): 125-26].

Holland identifies the mechanisms and interactions necessary for advanced modeling of emergence in his model system, Echo, where complex multiagents can evolve from a single free agents, and then into specific aggregates of multiagents from single seed multiagents. Models can employ rules to allow a range of control (as in flight simulators), by which players can see and manipulate the mechanisms and interactions underlying the models, and use their intuition to explore plausible regimes. In simulators, models can reveal what amounts to the crossword "breakthroughs" and "wipeouts" that could, as Holland describes, "appear and reappear under a wide variety of assumptions," without committing players to real consequences [(1998): 141, 243].

Sometimes, in scientific inquiry, it is possible to follow the classic "hypothesize, test, and revise" pattern but, as Holland argues, real innovation requires more than incremental revision. In his framework, there are two major steps: "(a) discovery of relevant building blocks, and (b) construction of coherent, relevant combinations of those building blocks." He speculates that the selection mechanisms in this creative process "are akin to those of evolutionary selection, simply running on a much faster time-scale." He even conjectures that there could be a "game" with the rigor of a *cgp* that would permit insightful combinations of symbols as building blocks for creating models—as well as metaphors [(1998): 217, and see 202].

9 Tentative Conclusions and Future Challenges

This prologue to more careful examination of Holland's models of emergence indicates that the design goal of Revelator should be to enhance the *creative* process of inquiry (or abduction), even though this emergent phenomenon is still in "a shroud of conjecture," as Holland puts it. Players *create* rules in a game of Revelator, with each responsible and legal play. These *agent-rules* are the building blocks from which players must select and construct *generators* as "winning combinations," multiagents with dynamic (logical) trajectories [(1998): 129]. In a normal game, such as checkers, what counts as winning is pre-established in the pre-set game environment (checker board with checkers). In Revelator, as in any inquiry, the players *create* their game environment by the rules they contribute, and winning involves strategically selecting and combining those agent-rules to formulate multiagents that reveal adaptive, higher-order behavior hidden in the complexity of their conceptual environment. Another way of saying this is: players contribute and attempt to aggregate and integrate their selected rules (or agent-conjectures) as the mechanisms that might generate a model (or multiagent-hypothesis).

The selective exploration of different possible combinations is quite like finding the strategies in playing any other game. Like good play in checkers, sophisticated actions in complex adaptive systems depend on crediting *anticipation* and *stage setting* (or *pragmatic* actions) [see Holland (1998): 54]. In selecting rules (or conjectures) that combine as mechanisms to specify a model (or hypothesis), how could players (with limited capacity for tracing out complexities) manage to identify generators of higher-level organization, the "levers" that make "breakthroughs" possible (remembering the crossword analogy)? Under Holland's framework, the process would start from a complex pattern of related conjectures from which players may have no idea what might emerge. In their selection process, induction must "mediate the transition between the patterns of interest and the rules that attempt to model those patterns." Knowing what details to ignore is *not* a matter of derivation or deduction; it *is* a matter of experience and discipline, as in any artistic or creative endeavor. When this process goes well, the resulting description reveals repeated elements and symmetries that suggest rules or mechanisms [see (1998): 230].

Rather than viewing rules as a set of facts about the agent's environment, which must be kept consistent with one another by consistency checking, Holland views rules as hypotheses that undergo testing and confirmation. "On this view, the object is to provide contradictions rather than to avoid them ... [and] rules amount to alternative, competing hypotheses. When one hypothesis fails, competing rules are waiting in the wings to be tried" [(1998): 53]. His technique for resolving the competition is experience-based (closely related to the concept of building confirmation statistically): a rule's winning ability depends on its usefulness in the past. Each rule is assigned credit strength that over time comes to reflect the rule's usefulness to the system, changing the system's performance as it gains experience (for adaptation, by credit assignment). An agent-rule's value is then based on its interactions rather than on some predetermined fitness function [see (1998): 97]. The goal is the improvement of relations among rules, not some pre-determined optimality [see (1998): 216]. "What actions and interactions between these individual agents produced an organized aggregate that persisted? What were the adaptive mechanisms that favored the emergence of this aggregate?" [(1995): 97]. Furthermore, "Only persistent patterns will have directly traceable influence on future configurations in generated systems. The rules of the system, of course, assure causal relations among all configurations that occur, but the persistent patterns are the only ones that lend themselves to a consistent observable ontogeny" [(1998): 225].

Holland's pragmatic approach encourages Pietarinen's hope that Peirce's final efforts might eventually be rewarded in a general framework for his rudimentary forms of strategic interaction, the EGs. Pietarinen concludes that while the CGs system of knowledge representation is "foundationally rich," it fails to be genuinely dynamic and interactive: "Instead, CGs throw light on what goes on in the one-sided case of a single bearer of a sentence, or in the monologic comprehension of discourse" [104]. He stresses that we will not realize the value of such graphical systems until we can make their "dynamic and dialogical character revealed in the apparatus of extensive games" [171]. If we are to understand how Peirce's EGs are a method that can "break to pieces all the really serious barriers ... to the logical analysis of thought," and really accomplish the rendering of the operation of thinking as "moving pictures of thought," we must first appreciate that "thinking always proceeds in the form of a dialogue ... essentially composed of signs, as its matter, in the sense in which a game of chess has the chessmen for its matter" [*CP* 4.6 (1898); and see Sowa (2005): 61-67].

Can CGs, together with (the more interactive) Formal Concept Analysis (FCA) evolve to meet this application challenge [see Sowa (2000) and Gerhing (2006)]? Taking the physical building-block analogy further, could we eventually have "GIS" and "GPS" technology for virtual exploration of the conduct of inquiry in a "semeotic game terrain?" Such virtual terrain with "global scope" could provide for the continuity of inquiry, as Peirce foresaw it: "there is no real reason why there must be a limit to the size of our hypotheses ... to maintain a single proposition tentatively should be no easier than to maintain a consistent set" [in Feibleman: 334; *CP* 6.277 (c. 1893)]. Rather than becoming merely "tools" in "the researcher's digital toolkit" [see especially Shum, et al., in Kirschner: 186], can Conceptual Structures technology become an *engine* for Revelator as a pragmatic methodological framework for continuing to improve its applications in their evolution [see Keeler (2006)]?

10 Notes

[1] An abductive argument has a relation of similarity between the facts stated in the premises and the facts stated in the conclusion, without compelling one to accept the truth of the conclusion when the premisses are true. Peirce goes on to say that the facts in the premisses of an abductive argument constitute an icon of the facts in the conclusion, asserted positively and admitted with suitable inclination. It is in this sense that abduction starts a new idea; in Peirce's words, it is "originary."

Deduction is, in Peirce's words, "an argument representing facts in the Premiss, such that when we come to represent them in a Diagram we find ourselves compelled to represent the fact stated in the Conclusion." The notion of index arises here, in that "the Conclusion is drawn in acknowledgment that the facts stated in the Premiss constitutes an Index of the fact which it is thus compelled to acknowledge." It is in this sense that deduction is demonstrative reasoning, "obsistent" and "compulsive" in Peirce's terms.

Induction is an argument starting from a hypothesis that is a result of abduction, interspersed with results of possible experiments deduced from hypotheses and selected independently of any epistemic access to its truth value. Peirce called them "virtual predictions." The hypothesis is concluded "in the measure in which those predictions are verified, this conclusion, however, being held subject to probable modification to suit future experiments." The relation between the facts stated in the premisses and the facts stated in the conclusion of inductive arguments is symbolic, as "the significance of the facts stated in the premisses depends upon their predictive character, which they could not have had if the conclusion had not been hypothetically entertained." In Peirce's terminology, inductive arguments are "transuasive" in the assurance of the amplification of positive knowledge [*CP* 2.96; Pietarinen: 26-27].

[2] The best hypothesis, in the sense of the one most recommending itself to the inquirer, is the one which can be the most readily refuted if it is false. This far outweighs the trifling merit of being likely. For after all, what is a likely hypothesis? It is one which falls in with our preconceived ideas. But these may be wrong. Their errors are just what the scientific man is out gunning for more particularly. But if a hypothesis can quickly and easily be cleared away so as to go toward leaving the field free for the main struggle, this is an immense advantage. [*CP* 1.120]

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