

wave theory of light -- to the quantum theory.<sup>35</sup> For psychologists, the import of this specific example may be somewhat sobering. Lewin was right, after all. Although our statistical techniques may help us locate and describe mass phenomena we can feel confident about, the cases that are remote from those of the average case may lead to more profound insights into phenomena of mind. The careful analysis of particular cases -- more in the style of ethological observation than laboratory experiment<sup>36</sup>-- can better focus our work on the issues and the appropriate grain of detail for understanding human behavior and the character and role of learning in it. Such studies will not, themselves, produce theory, but they will help us identify clearly those issues that must be confronted in the construction of an improved theory.

### **Lawler: The Internalization of External Processes**

"...The internalization of socially rooted and historically developed activities is the distinguishing feature of human psychology, the basis of the qualitative leap from animal to human psychology. As yet, the barest outline of this process is known..."

L. S. Vygotsky

If the psychological processes to which Vygotsky refers characterize productive intelligence in all forms, the development of self-control and the

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<sup>35</sup> If one wanted to find a scheme to give meaning to McCulloch's delphic pronouncement "...even Schroedinger and Heisenberg... have had their Dirac," here is one way. By suggesting how human-scale physical phenomena could be seen as a special case of quantum phenomena, Dirac established that the incompatibilities no longer needed to be regarded. The challenge changed from explaining apparent phenomenal differences (based on human-scale model differences) to rooting explanation in quantum level phenomena and theories.

<sup>36</sup> This suggested is put forward in a discussion of Ethology by Medawar and Medawar (1983), p.84. What specifically such a study should look like might be open to discussion. Barker and Wright (1951) provide one sort of answer, Lawler (1985) another.

internalization of exterior agents and context are transformations that need to be understood in both natural and artificial intelligence. The general objective of this section is to describe how it is possible for an egocentric system to transcend its limited focus. The central idea is that the system will adapt to an environmental change because of an insistent purpose; it will do so by interpreting the actions of an external agent in terms of its own possibilities of play. Two essential milestones on the path of intelligent behavior in interactive circumstances are, first, simulation of the activity of an opponent, and, second, the internalization of some control elements from the context of play. Here I consider only the first.<sup>37</sup>

In the human case, learning sometimes goes forward by a process I call "homely binding", an instruction by people or things in what this or that means or how it works.<sup>38</sup> Here I will focus on another kind of learning, which I call "lonely discovery." This sort of learning comes from the commitment to continuing an interaction, despite the loss of the external partner. Such a desire, which by definition can permit only vicarious satisfaction, is the motor of that internalization of "the world and the other" that is the quintessence of higher psychological processes.<sup>39</sup> The case study experiences are used to guide the development of an example-scenario of how a machine can confront such challenges.

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<sup>37</sup> Both the two issues are considered in more detail in Lawler (1987), *Coadaptation and the Development of Cognitive Structure*.

<sup>38</sup> I choose this name to avoid here any more extensive characterization of the process and argument about that. A behaviorist might see this as "shaping" the child. A Piagetian might see active imitation by the discovering child.

<sup>39</sup> The episode dealt with here is neither singular nor domain specific in character. The original observations on which this view is based were about the behavior of a newly verbal infant. See Chapter 4 in Lawler (1985) pp.113-115. This issue became prominent for me through its manifest importance in empirical observations on the learning of my children.

How can a system develop through interaction in such a way that when the environment becomes impoverished, the system can begin to function more richly by itself, and thereby become generally more capable? The particular problem through which I will approach this question is the inception of multi-role play (one player as both protagonist and antagonist). I do not want to impute to SLIM <sup>40</sup> the motive of understanding the play of an opponent to whom it initially pays little attention. Therefore, I grant the system an initial purpose of continuing play even under such limitations as to amount to a crippling of the environment.

### The Beginning of Multi-role play: The Human Case

After many sessions of her playing tic-tac-toe with me, in one experiment I asked the subject (my six year old daughter) to play against her brother. She surprised the boy (two years her senior) by her significant progress, for she beat him honestly and knew that she would do so in specific games before their completion. When I was called away to answer a knock at the door, I asked the children not to play any more games together until I returned. Coming back, I found the game below on the chalk board. When I asked the girl if she had let herself win, she explained that she had been 'making smart moves for me and the other guy.'

A	3	C
	1	
2		B

I believe what happened was this. The child wanted to continue playing tic-tac-toe, but she was hindered by my specific prohibition. She adapted her

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<sup>40</sup> As noted in Lawler (1987) these simulations were done with a more developed version of SLIM, referred to as IT (the "Interactive Thinker"). For the reader's convenience, in this text I will continue to refer to both versions of the program as SLIM.

earlier developed skills, partitioning them so that strategic, fork-oriented play remained her own prerogative while tactical play (winning when possible and blocking potential opponent wins) was assigned to her newly effective internal antagonist, 'the other guy.' Could such a process be made effective in a machine?

### The Form of the Solution for Machines

If the deprivation of interaction in the social milieu is one motor of human cognitive development, within the world of machine intelligence the corresponding circumstance would be the crippling of some other programmed modules of the system-universe in which both players are agents.<sup>41</sup> The desired consequence of this crippling should be one where continuing in the well worn path is an obviously losing maneuver, thus necessitating changes in the functions of existing structures. Furthermore, there should exist an alternative that is the marginally different application of an already existing structure.

The deprivation of interaction leads to the introjection of 'the other' within the 'self' through the assignment of one of alternative functions (strategic play) to the 'ego' (SLIM) and another (tactical play) to the new 'alter-ego' (let's call this agent REO-sim). What forces this reassignment is crippling the environment so that a decision needs to be taken on an issue which was inherent in but transactionally insignificant in the interactive context <sup>42</sup>. What makes this introjection possible is the successful application of established

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<sup>41</sup> In the world of SLIM and REO, this would mean that REO no longer functioned (see the more detailed discussion following).

<sup>42</sup> Chapter 4 of Lawler (1985) argues that in the human case "whose-turn?" at play was one issue upon which judgments were made at each move to prohibit or permit the effecting of intentions in behavior. Lawler's subject knew what she wanted to do, and when she knew also that the turn was not hers she suppressed her next intended move until it was her turn. Further, one of the ways the child cheated when she feared her plan might be frustrated was to make multiple moves in a single turn.



structures for a new function. Obviously, not every attempt to apply an old structure for a new function can be successful.<sup>43</sup> Consequently the character of structures which permit such successful re-application needs to be established through some sort of experience. In a system where internal simulation capabilities are limited, actual external simulations are needed.<sup>44</sup>

How extensive would be changes required for SLIM's programs to mimic the kind of behavior shown by this subject? For SLIM, the situation equivalent to having no opponent is: whenever SLIM returns its latest move, SLIM receives control again with no move made by REO. There are three possible responses to this situation:

1. SLIM could make its next planned move (without even noticing something novel had happened); the consequence of continuing to play with no responses from the antagonist would look like a plan rehearsal to an observer.
2. SLIM could respond, making moves for REO but do so in an imperfectly discriminated manner (for example, using the moves of its own plan for both its own moves and those of REO-sim); when SLIM attempts to assign moves without making a strategic/tactical division of moves, the play appears random, but is best characterized as confused tactical play by both; that is, SLIM's first move for REO-sim blocks SLIM's own plan after which both agents play tactically.
3. SLIM could partition its own capabilities so that SLIM alone made strategic moves and REO-sim made tactical moves; when SLIM's own internal structure is respected in the allocation of roles, play proceeds in the normal fashion. This is the articulation of complementary roles.

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<sup>43</sup> Because my simulations share tactical code, in fact, the internalization of REO as REO-sim is perfect. Such need not have been the case. REO could have been any arbitrarily baroque system of decisions; SLIM's simulation of such an alternative REO would still be the same as described here. Allocating a part of itself to represent the other is all that SLIM can do. The success of such a substitution may be rare. When it is successful, however, this functional re-application of existing structure is very powerful.

<sup>44</sup> In this case, the playing of a game with tokens on a chalk board represents itself an externalized simulation which could arguably have played a key role in helping the subject develop the internal control permitting the different application of her knowledge, that is, adaptation to the new circumstance.

I have programmed SLIM to function in each of these three different manners under control of global switches. The question remains of how one should view the transition from the states of rehearsing, to confusion, to articulated multi-role play.

### Limitations in Respect of Theory

I offer no general theoretical justification for the transition from one mode of response to another. There are reasons. Very little change was required to the original code, because the strategic and tactical play were functions of separate modules.<sup>45</sup> This is an important observation if and only if the modularity of the code for tactical and strategic play is justified by psychological data or epistemological argument.

The assumption of the modularity of cognitive structures and SLIM's pervasive use of modularity are based on the empirical witness of Lawler's case study.<sup>46</sup> If the human mind is organized as that study suggests, then it should be easy for the kinds of developments described here to occur. Furthermore, if the transition is representable by no more than the insertion of a control element, choosing between formerly competing or serialized subfunctions; and if the transition is driven by events in the environment upsetting ongoing processes which "want" to continue, the only "theory" possible is one about the characteristics of structure which permit this adaptiveness. My structural assertion in this context is that the coadaptation of disparate cognitive structures is the key element of mind enabling the

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<sup>45</sup> So limited was the change, in fact, that one can not help but recall Feynman's observation that "adding up arrows" doesn't seem like "real physics". No more does this seem like "real Artificial Intelligence".

<sup>46</sup> The details may be found in chapter 4 of Lawler (1985).

"internalization" of external agents and objects <sup>47</sup>. This is one way a machine can begin building a model of the external world.

### The Complementarity of Two Forms of Learning

Learning through composition of disparate components is one of the classical forms of symbol-oriented machine learning. In the preceding discussion, one can see that learning -- in the sense of adapting one's knowledge to a significant new external circumstance -- also can go forward through a complementary process, the decomposition of internal structure and reallocation of its components to other functions. If learning by composition leads to more powerful and fit internal structures of knowledge, learning by decomposition leads to an increase in the flexibility of what is known. In this sense specifically, it amounts to a de-particularization of knowledge. This view clearly relates to "abstraction", the final theme to which I will turn after reviewing Feynman's observations on the Uncertainty Principle and in what light that may be seen after "resolution" of the wave-particle duality. This is especially relevant to our central concern, consideration of the particular case, because Feynman probes the meaning of the uncertainty principle through constricting the flux of photons passing through an aperture -- that is moving from the mass effects of the average case to consideration of the particular case.

### **Feynman: on The Uncertainty Principle**

Much has been made of Heisenberg's Uncertainty principle -- popularized as the observation that if you look too closely at a subject you will so interfere

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<sup>47</sup> This view helps us appreciate that the animism of the young child is not at all bizarre if his only means of understanding 'the other' is through self knowledge. Like Descartes, he knows he has a mind because he thinks; he believes in his own past because of memory; and he imputes will to things because he feels the meaning of wanting.

with the natural processes at work that one cannot say that the observation has any general validity. As a general concern, the issue is surely legitimate.<sup>48</sup> Through his reformulation of Quantum Electrodynamics, Feynman is able to place the Uncertainty Principle in a new perspective, one which ultimately proves revealing of the relationship between the particular case and average behaviour. We all have been told that light travels in straight lines, but in general light travels in all ways, not merely in straight lines. By arguing that the paths off the straight lines do not add up – Feynman shows that the “straight and narrow” for a light path is more or less straight but not so narrow as a photon and that the “straight line” light travels is a bundle of possible paths from which an apparent “straight line” emerges due to mass behavior.<sup>49</sup>

When in experiments one constrains the paths of photons to pass through a small hole -- and then makes the hole smaller and smaller -- the random vagaries are no longer swamped by emergent order from masses of particles and the probabilistic uncertainty of the particular case is revealed. With two photomultipliers, one on the straight-line path (P) and the other off-center (Q), light shining through the hole results only in clicking at the centered photomultiplier (P). As the size of the hole is shrunk, the second photomultiplier starts clicking also:

“When the gap is nearly closed and there are only a few neighboring paths, the arrows to Q also add up, because there is hardly any difference in time between them either.... Of course, both final arrows are small, so there's not much light either way through such a small hole, but the detector at Q clicks almost as much as the one at P! So when you try to squeeze the light too much to make sure it's going in only a straight line, it refuses to cooperate and begins to spread out....

*QED*, Photons: Particles of Light, pp. 54-55

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<sup>48</sup> This is as true in psychology as in other sciences. The intrusiveness required for thorough data capture of natural behavior -- which may be well represented by the methods used by Barker and Wright in their ecological-psychology studies -- can serve as the prototypical situation.

<sup>49</sup> For Feynman's text on the theme, see *QED*, pp 54-55.(See Feynman.6)



"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