INTERACTIVISM AND GENETIC EPISTEMOLOGY

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Interactivism (Bickhard, 1980a, b; Bickhard & Richie, 1983) is a radical thesis about the nature of representation that has deep affinities with some of Jean Piaget's fundamental insights, provides logical derivations of other key aspects of Piaget's epistemology, and thus integrates them into a single necessary framework (Bickhard, 1978, 1980a; Campbell & Bickhard, 1986). At the same time, however, interactivism requires the rejection of other parts of Piaget's epistemology. Our aim will be to elucidate these relationships between interactivism and Piaget's genetic epistemology[1].

One of Piaget's deepest insights was that knowledge is primarily operative or interactive in nature, rather than consisting of «copies» or encodings of reality. Interactivism extends that insight by recognizing that all representation[2] (including perception) is *entirely* interactive, not just primarily so. In fact, interactivism provides powerful arguments that encodings cannot be epistemologically foundational — that to assume they are leads to logical contradictions. By contrast, a derivative form of encoding representation can easily be defined on a basis of interactive representations. We will show that interactivism yields — as logical consequences — both epistemological constructivism and a powerful form of developmental stages. Moreover, it provides a natural approach to modeling reflective abstraction. We will further argue that neither structuralism nor information processing is capable of expressing Piaget's basic interactive insight, because both structuralism and information processing are fundamentally committed to an encoding view of representation.

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1 We use such terms as *interactivism*, *interactionism*, *constructivism*, and *reflective abstraction* in the course of developing our framework. We are not attempting an exegesis of Piaget's usage of these terms, and our understanding of them may disagree with his.

2 Our use of the term *representation* differs from Piaget's. For Piaget (1946), representations requires signs and symbols (the semiotic function). For us, all knowledge, including sensory-motor abilities, involves representation.

Piaget's interactive insights

There are two primitive forms of knowledge in Piaget's epistemology: knowledge of states, or the *figurative* aspect, and knowledge of transformations among states, or the *operative* aspect (e.g., Piaget, 1977a, p. 18). Piaget always regarded figurative knowledge as intrinsically subordinate to operative knowledge. He argued that knowledge of a state by itself hardly qualifies as knowledge: the individual does not really have any knowledge of a state without knowing how that state fits into a system of potential transformations. Knowledge, then, is intrinsically active and interactive: knowledge is essentially of what we can do in the world, of how we can transform one state into another (Piaget, 1970, ch. 1). The ascendancy of operative knowledge was one on Piaget's central insights.

When Piaget began propounding such an idea, the dominant conceptions of knowledge were quite different. Knowledge was conceived as internalized pictures of the world, internalized sentences, or even more primitively, internalized associations between stimuli and responses. Each of these approaches views knowledge as internalized static copies of the world. In Piaget's terms, each of them views knowledge as strictly figurative. Piaget (e.g. 1936) recognized the inadequacy of such approaches, and argued against them, at a time when few others sensed anything wrong (Furth, 1981). More recently, information prossessing and computer modeling approaches, and even Chomskyan linguistics, have presented forms of the idea that knowledge has an intrinsically active aspect.

The incoherence of encodings

Piaget's argument against copy theories

Interactivism contends that knowledge does not just have an intrinsically active aspect, but that all knowledge, without exception, is essentially interactive. The interactivist argument that knowledge cannot have any independent figurative aspect is an extension of Piaget's argument that knowledge cannot be totally figurative. Piaget objected to a strictly figurative conception of knowledge on at least two grounds: (1) A static figural ground cannot be adequate to knowledge as action, knowledge of how to transform the world (Piaget, 1947, 1967). (2) Piaget recognized a logical defect in a purely figural model of knowledge. To know the world by means of a figural copy requires that the world already be known in order for it to be copied. This logical vicious circle is unavoidable, and it destroys any treatment of knowledge as essentially consisting of static copies (Piaget, 1970, ch. 1).

Piaget's argument that figurative knowledge is inadequate to knowledge as action (no. 1 above) suffices to conclude that knowledge must have an operative or interactive aspect. Piaget did not realize, however, that his logical argument against copy theories of knowledge (no. 2 above) belongs to a class of arguments that apply much more widely. Pursuing these deeper arguments leads to a purified form of Piaget's operative insights: all knowledge is essentially active, constituted as knowledge of potential interactions. All knowledge is essentially operative, and it cannot have any irreducible figurative aspect. That is, we regard Piaget's operative insight as a major but partial step toward a strictly interactive conception of knowledge.

The incoherence of foundational encodings

Piaget's copy argument belongs to a general class of arguments propounded by the philosophical skeptics. Such skeptical arguments are directed against a conception of knowledge as encodings. An *encoding* is an element in a known representational relationship with something that it encodes. As such, an encoding element stands in for whatever other representation is used to specify what that element represents. Thus «...» stands in for the character «S» in Morse code, various voltage patterns stand in for corresponding characters and numerals in computer codes, and so on. Encodings are useful (sometimes enormously so) because they change the form of representations — from characters to dots and dashes, or to electronic bits, etc. — and thus allow new things to be done to those representations in their new encoded forms.

Encodings, however, cannot be a foundational form of representation. An encoding consists of an already known stand-in relationship with an already known representation. The character «S» must already be known before «...» can be defined in terms of it; the sound class /s/ must already be known before the character «S» can be defined in terms of that; and so forth. The stand-in relationship can iterate, but not infinitely. There must be a ground or foundation, and that foundation cannot consist of encodings.

The classic skeptical argument is that we cannot know whether our representations are veridical because we cannot access the world directly to check our encodings against what they are supposed to represent. Our variant is that we cannot even specify what a foundational encoding is supposed to represent. If we could specify its representational content, then it would not be foundational: it would instead be dependent on what was used to specify its content. If we try to specify its content in terms of itself (the only option remaining), we end up with the following definition for a purported foundational encoding «X»: «X» represents whatever it is that «X» represents. The is incoherent as a definition of an encoding. It provides no encoded content for «X», and thus fails to constitute «X» as an encoding at all.

The problem, in essence, is that encodings are changes in the form of representation of *already known representational contents*. Encodings cannot provide new knowledge; they can only change the form of old knowledge. Encodings carry representational content, but they cannot generate or constitute representational content.

Consequences of encodingism

This logical insufficiency of encodings, and the consequent incoherence of encodingism, yields a plethora of unwanted, and even bizarre, logical consequences. Such consequences are sometimes unsuspected, sometimes ignored, and sometimes defended as truths — even necessary truths — about cognition and epistemology. Given the standard presupposition that representation *is* encoding, the consequences do in fact logically follow.

Impossibility of novel encodings

One such consequence derives from the fact that it is impossible, within the encodingist framework, to generate novel representational content. At best, already available encodings, with already available representational contents, can be combined in novel ways to generate new derivative encodings, but genuinely novel representations are impossible. Any alleged way to generate such novel representations directly encounters the incoherence problem: the representational content that would make them into genuine encoding representations cannot be specified except in terms of representations already available, which makes them not genuinely novel, but derivative. This constraint holds not only for cognition, but also for learning and development, with the consequence that no genuinely novel representations can be acquired in any manner whatever.

An apparent consequence of the impossibility of novel encodings is that all basic representations, sufficient for every cognition that any individual has ever had or will ever have (throughout history), must be preformed at birth. All representations can at best be combinations of representations that are already innately present, because it is impossible to generate any representation outside of that combinatoric space. This bizarre conclusion — which destroys any true developmental psychology — is seriously proposed (Chomsky, 1975, 1980, 1988; Fodor, 1975, 1981; Piattelli-Palmarini, 1980) and even seriously accepted by some «developmentalists» (Gelman & Baillargeon, 1983; Haroutunian, 1983). It is a consequence, however, that any theory is committed to, wittingly or unwittingly, that makes encodingist presuppositions. Because the incoherence problem is a problem in principle, however, this preformationist «solution» is illusory: it assumes that the basic encoding representations have been constructed by evolution, but evolution, as a process of variation and selection, can no more resolve the incoherence, and succeed in providing novel representational contents, than can learning or development (Campbell & Bickhard, 1987).

Innate bounds on representational capacity

A direct corollary of this preformationist conclusion is the possibility that the innate encoding resources that evolution has provided us may be adequate for some domains of knowledge and inadequate or even absent for other domains of knowledge. Our potential knowledge, then, may be intrinsically limited by that innate foundation, and what potential we do have may be modularized in various domains. Again, such conclusions are being seriously proposed (Fodor, 1983) and seriously accepted within developmental psychology (Keil, 1981). There are certainly evolutionary reasons why our basic adaptational resources may be partially modularized — in particular, specialization and differentiation of resources for differentiated domains of evolutionary selection pressures, e.g., vision, locomotion, or the tendency to learn a relationship between food and nausea even with a long delay — but the conclusion that such modularization involves an intrinsic limitation on our representational capacities follows uniquely from encodingism.

Impossibility of developmental stages

Encodingism, in several ways, makes genuine epistemic stages impossible. We have already shown how encodingism leads to preformationism and anticonstructivism. Another consequence is a kind of «transitive collapse» of any purported hierarchy of encodings, and, thus of any stage model based on such a hierarchy. The basic point is that encodings may be defined in terms of various combinations of previous encodings, and further encodings may be defined in terms of combinations of those thus defined, but combinations of combinations of encodings still amount to combinations of the basic encodings. There is no basis for any layering or stage structuring of the representations generated within a combinatoric space of encodings. Another perspective on this same point is to note that encoding «A» may stand in for «B», and «B» may stand in for «C», «C» for «D», and so on, but the stand-in relationship is transitive, so «A» is just as much a stand-in for «D» as it is for «B». The apparent hierarchy of «A», «B», «C», «D», and, thus, the apparent structure, collapses. «A» is not in any epistemic sense at a higher level than «B» — the sequence is definitionally arbitrary, and not one of epistemic level — and so from an encoding standpoint there are no consistent grounds for defining epistemic stages.

No implicit epistemic properties

A related point concerning encodingism and stages derives from the distinction between the properties that are represented by the representational content of an encoding element (or combination of elements) *qua* representational encoding, and the properties that are instantiated or possessed by an encoding element *qua* physical or functional entity or event. The physical entity or event that is being used to carry the representational content, that is being constituted *as* an encoding, will have its own properties — such as weight, size, form, duration, and so on — but these are explicit physical properties of the independent of its being an encoding, not implicit epistemic properties of the element encoding *qua* encoding. Such physical properties may be of central importance in manipulating and transmitting such elements, but that, again, is independent of their use as encodings. Encoding elements have no *implicit* epistemic properties; their epistemic properties are entirely *explicit* in the representational content that they carry. Thus encoding elements *qua* encoding elements do not provide any new knowledge that a higher epistemic level could represent, even should such a higher level be possible on other grounds.

A similar point holds for combinations of encoding elements. Combinations of encoding elements do manifest representationally significant relationships that are not representationally present in the elements themselves, but this introduces only a variation on the point concerning single elements — combinations of encodings do not generate newly epistemically accessible knowledge any more than do single elements. To see this requires a slightly more sophisticated understanding of the nature of an encoding system. The relationships that constitute the combinations of elements will in general represent some sort of corresponding relationships among the things that those elements encode. For example, one element may encode an object and another a set, while their relationship of left to right physical contiguity may represent that the object is an element of the set. This is Wittgenstein's distinction between «saying» and «showing» (Bickhard, 1987).

This «showing» relationship, however also does not provide new implicit knowledge that could represented at a higher level, because it too must be explicit in order to be epistemically present at all. For example, the letters and words on a printed page provide many instances of the relationship of «one being above another», but that relationship is epistemically irrelevant to whatever those letters and words might be taken to represent. That relationship could be epistemically relevant, however, if, for example, it were part of a code or cipher, but then it would be explicit in the coding system. The relationships among encoding elements that represent corresponding relationships among what the elements represent do so only insofar as their representational power, their representational content, is explicitly defined as such, just as with single elements. Any other relational properties are not epistemically relevant, and, as far as the representational system is concerned, are not there at all.

Epistemic *vs* physical properties of encoding elements

This latter version of the basic point will be important in a later example, and, for that purpose, we will elaborate it further. Encoding elements *represent* entities and properties, but, as mentioned above, encoding elements also *instantiate* or possess properties by virtue of their physical nature. Furthermore, it may happen that the properties instantiated are not themselves represented within that encoding space. For example, an element may be blue even if the encoding system of which it is a part cannot represent colors. The blueness, or any other property, of an encoding element does not in itself constitute a representation of that property.

Combinations of encoding elements can also instantiate properties or relationships that are not themselves represented within that encoding space. For example, a combination of four physical encoding elements may instantiate the corners of a square even if «square» is not representable within that encoding space. That combination would represent «square» only if the physical relationships among the encoding elements were in fact taken to encode corresponding physical relationships among whatever the elements encoded — only if those physical relational encodings were already part of the encoding system. In other words, as argued above, the representations that are «shown» by the combinatoric relationships among the elements in an encoding system are also not novel, but must be already included in the combinatoric potentialities of the foundational encoding system. The converse point, however, is of greatest relevance here: any properties or relationships that are instantiated by combinations of encoding elements, and that are truly novel for that encoding system, will not be representable in that encoding system.

Unrepresentability of novel properties of combinations of encodings

In other words, even the combinatoric relationships among encoding elements that encode relationships among whatever the elements encode must be explicit in the combinatoric principles of the foundational system. Novel *representations* cannot be generated implicitly in the combinatoric relationships *even if novel properties are in fact instantiated in those relationships*. Any such instantiation is just another potentiality in the world which the encoding system is not capable of representing: the mere fact that the very elements that that encoding system uses as encoding elements happen to instantiate the property does not imply that the system can encode that property.

Just as single encoding elements may have physical properties that are epistemically irrelevant, and may or may not be representable within the encoding system, so also may combinations of encoding elements have or instantiate properties that are epistemically irrelevant and may or may not be representable within the encoding system. The possession or instantiation of a property by an element or a system of elements does not by itself constitute the representation of that property.

Encodings, then, can neither represent novelty nor epistemically provide (although they might instantiate) anything novel to be represented. This is another sense in which encodingism provides no basis for epistemic stages.

Need for an interpreter

Further understanding why properties of encodings (elements or combinations) are not necessarily representations of those properties can be derived from further examination of the stand-in relationship that constitutes encodings. Encondings exist only for an agent that knows the relevant stand-in relationships and can interpret the elements and combinations in terms of those epistemic stand-ins. Encodings, in other words, require an interpreter. The interpreter must know how to interpret and understand the stand-in relationships and their foundational representational contents. Novel properties of encodings, then, are epistemically irrelevant *unless the interpreter already knows how to interpret and understand them.* If the interpreter does know how to understand them, then those properties are not novel, but are included in the potentialities of the encoding system foundations.

Encodingism's logical requirement for an interpreter is itself still another aspect of the logical insufficiency and incoherence of encodingism. For real encodings in the world, this is not problematic because *we* are the interpreters — of dots and dashes, printed characters, and so on. But when we are trying to model ourselves, and making the attempt within the constraints of encodingism, this need for an interpreter cannot be unloaded on the readers of our theories — whose representational and interpretive ability is exactly what we are trying to model — without begging the question. Yet any model within the framework of encodingism needs such an interpreter for its encodings, and *it is intrinsically incapable of modelling that interpreter.* To model a representational interpreter would be to model the understanding and the generation of representational content — it would be to make good on the encoding stand-in relationship, including its foundational representational contents that are carried by those encodings — and that is exactly what encodingism cannot do. Any encodingist attempt to do so collapses on the impossibility of providing and understanding the foundational representational contents — it collapses on the incoherence problem. Encodingism, then, is committed to the existence of a representational interpreter, to provide representational content for basic encodings and to understand the representational contents carried by encodings, which it cannot itself account for.

Encodingism, in any version, involves an undischarged and undischargeable promissory note for the interpreter of its encodings;

encodingism presupposes an unanalyzable epistemic homunculus to provide and to interpret its representational contents. Encodingism, therefore, is intrinsically circular: it requires a homunculus to do exactly what encoding-based models purport to do — model the representational properties of epistemic agents. The incoherence problem, in fact, is itself just a manifestation of that homuncular circularity (Bickhard, 1982; Bickhard & Richie, 1983). The homunculus problem for encoding models can provide a powerful perspective for recognizing their encoding nature — most encoding models do not label themselves as encoding models, and are often so inadvertently rather than intentionally — and for analyzing their inadequacies.

Pitfalls of encodingism

This discussion of problematic consequences of encodingism is far from exhaustive. But it should suffice to make clear that encodingism is untenable and highly dangerous to the consistent exploration of any epistemological model. Encoding presuppositions, even latent and deeply non-obvious ones, can force bizarre distortions and impossible conclusions. Piaget was aware of and argued forcefully against some of the pernicious forms and consequences of encodingism, but, we will argue, was inadvertently committed to encodingism in certain other aspects of his epistemology.

In Piaget's epistemology, encodings must be subordinate in importance to an alternative, operative form of knowledge. In our epistemology, encodings must be subordinate in constitution or ontology to an alternative, interactive form of knowledge. Our position will be called *interactivism.*

The interactivist alternative

Interactivism begins by considering a goal-directed system interacting with its environment. The internal course of system processes during an interaction, the path of transitions from internal state to internal state, depends jointly on the organization of the system and on the environment with which it is interacting. Some environments will leave that system in one internal state when the interaction is completed, while other environments will leave the system in some other final internal state. Our basic insight is that the final internal state that a system ends up in when the interaction is completed can serve to differentiate environments into those that yield that final state versus those that yield some other. Each possible final state of the system corresponds to, and differentiates, those environments that yield that final state. This conception is the interactive version of what is known as a *recognizer* in automata theory (Bickhard, 1980b).

A final state of a goal-directed system differentiates the environment, but it does represent anything about the class of environments differentiated except that they yield that final state. Such final states do not specify any content for what they differentiate. In consequence, they cannot be encodings: they do not specify what they would encode if they were taken as encodings. Encodings require known correspondences, whereas interactive differentiations are contextually open. An interactive differentiation does not require that anything be already known in order for the differentiation to be made. Because the final state does not represent what the differentiation is a differentiation *of*, there is no need to specify what the representational content of the differentiation is in order to *make* such a differentiation. Interactive differentiations, then, are not vulnerable to Piaget's argument against copies, nor to any of the skeptics' arguments, including the incoherence argument.

Interactive differentiations are immune to classical skeptical arguments precisely because they can be made without representing what has been differentiated. It might be reasonably asked what possible use such a form of representation could have. In answering this question, interactivism adopts Piaget's insights into the active or operative nature of knowledge. Final states differentiate without representing anything about what has been differentiated. Other parts of the system, however, can learn to make their interactions dependent on those differentiations. For instance, an interaction outcome of type A may indicate that strategy Q7 should be used, while outcome type B may indicate strategy T13, etc. (Bickhard, 1980b). In consequence, although final states *per se* do not contain representational content, such uses of a final state do constitute further knowledge of what has been differentiated — knowledge of further interactive properties of the differentiated environments. Knowledge, therefore, is distributed in the interactive, the operational, uses that can be made of the differentiations — but it does not have to be present prior to the original interactive differentiations. Unlike encodings, interactive representations do not require knowledge of what is represented as a precondition of representation.

The incompleteness of Piaget's interactivism

Although Piaget to some extent recognized the interactive nature of knowledge, and his operative conceptions in some ways resemble interactivism, he failed to build consistently on an interactivist basis, and retained certain copy principles in his theory of knowledge. One problem with Piaget's epistemology resides in his figurative aspect of knowledge.

Figurative knowledge

Figurative knowledge is embedded in operative knowledge, and the concept of operative knowledge bears similarities to interactivism. Interactive knowledge is constituted as a distributed network of functional relationships (among possible system functions and potential outcome differentiations), and this interactive conception roughly resembles Piaget's view of systems of operative knowledge of possible transformations. There is a crucial difference, however: Piaget's operative transformations are from figural state to figural state, and figural states are encoded representations. Piaget's operations transform one encoded environmental state into another: figural knowledge of environmental states is constituted as epistemic correspondences to environmental «configurations» (e.g., Oléron, Piaget, Inhelder & Gréco, 1963), and such epistemic correspondences *are* encodings. Although Piaget argued throughout his career for subordinating figurative knowledge to operative knowledge, figurative knowledge never lost its status as an independent form of representation. The argument for the incoherence of foundational encodings is a version of Piaget's own argument against knowledge as a copy, yet it applies directly against Piaget's conception of figurative knowledge. How can we know what the states of the environment are, or might be, in order to define (or construct) our figural representations of them?

The residual encodingism in Piaget's epistemology is evident in his view of perception as a series of static «snapshots» (Piaget, 1961; for an interactive alternative, see Bickhard and Richie, 1983, and Richie and Bickhard, 1988). Higher level figurative representations like images (Piaget & Inhelder, 1966) are also encodings (Bickhard, 1978). Indeed, even *schemes* and *operations*, central types of representation for Piaget (1936, 1972), are encodings.

Operations

Because operations seem to be the primary vehicles for Piaget's operative insights, it is vital to recognize how encodingism penetrated even here to the heart of Piaget's epistemology. The basic problem is that operations are system structures that correspond to, that are structurally isomorphic to, possible transformations in reality: «Knowing reality means constructing systems of transformations that correspond, more or less adequately, to reality. They are more or less isomorphic to transformations of reality» (Piaget, 1970, p. 15). If possible states of the environment are pictorially rendered as points or configured diagrams, and possible transformations as arrows among those points or diagrams, then figural knowledge is constituted as encoded correspondences to those configurations, and operative knowledge is constituted as encoded correspondences to those arrows.

Representation by structural correspondence is the core of encodingism. There is no such structural correspondence in interactive representation: a system that quite successfully differentiates its environment, and then differentiates its activities on the basis of those environmental differentiations, need have no particular structural relationship with its environment. In the interactive view, the critical epistemic relationship is functional, not structural, and system structure bears only an indirect relationship to interactive system functioning.

Piaget (1971, ch. 1) hastens to add that structural correspondences need not be copies, but what else could «structural isomorphisms» possibly be (cf. Kitchener, 1986, ch. 4)? This perplexity shows how Piaget struggled with his own vestigial encodingism. In stressing the active nature of knowledge, and attacking existing models of passive copies, Piaget seems to have overlooked a fundamental point. Actively constructed foundational encodings are no more possible than passively induced ones. Active construction or assimilation still requires that what is to be copied (encoded) be already represented in order for that copy (encoding) to be constructed. Piaget was profoundly correct in contending for an active, constructivist conception of the origin of representations, and against a passive one. The active-passive distinction regarding the *origin* of representations, however, should not be confused with the interactivism-encodingism distinction regarding the *nature* of representation.

Convergent derivations from interactivism

Interactivism not only carries forward Piaget's basic insights into the operativity of knowledge, it also yields other aspects of Piaget's epistemology as logical derivations. These are not just isolated points of convergence with Piaget's epistemology. Interactivism, consistently developed, logically forces a number of additional epistemological positions and provides a solid foundation for those positions. Interactivism *per se* captures the essentially active *nature* of knowledge. The first derivation from interactivism that we will consider is the necessarily active, constructive *origin* of knowledge.

The necessity of constructivism

As long as representation is regarded as internal structures corresponding to external structures, learning tends to be modeled as the impression of external structure onto an internal substrate (the classic *tabula rasa*). Perception is taken to be a structural impression at one point in time. Learning is taken to be a process of impression extended over time — a form of induction. Structural encodingism, then, presents strong temptations to model knowledge acquisition as a passive impression process. Piaget resisted these temptations, and argued from the beginning for a constructivist position. Interactivism, when consistently pursued, presents no such temptations in the first place.

From the interactive standpoint, structural correspondences between the system and the environment play no epistemic role. The representational relationship is an interactive functional relationship, not a structural relationship. Therefore, learning cannot be regarded as the impression of structure by the environment. Learning can only occur when the system tries out new system organizations, to see if they work (succeed in their interactions). Learning and development must consist of constructive system variations and interactive selections. Interactivism forces a constructivist model of learning and development. (It should be noted, however, that Piaget [e.g., 1967] argued that constructivism by variation and selection is logically inadequate — that it lacks sufficient constructive power. Bickhard [1988] examines this question and responds to Piaget's concerns.)

Interactivism and interactionism

A second convergence with Piaget is that interactivism entails *interactionism*. Interac*tiv*ism is a conception of representation. It is concerned most directly with issues of cognition and epistemology. Interac*tion*ism (sometimes called transactionism) is a conception of development. It contends that development is neither preformed by innate genetic factors, nor passively determined by the environment, nor the result of an additive combination of the two. Instead, interactionism claims that development is constrained by the course of interaction between the system and the environment. Such interactions, and their time course, impose constraints that are not present innately in the system nor resident in the environment.

The variations of constructivism are generated within the system, while the interactive selections are made by the environment. The constructive variations are made in the context of the system's prior history of constructions and selections, and the selections can only be applied to the attempted constructions. The properties of such a developmental process cannot be captured by any simple additive model of genetic and environmental influences. Constructivism, then, is a version of interactionism (if they are not the same thing). Since interactivism implies constructivism, interactivism also implies interactionism.

Knowing levels and developmental stages

Still another derivation from interactivism that converges with Piaget is a model of developmental stages. One way to approach this derivation is to ask how an interactive epistemology can handle abstractions.

It might be granted that an interactive system can know the external environment, but it could still be asked how an interactive epistemology could handle abstractions, such as mathematical or theoretical knowledge. A system knows the external environment by interacting with it, but where is the environment of abstractions with which the system could interact?

Our contention is, as Piaget himself stressed, that the interactions of the system in knowing the physical environment, and the system relationships themselves, are more abstract than the physical environment. That is, the system knows the environment, but the system itself has (more abstract) properties that might be worth knowing. This distinction is close to Piaget's (1967, ch. 6) own distinction between physical experience and logico-mathematical experience.

Those properties of an interactive system cannot be known by the system itself (Bickhard, 1980b). They can be known by a second-level interactive system that interacts with and knows the first-level system. That second-level system, in turn, will have properties that can be known by a third-level system, and so on. Interactivism, then, implies a hierarchy of levels of potential knowing, beginning with a first-level interactive system that knows the external environment, and progressing to higher levels of knowing, each of which knows the properties of the next lower level.

This hierarchy of knowing levels, in turn, forces a necessary sequence of developmental stages. Because development is necessarily constructive, there is no way for developmental processes to reach a given knowing level unless there is already something to be known in the next lower level (Bickhard, 1978, 1980b). Developmental constructions must ascend the levels of knowing in sequence. Each knowing level corresponds to a potential stage of development. These knowing-level stages bear striking resemblances to Piaget's stages: they form an invariant sequence, they apply across domains, and each stage is related to the preceding by reflective abstraction (see below). There are, however, also important differences. The first of the differences is that knowing-level stages are not defined in terms of structures and are not *structures d'ensemble* in any sense. A second difference is that knowing-level stages are half a stage cycle advanced on the Piagetian stages: stage 1 lasts from birth to roughly 4 years of age; stage 2 to roughly 8 or 9; and so on. Correspondingly, a third difference is that knowledge of major invariants, such as object permanence or quantity conservation, and of systematic algorithms, such as seriation by length, tends to be constructed in the middle of knowing-level stages. Such major developmental attainments do not mark knowing-level stage boundaries. Campbell and Bickhard (1986) contrast knowing-level stages and Piaget's structural stages in detail.

Reflective abstraction

A final way in which interactivism converges with Piaget's epistemology is in generating a principle of *reflective abstraction (abstraction réfléchissante).* Knowing level stages are related to each other by reflective abstraction: properties at a given stage are abstracted from the actual system and its interactions, and are «reflected» into the next higher stage. The knowing-levels stage model, thus, resembles the conception of stages that was emerging in Piaget's late work (e.g., 1977b).

Interactivism goes farther, however. Piaget lacks an explanatory process model of reflective abstraction, whereas interactivism provides a model of this process, not just of the relationship between the stages. The abstraction in reflective abstraction may be highly complex, but it is in principle nothing more than pattern extraction, and poses no new problems of cognitive modeling. Indeed, the differentiations of interactive knowing are intrinsically abstractive. What makes reflective abstraction difficult to model is the reflective part: how can a knowing system reflect on itself? Basically, if indicators of system process could be externalized, then they could be reflected on by new components of the system. If these new components succeeded in abstracting system properties from those indicators, then those new components would be at the next higher logical level in the knowing hierarchy. That is, those new components would have been generated by a process of reflective abstraction from the next lower level.

The model and its arguments from this point can only be abbreviated here (for an extensive treatment, see Campbell and Bickhard, 1986, ch. 5). The key problem is to understand how the external indicators needed for reflective abstraction could arise. Such indicators could arise through external symbols — primarily through language, though not necessarily so. Language allows the logical ascent through the knowing-levels hierarchy by reflective abstraction. From the interactive standpoint, however, the evolutionary emergence of language in a species requires that the species be capable of true symbols. The capacity for true symbols, in turn, requires that the species already *physically* realize the first two knowing levels. The manner and likelihood of the evolution of such a system with two knowing levels is, in turn, explained by another part of interactivism. That other part is the biological foundation of interactivism. It defines a sequence of system types consisting of knowing, learning, emotions, and consciousness (Bickhard, 1980b). Each step in this sequence arises as a modification of the preceding, and each step provides greater adaptability over the preceding. The sequence *knowing, learning, emotions, consciousness,* therefore, is a sequence of potential macroevolution (and, in fact, is the sequence in which these capacities evolved). The critical point for our purposes is that consciousness is modeled as internal reflective knowing, that is, knowing at the second level. The ground for reflective abstraction in human beings is thus provided.

Divergent consequences of interactivism

As we have just demonstrated, there are many ways in which interactivism provides an integrated foundation for aspects of Piaget's genetic epistemology. There are other ways, however, in which Piaget's approach requires revision. Most important of these is Piaget's conception of mental structures.

Structuralism

Piaget recognized that knowledge is essentially active. We have indicated how interactivism builds on this insight and generates constructivism, developmental stages, and reflective abstraction — all core concepts in Piaget's theorizing. All this being true, why did Piaget fail to maintain and develop a consistently interactive approach? We believe it was in large part because Piaget had inadequate conceptual tools. The first of these was structuralism.

From Piaget's structuralist point of view, stages were defined in terms of characteristic structures — for instance, the eight groupings of concrete operations, and the combinatorial lattice and INRC group of formal operations (Piaget, 1972). Basic concepts like scheme and operation were defined in terms of structures. The nature of knowledge was conceived in essentially structuralist forms.

Structures and dynamism

One problem with this is that mathematically, the algebraic structures like groups and groupings that Piaget used to model mental structures are static. They cannot explain or account for process of any kind, and lack the dynamism that Piaget wanted his structures to have (Campbell & Bickhard, 1986, ch. 4). This problem arises in addition to the one that we have already mentioned: recall that if knowledge consists of internal structures that represent by virtue of known structural correspondences with what they represent — internal structures isomorphic to external structures — then those structures are encodings. By constrast, the functional relationships of interactive representations are not constrained to be in any particular structural relationship with what they represent. Structuralism, in any form, is inherently inadequate to express Piaget's interactive insights.

Structures and understanding

Structuralism is not only an encodingist position in itself, it also led Piaget into some distinct encodingist traps. Most basically, structures are supposed to represent by virtue of being in isomorphic correspondence with the potential transformations of the world. But this does not address the problem of how such correspondences are to be known, nor, even more fundamentally, how the potential transformations to which the structures are supposed to correspond come to be known. In other words, structures as representations suffer directly from the homunculus problem.

It might be countered that structures are composed simply of the potential transformational activity of the system, which, if it succeeds, must be in some «correspondence» with transformational potentialities. In this view, the potential transformations that constitute structures are not themselves known, they are simply enacted when appropriate, and are potentials of the system otherwise. Such a strictly pragmatic or instrumental view of structures, however, even if it were faithful to Piaget's conception, does not explicate how such structures ever yield representation or understanding. Structures are supposed to be the central focus for the emergence of knowledge out of activity, but if they are merely (potential) activity, then they do not solve the problem of that emergence, while if they are taken to be representations themselves, then they «solve» it only by recourse to an unanalyzed homunculus. What structures are supposed to be — closed systems of operations — cannot explicate or model what structures are supposed to do — represent and understand.

The tension between knowledge and activity in Piaget's structuralism became even more apparent when the distinction between procedures and structures was introduced (Inhelder & Piaget, 1979). Procedures provide the potentials for activity, for practical success, in the system, while structures provide understanding. But, in some passages (e.g., p. 169), procedures are supposed to construct structures (as well as act on the world) — without explaining how this process occurs or how it could lead to understanding. In other passages (e.g., p. 173), procedures are said to yield structures as a closure and consequent reversibility of the procedural potentialities themselves — without explaining how closure and reversibility constitute understanding. As before, insofar as procedures or structures are taken to represent potentialities or actualities in the world, as distinguished from being instrumentally competent to them (thermostats exhibit instrumental competence), they do so only by recourse to an unacknowledged homunculus. Similarly, procedures are supposed to construct «presentational schemes», but it is not explained what such schemes are «presented» to.

Structures and necessity

A related problem arises in Piaget's model of the emergence of necessity. One of Piaget's deepest insights was the recognition that logical necessity must play a central role in any epistemology (Piaget, 1950). Modalities are intrinsic in the operative character of knowledge because operativity concerns the potentialities or possibilities of transformations in the world — this focus on potentiality is another property that interactivism shares with Piaget. Further, Piaget recognized that this intrinsic involvement of modality, and especially the epistemological problem of necessity, was a fatal challenge to any empiricist epistemology. But Piaget's structuralist answer to the problem of necessity was that necessity emerged in the closure of operations that constituted structures. It is certainly true that closed systems of transformations, such as groups, possess many properties, and possess them necessarily, but to conclude that such a possession of necessary properties constitutes a representation or understanding of necessity is a fundamental encoding-based error. It is to assume that properties possessed by a representational (or instrumental) system are thereby somehow represented or understood by that system; it is to assume that a blue encoding element thereby represents «blue». Piaget's later introduction of the intensional understanding of «local» necessities (Piaget, 1977b) only highlights this problem: a homunculus is required to understand these local, intensional necessities just as much as one is required to understand the «global» necessities of structural closure. Another manifestation of this hiatus between activity and representation is the lack of differentiation between instrumental or pragmatic modalities, on the one hand, and logical modalities, on the other, in Piaget's last work on the subject (Piaget, 1981, 1983): there is an unacknowledged slide between activities as *instrumentally* possible or necessary, relative to a pragmatic goal, and properties and relationships being *logically* possible or necessary, independent of any goal.

The encodingist presuppositions of structuralism did not serve Piaget, nor his major insights, well. They are in fact fundamentally incompatible with those insights, as well as being intrinsically logically incoherent. Structuralism forced an unresolved and unresolvable tension in Piaget's system.

Information processing approaches

A second problematic conceptual tool that prevented Piaget from developing a consistent interactive view was his increasing use of cybernetic and information processing models. This turn toward functionalism was inspired by his growing awareness of the problems that arise because structures are inherently static. The Genevan research program on children's problem-solving strategies (Cellérier, 1972; Inhelder *et al.*, 1976) impressed on Piaget the need to model problem-solving procedures as distinct from structures (Inhelder & Piaget, 1979; Piaget, 1981). Cybernetics and information processing provided more natural ways to talk about organizations of possible process than structuralism had. Piaget (1977b) moved from exclusively structural stage definitions toward a definition based on reflective abstraction; he employed cybernetic concepts in reconstructing his model of development through equilibration (Piaget, 1975); and he affirmed that procedures, not structures, formed the leading edge of development (Piaget, 1981).

Unfortunately, these approaches are only slightly more suited to Piaget's underlying interactivism than structuralism was. They allow process modeling in a way that structuralism does not, but they still rely on an encoding conception of representation. Even if he had entirely rejected structuralism in favor of functionalism, instead of viewing them as somehow complementary (Piaget, 1977b; Inhelder & Piaget, 1979), he would not have escaped encodings and their deficiencies. Information processing systems consist of procedures that operate on encoded information, on encoded data structures in the form of sensations, perceptions, images, or «declarative» propositions. Cellérier (1979), in his ambitious synthesis of structuralism and information processing, retains encodings in his treatment of perception and of «internal models of the world». In the classic style of information-processing modeling that employs production rules (Newell & Simon, 1972; Anderson, 1983; Klahr, Langley & Neches, 1987), every rule contains encoded information as part of its condition. No version of information-processing functionalism is appropriate for an interactive epistemology. Information processing, in any form, is inadequate to express Piaget's interactive insights (Campbell & Bickhard, 1986).

Conclusion

Essentially, then, interactivism accepts Piaget's insight into the operative character of knowledge and filters out Piaget's vestigial commitment to encodingism. Such filtering follows from applying Piaget's own argument against copy theories of knowledge against the figural, «state representing», and structural aspects of his own epistemology. The purified interactivism thus obtained yields many of the core features of Piaget's epistemology as intrinsically necessary implications and possibilities: constructivism, interactionism, developmental stages, and reflective abstraction. (For a discussion of explanations in terms of intrinsic necessity, see Campbell and Bickhard, 1986, ch. 2.) At the same time, interactivism undermines, and forces the rejection of, structuralism and information processing.

Of course, our claim that Piaget's interactivism was his deepest theoretical insight could be disputed by those who regard structuralism or information-processing models as the core of his theory. What is clear is that interactivism is logically incompatible with either structuralism or information processing. Both structuralism and information processing are destroyed by variants of Piaget's own argument against copy models, and interactivism is not. Interactivism results, we believe, when Piaget's views are pressed for internal consistency. Moreover, considered on its own, interactivism is necessitated by the logical incoherence of foundational encodings.

Interactivism provides a conception of representation that captures and implies Piaget's deepest insights. Interactivism avoids the fatal logical incoherence inherent in structuralism and information processing. Interactivism has a reasonable claim, then, to being a new foundation for cognitive and developmental psychology. The elaboration of the interactivist program will be convergent with fundamental themes in Piaget's genetic epistemology, but, by the same token, it will require the rejection of other important themes in Piaget's work.

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SUMMARY

Interactivism is a new conception of the nature of knowledge: all representation is entirely interactive, not just primarily so. There can be no foundational encodings, no irreducibly figural or structural forms of knowledge. Interactivism deeply converges with Piaget's insights into the operative nature of knowledge. It logically implies, and thus integrates, central aspects of Piaget's genetic epistemology, such as constructivism, developmental stages, and reflective abstraction. Interactivism, however, argues against the logical tenability of other aspects of Piaget's epistemology, such as structuralism and information processing models.

RÉSUMÉ

L'interactivisme conçoit de façon nouvelle la nature de la connaissance: toute représentation mentale est entièrement interactive. Selon l'interactivisme, les codages de base, les formes de connaissance irréductiblement figurales ou structurales, sont impossibles. L'interactivisme est profondément en accord avec les insights de Piaget sur la nature opératoire de la connaissance. Il implique logiquement, donc fait l'intégration, des aspects centraux de l'épistémologie génétique, tels que le constructivisme, les stades du développement, et l'abstraction réfléchissante. L'interactivisme, cependant, rejette comme logiquement intenable d'autres aspects de l'épistémologie piagétienne, tels que le structuralisme et les modèles cybernétiques.

ZUSAMMENFASSUNG

Interaktivismus ist eine neue Auffaßung von Wissen: nicht nur der überwiegende Teil, sondern alle mentale Repräsentation wird als interaktiv betrachtet. Es kann keine Grundkodierungen, keine irreduziblen figuralen oder strukturellen Wissensformen geben. Interaktivismus zeigt eine fundamentale Übereinstimmung mit den Einsichten Piaget's in die operative Natur von Wissen. Er integriert zentrale Aspekte von Piaget's genetischer Epistemologie, wir z.B. Konstruktivismus, das Konzept der Entwicklungsstadien und der reflektierenden Abstraktion, in dem er sie logisch einschließt. Andere Aspekte der Piaget'schen Epistemologie, wie Strukturalismus und Modelle der Informationsverarbeitung, erscheinen vom Standpunkt des Interaktivismus aus als unhaltbar.

REFERENCES

ANDERSON, J.R. (1983). *The architecture of cognition.* Cambridge: Harvard University Press.

BICKHARD, M.H. (1978). The nature of developmental stages. *Human Development, 21,* 217-233.

BICKHARD, M.H. (1980a). *Cognition, convention, and communication.* New York: Praeger.

BICKHARD, M.H. (1980b). A model of developmental and psychological processes. *Genetic Psychology Monographs, 102,* 61-116.

BICKHARD, M.H. (1982). Automata theory, artificial intelligence, and genetic epistemology. *Revue Internationale de Philosophie, 36,* 549-566.

BICKHARD, M.H. (1987). The social nature of the functional nature of language. In M. Hickmann (Ed.), *Social and functional approaches to language and thought* (pp. 39-65). New York: Academic Press.

BICKHARD, M.H. (1988). Piaget on variation and selection models. *Human Development, 31,* 274-312.

BICKHARD, M.H., & RICHIE, D.M. (1983). *On the nature of representation: A case study of James J. Gibson's theory of perception.* New York: Praeger.

CAMPBELL, R.L., & BICKHARD, M.H. (1986). *Knowing levels and developmental stages.* Basel: Karger.

CAMPBELL, R.L., & BICKHARD, M.H. (1987). A deconstruction of Fodor's anticonstructivism. *Human Development, 30,* 48-59.

CELLÉRIER, G. (1972). Information processing tendencies in recent experiments in cognitive learning — theoretical implications. In S. Farnham-Diggory (Ed.), *Information processing in children* (pp. 115-123). New York: Academic Press.

CELLÉRIER, G. (1979). Structures cognitives et schèmes d'action. *Archives de Psychologie, 47,* 87-122.

CHOMSKY, N. (1975). *Reflections on language.* New York: Pantheon.

CHOMSKY, N. (1980). *Rules and representations.* New York: Columbia University Press.

CHOMSKY, N. (1988). *Language and problems of knowledge.* Cambridge, Mass.: MIT Press.

FODOR, J. (1975). *The language of thought.* New York: Crowell.

FODOR, J. (1981). The present status of the innateness controversy. In J. Fodor, *Representations* (pp. 257-316). Cambridge, Mass.: MIT Press.

FODOR, J. (1983). *The modularity of mind: An essay on faculty psychology.* Cambridge, Mass.: MIT Press.

FURTH, H.G. (1981). *Piaget and knowledge* (2nd ed.). Chicago: University of Chicago Press.

GELMAN, R., & BAILLARGEON, R. (1983). A review of some Piagetian concepts. In J.H. Flavell & E.M. Markman (Eds.), *Handbook of child psychology. Vol. 3: Cognitive development* (pp. 167-230). New York: Wiley.

HAROUTUNIAN, S. (1983). *Equilibrium in the balance.* New York: Springer.

INHELDER, B., ACKERMANN-VALLADÃO, E., BLANCHET, A., KARMILOFF-SMITH, A., KILCHER-HAGEDORN., H., MONTANGERO, J., & ROBERT, M. (1976). Des structures cognitives aux procédures de découverte. *Archives de Psychologie, 44,* 57-72.

INHELDER, B., & PIAGET, J. (1979). Procédures et structures. *Archives de Psychologie, 47,* 165-176.

KEIL, F.C. (1981). Constraints on knowledge and cognitive development. *Psychological Reviews, 88,* 197-227.

KITCHENER, R.F. (1986). *Piaget's theory of knowledge: Genetic epistemology and scientific reason.* New Haven: Yale University Press.

KLAHR, D., LANGLEY, P., & NECHES, R. (1987). *Production system models of learning and development.* Cambridge, Mass.: MIT Press.

NEWELL, A., & SIMON, H.A. (1972). *Human problem solving.* Englewood Cliffs, N.J.: Prentice-Hall.

OLÉRON, P., PIAGET, J., INHELDER, B., & GRÉCO, P. (1963). *Traité de psychologie expérimentale. Vol. 7: Intelligence.* Paris: Presses Universitaires de France.

PIAGET, J. (1936). *La naissance de l'intelligence chez l'enfant.* Neuchâtel: Delachaux et Niestlé.

PIAGET, J. (1946). *La formation du symbole chez l'enfant.* Neuchâtel: Delachaux et Niestlé.

PIAGET, J. (1947). *La psychologie de l'intelligence.* Paris: Colin.

PIAGET, J. (1950). *Introduction à l'épistémologie génétique. Vol. 1: La pensée mathématique.* Paris: Presses Universitaires de France.

PIAGET, J. (1961). *Les mécanismes perceptifs.* Paris: Presses Universitaires de France.

PIAGET, J. (1967). *Biologie et connaissance.* Paris: Gallimard.

PIAGET, J. (1970). *Genetic epistemology.* New York: Columbia University Press.

PIAGET, J. (1972). *Essai de logique opératoire* (2nd ed.). Paris: Dunod.

PIAGET, J. (1975). *L'équilibration des structures cognitives: Problème central du développement.* Paris: Presses Universitaires de France.

PIAGET, J. (1977a). The role of action in the development of thinking. In W.F. Overton & J.M. Gallagher (Eds.), *Knowledge and development (Vol. 1)* (pp. 17-42). New York: Plenum.

PIAGET, J. (1977b). Essai sur la nécessité. *Archives de Psychologie, 45,* 235-251.

PIAGET, J. (1983). *Le possible et le nécessaire. 2: L'évolution du nécessaire chez l'enfant.* Paris: Presses Universitaires de France.

PIAGET, J., & INHELDER, B. (1966). *L'image mentale chez l'enfant.* Paris: Presses Universitaires de France.

PIATTELLI-PALMARINI, M. (1980). *Language and learning: The debate between Jean Piaget and Noam Chomsky.* Cambridge: Harvard University Press.

RICHIE, D.M., & BICKHARD, M.H. (1988). The ability to perceive duration: Its relation to the development of the logical concept of time. *Developmental Psychology, 24,* 318-323.

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