THE ROLE OF EXPERIENCE IN MODELS OF THE PHYSICAL WORLD

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In recent years there has been a growing body of research dealing with "naive physics:" what people, prior to extensive instruction, expect are the principles governing the everyday workings of the physical world. This research is extremely interesting as a study of untutored learning since presumably whatever systematic understanding physics-naive individuals arrive at must be due primarily to their direct experience with the physical world. Here we would like to summarize briefly some results of that experimental work and a tentative theoretical interpretation of it. Then we will be in a position to speculate on the general nature of the models people make of their experience in order to cope with it.

What has emerged from naive physics research is a surprisingly robust and systematic set of ideas about mechanic which are often, however, decidedly non-Newtonian. Studies fron age 10 upward to university students and physics-naive adults hav given in many cases very uniform results (Viennot, 1979; Clemen 1979; McCloskey, *et al*, 1980; White, 1981). In one study (diSess 1981) we let elementary school students and universit undergraduates play with the same computer simulation of an obje obeying Newton's Laws. Despite many more years experience, year of high school physics and a university level course o mechanics one could see a clear overlap in the set of strategies th university students used as compared to the elementary student Moreover, many of these common strategies were not neutral, n merely based on other-than-textbook analyses, but were overtly no Newtonian. The university students often had difficulty applyin the simplest classroom concepts to the simulation, even when aske One of the prominent expectations most students showed was th force acts by directly producing motion in the direction of the for rather than by combining with previous motion. Thus the students sided with Aristotle against Newton.

Besides the obvious pedagogical problems, data such as th pose in a very direct form the fundamental question of what o learns from experience. How can it be that people come to a robu non-Newtonian understanding, even resisting instruction, of a wor with which they deal everyday, a world governed by Newtoni principles?

No one expects the answers to such a question to be simp But some analysis of a set of naive conceptions (diSessa, to appe suggests that something like the following mechanism may play important role. It is a mechanism concerning incremental learni based on experience. The basic idea is that among all t experiences one has regarding a class of phenomena, for exam pushing and pulling things around, a few are selected to stand as prototypical for the class and are systematically used in both explanations and predictions. It is not, of course, a literal recall of an observed phenomenon which serves this purpose but what the person establishes as a conventional interpretation of the phenomenon in terms which that person already understands. I call these paradigmatic interpretations of experience "phenomenological primitives." In the case of the Aristotelian expectation of motion always in the direction of force, one might hypothesize that the common event of pushing an object from rest serves as an important prototype. Thus the phenomenological primitive here is the "theory" that things simply move in the direction you push them, and previous momentum is generally ignored since it plays no role in the prototype. I suspect that the interpretation of pushing from rest is based on prior, common-sense notions of agency and causality which one finds associated with naive conceptions of force in many ways. Indeed, what is more surprising, one can make a rather strong case that these same ideas had a great impact on the historical development of the science of mechanics as well. (See diSessa, 1980.)

Though the notion of phenomenological primitive might help account for the origins of false "theories" like the Aristotelian expectation, we must look to the knowledge system in which these structures operate in order to account for their long term stability. Here we can offer only the briefest suggestion as to the character of this system, again by example. The example involves a counter-example to the Aristotelian expectation. Imagine a ten-ton truck hurtling down the highway and a small push on its side. Who could believe the truck will move in the direction of the push? Indeed, no one does! When subjects are prompted in such a way, the Aristotelian intuition is not even considered, or, if it is, excuses for its inapplicability are found: "The force (sic) of the truck is too big; it's overcoming the sideways push." But either way, (through selective cueing or maintaining excuses as part of the knowledge base) the Aristotelian expectation is isolated and kept safe from refutation.

What generalizations can we draw from this story of naive physics about the models people spontaneously make? The first is that these models are robust, that naive ideas and the interpretations of experience one makes with them can have a powerful effect on long term understanding or misunderstanding. All the evidence points to the conclusion that naive physics plays a large role in learning textbook physics. To draw a caricature, it is almost as if one is trying to teach physics to a stable cognitive system which already knows a different physics.

The second generality is the importance of knowing the particular pre-existing notions. What one carries away from an experience is one's interpretation of it. Such a truism only warrants attention when we remind ourselves of how little we know about the naive vocabulary and about how one builds deeper understanding out of it. The surprise of a Newtonian world teaching Aristotelian physics, however, should serve as a reminder.

The third generality concerns the fragmentation exhibited by spontaneous models. One can find people both believing and disbelieving their Aristotelian expectations depending on circumstances. This apparent incoherence is puzzling. After all, what other than a coherent system could exhibit such robustness. In fact, it is in this area, coherence, that I believe our own naive ideas about knowledge systems most need refining.

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