"This is an example of the 'uncertainty principle': there is a kind of 'complementarity' between knowledge of where the light goes [through the hole] and where it goes afterwards -- precise knowledge of both is impossible. I would like to put the uncertainty principle in its historical place: When the revolutionary ideas of quantum physics were first coming out, people still tried to understand them in terms of old-fashioned ideas (such as, light goes in straight lines). But at a certain point the old-fashioned ideas would begin to fail, so a warning was developed that said, in effect 'Your old-fashioned ideas are no damn good when...' If you get rid of all the old fashioned ideas and instead use the ideas that I'm explaining in these lectures - adding arrows for all the ways an event can happen - there is no need for an uncertainty principle !..."

QED, Photons: Particles of Light, p.55-56 (text raised from footnote)

For QED, predictability is beyond reach because the primitive terms of the model are probability amplitudes.

For SLIM, the epistemological objective has become a constructive characterization of a space, not the selection of a single path through the space, so prediction of a specific knowledge element being learned is not an issue in general. One could at any time, however, construct a simulation to determine the learnability of a specific strategy given particular prototypes and interactions with an opponent. For any human, prediction is always risky because one can not now know enough about a specific human mind. Perhaps, in some future time we may penetrate to that level of detail where it will be possible to relate specific details of brain localization of information to what is known and used. I do not expect to live long enough to see that day.

Lawler: on The Spiral of Learning

The learnability of a domain can be characterized by the connectedness of all paths of concrete learning possible with specified learning mechanisms. This principle of learnability introduced earlier with SLIM is so particular that it can not be the entire answer to how human learning occurs. Although the

forks and the networks of genetic descent exhibit symmetry relations, for example, they do not contain any explicit knowledge about symmetry. Yet we all know knowledge of symmetry is useful in play. If one asks where knowledge of symmetry comes from in a world of highly particular descriptions, the answer MUST involve abstraction, but which form of those kinds possible? Robust data argue that such well articulated, reflective forms of thought are less accessible to children than adults. The possibility that mature and reflective abstraction is unavailable to naive minds raises these questions: what process of functional abstraction precedes such fully articulated reflective abstraction; could such a precursor be the kernel from which such a mature form of functional abstraction might grow ?

The Multi-modal Mind

Let us discriminate among the major components of the sensori-motor system and their cognitive descendants, even while assuming the preeminence of that system as the basis of mind. Imagine that the entire sensori-motor system of the body is made up of a few large, related, but distinct sub-systems, each characterized by the special states and motions of the major body parts of Figure 8:

BODY PARTS SUB-SYSTEM	SENSORI-MOTOR SUB-SYSTEM	MAJOR OPERATIONS SUB-SYSTEM
trunk	somatic	being here
legs	locomotive	moving from here to there
head-eyes	visual	looking at that there
arms-hands	manipulative	moving that there
tongue, etc.	linguistic	saying whatever

Figure 8: Some subsystems for the Human Body

I will assume the representations of mind remain profoundly affected by the modality of experienced interactions through which each was developed. One

implication is that the representations built through experience will involve different objects and relations, among themselves and with externals of the world. Even if the atomic units of description (be they condition action rules or whatever) are shared between modes, the entities are different; and they bear relation to each other only through learned correspondences. This general description of mind contrasts with the more uniformitarian visions that dominate psychology today. These major modal groupings of information structures are imagined to be populated with clusters of related cognitive structures, called "microviews", with two distinct characters. Some are "task-based" and developed through prior experiences with the external world; others, with a primary character of controlling elements, develop from the relationships and interactions of these disparate, internal microviews. The issue of cognitive development is cast into a framework of developing control structure within a system of originally competing microviews [50].

Redescriptive Abstraction

The multi-modal structure of the human mind permits development of a significant precursor to reflective abstraction. The interaction of different modes of the mind in processes of explaining unanticipated outcomes of behavior can alter the operational interpretation and solution of a problem. Eventually, a change of balance can effectively substitute an alternative representation for the original; this could occur if the alternative representation is the more effective in formulating and coping with the encountered problem.

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[50] This view of mind is presented and applied in "Cognitive Organization", Chapter 5 of Lawler (1985). An extensive discussion of microviews appears in Chapter 7. Since the view presented here is not widely held, it should be noted that the coordination of separately developed sensory motor schemes is one of the primary achievements of the first two years of life (Piaget, date). The point here is that those original differences in schemata -- though coordinated -- continue to impact the representations in which humans encode knowledge developed through interactions with the world.

In terms of the domain of our explorations and our representations, there is no escape from the particularity of the GAC representation unless some other description is engaged. A description of the same circumstance, rooted in a different mode of experience, would surely have both enough commonality and difference to provide an alternative applicable description. I think of the GAC number-cell grid as one capturing important characteristics of the visual mode [51]; while other descriptions based on the somatic or locomotive subsystems of mind could provide descriptions which would let one escape from the particularity of the visual-system based one.

Why should explanation be involved? Peirce argues that "doubt is the motor of thought" and that mental activity ceases when no unanswered questions remain.[52] Circumstances requiring explanation typically involve surprises; the implication is that neither was the result intuitively obvious nor were there adequate processes of inference to predict the outcome.

I propose that a different set of functional descriptions, in another modal system, can provide explanation for a set of structures controlling ongoing activity. When a surprising victory occurs, the surprise is certainly worthwhile explaining. The initial purpose served by alternative representations is explanation. Symmetry, however, is a salient characteristic

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[51] The GAC description is cast in terms of an external thing seen by the person referring to it, with no hint of an imaginary homunculus in view. Further, the absolute reference, assigning numbers to specific cells preserves a top-down, left to right organization. Notice however, that even if a specific person's internal representation were different -- based perhaps on a manipulative mode of thought and representation -- the essential points of following arguments remain sound.

[52] Peirce's position (presented lucidly in "The Fixation of Belief" but ubiquitous in his writing) was the primary observation leading me to focus on on this theme. He uses the term doubt because his discussion is cast in terms of belief; mine, cast in terms of goals, finds its equivalent expression as surprise. Doubts require evidence for elimination (at least, scientific thought does so); surprises require explanations. Surprise is accessible to mechanical minds as the divergence between expectation and outcome under a specific framework of interpretation.

of body-centered descriptions; this is the basis of their explanatory power
when other descriptions are inadequate. Going beyond explanation, when
such an alternative description is applied to circumvent frustrations
encountered in play, the alternate structure is applied with an emergent
purpose. In this way, the interaction of multiple representations permits a
concrete form of abstraction to develop, one emergent from the application of
alternative descriptions. In the following scenario, I will sketch the
interaction of different modes of mind as an example of how this early form
of functional abstraction permits breaking out of the original description's
concreteness. To do so, I need to establish the basic kinds of alternative
descriptions to be involved.

Alternative Descriptions in Tic-tac-toe

The GAC formulation is primarily visual, and I begin with the assumption that
one should seek familiar schemes for representing things, relations, and
actions that are from a different mode of experience. Descriptions based on
activity lead to the somatic and locomotive body systems as the two obvious
primary candidates. Consider an "imaginary body-projection" onto the tic-tac-
toe grid as the somatic candidate description [53]. How would this work in
practice?

Somatic Symmetries

Flipping symmetry will name the relation between a pair of forks (or more
complex structures) when they are congruent after the grid is rotated around
some axis lying in the plane of the grid. Examples of symmetrical forks might

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[53] The following descriptions are rather like imputing thought experiments to subjects
but such with a decidedly personal and everyday content; the "dramatic style" seems
natural enough for people. If it seems unnatural for machines, the reason is that we do
not yet provide our machines with so rich and powerfully various a collection of
interacting descriptions as humans are fortunate enough to inherit from the long
history of life's evolution.

be {139} and {179}[54]. An example of an explanation for this fork symmetry is based upon an alternative, somatic description, focusses on symmetry with respect to the body axis:

> If I sat in the center of the grid and lay down with my head in cell 1 and my feet in cell 9, then cell 3 would be at my left hand. The forks {139} and {179} are the same in the way that my right and left hands are the same, for cell 7 would be at my right hand.

When an alternative mode of description first explains a surprising win, then later provides guidance in play, adaptation has occurred. It is a kind of reflective abstraction through redescription; but it is as concrete as anything can be. It does not involve the specification of axioms based on the properties of objectives referred to in a proof (as Bourbaki described the process) nor does it involve steps of mathematical construction (as described by Weyl). If such an explanation can become salient as presenting an alternative plan for achieving an equivalent goal, then symmetry begins to function and the knowledge of explanation operates with an emergent purpose. This process -- beginning in explanation and concluding with the emergence of a new function through a better fit of a second description to an external domain of activity -- I call "redescriptive abstraction" and propose it as the natural, commonplace prototype of the reflective abstraction described by Piaget and characterized through quotations from Bourbaki and Weyl. What mathematicians employ as their most powerful form of abstraction is prefigured in redescriptive abstraction. The latter is an artifact of the disparateness of the biological subsystems which have evolved to cope with the world in which we have come to be. In this specific sense, even the power of abstraction -- in respect at least of its usability by people -- can be

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[54] Referring only to the set of markers here, we need not distinguish between the forks achieved by various plans such as [1 9 3] or [3 1 9].

seen as a further articulation of vital processes, one way that mind grows out of life.

A Few Final Words

Whitehead noted that the value of a formalism is that it lets you apply a practical method without concentrating too much on it; so that one's attention can be given to inventing and applying methods to other problems. Knowing how to add, for example, permits us to ignore the process and to focus on the meaning or significance of elements operated on. Whitehead asserted that that is true for the calculus. It is also true for SLIM—which generates dependably all relevant games playable given a particular player objective. That list can be filtered to permit focus on some subset of games of high interest—such as those won by the player. Computational procedures are formal, but the method itself is one more constructive than analytic. That may make it more apt for representing knowledge and its growth than analytic methods.

One would like to understand in detail what is in the brain and how that changes through interactions of the individual with the world and through interior interaction. This is surely at least as hard as asking how a specific photon "decides" to reflect from or pass through a surface. Even if one cannot explain human learning at a comparable level to that at which one can explain reflection:

- Given that the principle that co-generativity under specific algorithms provides the explanation of differential learnability, one should be able to articulate why learning is possible in specific domains on the basis of the internal relationships of schemes of representations and learning algorithms, the latter seen as transformations between the states of those relationships.

- This is a retreat from psychology to epistemology: others have retreated before us and still made a contribution, as physicists did in order to "resolve" the wave-particle duality.