Commentary

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Stepping Back: Reflections on a Pedagogical Demonstration of Reflective Abstraction

Commentary on Abrahamson, Shayan, Bakker, and van der Schaaf

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The study by Abrahamson, Shayan, Bakker, and van der Schaaf [this issue] makes important contributions to several aspects of research, including pedagogy, methodology, and theory. The use of tablet technology to implement new pedagogical practices was innovative. Further, the integration of eye-tracking, microgenetic, and clinical interview methods enabled the researchers to capture ecologically valid data with all the rigor of more quantitative procedures. In turn, such a rich data set provided a concrete explication for some of Piaget's more abstract theoretical ideas. In our commentary, the focus will be on issues that are most directly related to theory. We are in general agreement with the underlying theoretical frameworks and many of the specific aspects of the model that are being advocated in the target article. Given this general convergence we offer areas in which we think the underlying framework could be extended or clarified. First, let us summarize what we take to be the theoretical core of the article.

Abrahamson and colleagues provide a theoretically substantive answer to the following pedagogical question: "How does one steer conceptual construction?" In answering this question, Abrahamson and colleagues suggest that we revisit Piaget in order to better understand children's development of new conceptual categories with a particular focus on the area of mathematics learning. The general Piagetian insight which their analysis is based on concerns the emergence of conceptual knowledge from within a sensorimotor ground. More specifically, reflective abstraction was the process through which Piaget modelled "conceptual schemata rising from sensorimotor operatory schemes" [Abrahamson et al., this issue]. In turn, Abrahamson and colleagues enlist the process of reflective abstraction in order to teach children in elementary school about mathematical concepts. Finally, Abrahamson and colleagues

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also draw on Vygotsky's sociocultural approach in order to forge a dialectical view that situates action-based learning in facilitated settings through symbolically mediated, pedagogical guidance.

The remainder of the commentary will address the following four topics: (1) how an action-based approach goes beyond a dynamical systems (DS) framework with respect to issues of normativity and emergent representation; (2) how an action-based approach goes beyond embodiment with respect to implicit versus explicit knowledge; (3) the relation between action-based and sociocultural approaches with a constructivist model of scaffolding and self-scaffolding; and (4) issues concerning evidential relations to hypothesized cognitive constructive processes.

An Action-Based Approach Goes beyond a DS Framework

We would like to highlight some ways in which an action-based approach goes beyond a DS framework with respect to issues of normativity and emergent representation. The introduction of DS theory into developmental psychology emphasized the emergence of global structure through local self-organizing process [Port & van Gelder, 1995; Thelen & Smith, 1994]. That developmental outcomes could arise from self-organization, and, therefore, need not be pre-specified, was a powerful counter argument to the prevailing nativism of the time. Of equal relevance for the cognitive sciences more broadly was the move away from representation (as encoded symbols) to the real-time dynamics of embodied systems (organic or artificial).

We suggest, however, that a DS framework per se is incomplete. A major part of what is missing from the DS framework is an account of emergent representation.[1] Accounting for *emergence* through *self-organization* requires consideration of thermodynamics, and the move to thermodynamics also enables an account of the emergence of *normative* phenomena – including representation. In short, thermodynamics enables the emergence of normative success, and normative success is the most proximal foundation for the emergence of representation.[2]

The crucial contribution of thermodynamics to this model is that processes that are *far from* thermodynamic equilibrium must be *maintained* in those far-from-equilibrium conditions. Otherwise they go to equilibrium and cease to exist – and, therefore, whatever pattern of process that might have self-organized ceases to exist. In that sense, whatever contributes to the maintenance of that far-from-equilibrium condition is *functional* for the continued existence of the system and its properties. This is a normative functionality in that dysfunction is itself readily modelable, as influences that tend to disrupt the far-from-equilibrium conditions.

Some processes make contributions to the maintenance of their own (far-from-equilibrium) existence conditions. A candle flame, for example, maintains above combustion threshold temperature, induces convection bringing in oxygen and taking away waste products, vaporizing wax, and so on. A candle flame, therefore, manifests the property of *self-maintenance* – it contributes to its own far-from-equilibrium existence.

[1] Dynamic field theory [Spencer & Schöner, 2003] attempts to address this limitation, but see Allen and Bickhard [2013] for critical discussion.

[2] For elaboration on normative emergence see Allen and Bickhard [2011c] and Bickhard [2009a].

Candle flames can only do one thing (though it has multiple consequences). If the candle is running out of wax, for example, it cannot change processes to attempt to accommodate to that situation. A bacterium, in contrast, can, for example, detect if it is swimming up a sugar gradient, and, if it is, will tend to continue swimming, while if it is swimming down a sugar gradient, it will tend to tumble and then resume swimming. In these ways, it will tend to move into higher concentrations of food (sugar), thus maintaining its property of being self-maintaining in the face of changes in its relations to its environment: swimming is self-maintaining if it is going up a sugar gradient, while tumbling is self-maintaining if it is headed down a sugar gradient. In this sense, a bacterium exhibits the property of recursive self-maintenance: it self-maintains its property of being self-maintaining.

Indications that, for example, a bacterium should continue swimming, can be correct or incorrect: the bacterium might, for example, be swimming up a saccharine gradient. That is, the indication that *this* is an environment in which swimming is functional can be *true or false*. Here is the emergence of primitive normative representation: processes that possess *truth value*.

Indications of interactive potentialities may have truth values, but they do not look much like "standard" kinds of representation, such as of objects. The basic model, however, does have resources for such more complex representing. To see this, consider a frog. In general, a frog will have multiple possible interactions amongst which it will need to select one. Specifically, a frog may have the option to flick its tongue and eat a fly, or to flick its tongue in a different way and eat a worm; alternatively, the frog may hop in the water to avoid an approaching predator [Bickhard, 1993, 2009b]. As with the bacterium, the interaction possibilities indicated for the frog implicitly predicate that the environmental conditions are appropriate for the actions to be successful. If the environmental conditions hold, the indicated action will succeed and the implicit predication will be true. If the conditions do not hold, the interaction will fail and the implicit predication will be false (e.g., the frog flicks its tongue at an iPad screen with moving images). Indications of interactive possibilities form the core of this perspective for modeling the dynamic emergence of an action-based model of representation [Bickhard, 2009b]. Importantly, the frog example illustrates that there can be multiple, branching interactive possibilities. This is part of the resources of the model to be able to account for more complex representation.

Making use of these resources, this framework can borrow from Piaget's [1954] model of object representation because both frameworks share a pragmatist commitment to action as the locus for modeling mental phenomena. For pragmatists, knowledge is a matter of *competent* interaction with the world and in that sense it is already normative. For Piaget's action-based model, object representation is constituted as a structured web of possible interactions (e.g., visual scans, hand manipulations) that remain invariant with respect to other types of transformations (e.g., occlusion, displacement, etc.). Thus, the emergence of object representation is constituted in the *organization* of the internal processes that underlie increasingly competent interaction capabilities. It is here that Thelen and Smith's [1994] version of DS diverges sharply from Piaget's action-based approach. For Thelen and Smith it is exclusively the real-time embodied dynamics that are relevant and the emergent global structure is epiphenomenal [Witherington, 2011]. However, for Piaget, the emergent global structure (e.g., object representation) contributes in extremely important ways – *not* epiphenomenally – to the further functioning and development of the child [Piaget, 1962].

The crucial point for current purposes is that something more than DS theory per se is required in order to account for normative emergence – the emergence of representation in particular. In the model outlined, DS theory must be supplemented with the thermodynamic considerations of far-from-equilibrium systems.

An Action-Based Approach Goes beyond Embodied Knowing

The ontological emergence of new "organizations" is especially apparent for any attempt to account for knowledge and representation beyond the level of sensorimotor/interactive knowing. Accordingly, any version of DS that does not allow for the ontological emergence of such organization may be trapped in the snares of an embodied reductionism [Witherington, 2014]. Piaget's notion of reflective abstraction is an important aspect of his attempt to explain how new knowledge emerges beyond sensorimotor knowing. Although not in agreement with the specifics of Piaget's stage model and process of reflective abstraction [Campbell, 2001; Campbell & Bickhard, 1986], the basic principle that higher forms of new knowledge involve some sort of reflection process on lower levels is convergent. Otherwise, without reflection, humans would be restricted to sensorimotor/interactive knowing (i.e., "thought-in-action").

For an action-based approach, reflection on lower levels will render explicit what is only implicit at the lower level. In this way, the lower levels serve as the origins of properties and features with no obvious observable presence "in" the world (e.g., logical necessity, object permanence, modality, grammar, mental states, etc.). The issues related to implicit knowledge are not new in psychology and have been discussed in a multitude of ways: tacit knowledge, sub-personal representations, procedural know-how, unconscious heuristics, system one processing, and so on [Fodor, 1968; Simon, 1976; Stanovich & West, 2000; Stich, 1983; Tulving, 1972; Tversky & Kahneman, 1974]. However, these approaches either claim not to be dealing with representations proper or they do not attempt to propose an account of implicit knowledge at all. That is, the underlying representations are all explicit and it is the differences in the processes that make the knowing implicit or explicit (e.g., heurist vs. rule-based, intuitive vs. rational, unconscious vs. conscious, etc.). In his criticism of Karmiloff-Smith's [1992] attempt to address implicit knowledge per se, Fodor [1998] argued that "all representations are explicit about something" (p. 134). Fodor is correct if all representations are encoded symbols. That is, encoded symbolic representation only has content if that content is explicit, and so models of representation as encodings preclude implicit content altogether.

In contrast, for action-based approaches in general, competent interaction systems will have implicit properties and features that can, potentially, become known explicitly. Specifically, the *potential* explicit knowledge is implicit in the (properties of the) internal organization of the system that produces the competent interactions with the world. The emergence of *representation* discussed above provides an account of the emergence of implicit representational content that helps to clarify the idea of implicit versus explicit knowledge. Recall that a predication that some particular interaction is appropriate for this environment is a predication *about* the environment. It is the indication or predication that is *explicit* for the system. Such indications or predications *presuppose* that the appropriate success conditions for such an interaction hold in the current environment. Such presuppositions are *implicit*. Success or failure of the indicated interaction provides system-detectable feedback depending on whether the implicit presuppositions were true or false.

When the internal indications iterate – for example engaging in *this* interaction brings these *other* interactions into the range of possibility – and form sub-webs with a certain organizational structure, they will manifest relevant properties that could be useful for the system to represent explicitly. For example, object representation discussed above manifests the property of permanence but this not explicitly represented by the system. Instead, toddlers' competent interaction with objects implicitly presuppose the permanence of the objects. Accordingly, toddlers do not *explicitly* represent objects as such because their explicit knowledge is restricted to the webs of indicated interaction possibilities.[3]

However, if children can reflect on their interactive knowledge then the implicitly presupposed content can be represented explicitly. Piaget's reflective abstraction was an attempt to model such processes and the research by Abrahamson and colleagues has built an innovative pedagogical practice around such processes. The contrast between implicit and explicit knowledge is particularly difficult to consider in the case of object representation because the differences between children's performances who are implicitly presupposing objects versus explicitly representing them can be subtle [Bickhard, in preparation]. However, in the more abstract domains of logic or mathematics, the transition is easier to appreciate because those domains have clear implications that depend on whether some axiom or principle is implicit in the child's current level of reasoning or explicitly part of that reasoning. Regardless, from an action-based approach, implicit knowledge is an intrinsic aspect of the ontology of knowing; and, in general, throughout development the emergence of new knowledge within and between domains will proceed from implicit to explicit.

In sum, embodiment is at times taken to entail that only full body interactions are relevant to issues of cognition and interaction [Bickhard, 2015]. The interactivist model outlined above, however, *requires* embodiment – a body is necessary for interaction [Bickhard, 2008] – but internal organization of processes, including reflective processes, are nevertheless crucial as well.

An Action-Based Approach and a Sociocultural Approach

Abrahamson and colleagues argue that learning is an action-based constructivist process in settings that can be facilitated by the sociocultural context. That is, their dialectical view offers a way to understand mathematical learning as a Piagetian constructivist process that is embedded in a Vygotskian sociocultural framework. We are in full agreement that learning is a process of (potentially scaffolded) construction and would like to suggest an action-based constructivist model of scaffolding and self-scaffolding [Bickhard, 2005]. First, we need to say a little bit more about action-based constructivist learning and how it relates to a functional model of scaffolding – which then motivates why self-scaffolding would be a major realm of development.

We have argued elsewhere that the move to an action-based approach is *necessary* to transcend the shared limitation of nativism and empiricism (i.e., foundation-

[3] This is different from Piaget's model in which the toddlers are assumed to symbolically represent objects once they have developed structures that manifest certain properties [Müller, 2009].

alism) in that such an action-based approach allows for the emergence of representational phenomena [Allen & Bickhard, 2013]. Accordingly, an action-based *constructivism* can be contrasted with multiple nativist and empiricist constructivist varieties in that an action-based constructivism accounts for the *emergence* of new knowledge *throughout* development [Allen & Bickhard, 2011a, b]. What gets constructed are new internal organizations for competent interaction. If there is no foresight, this will need to be a variation and selection process – an evolutionary epistemology [Campbell, 1974]. Thus, the move to an action-based framework forces a variation and selection emergent constructivism [Bickhard, 2006].

Constructivist learning capabilities will be greater if the process is *recursive*: the ability of current constructive processes to make use of previous constructions. For an action-based constructivism, recursivity will manifest in two ways: as the unitization of prior constructions, i.e., past constructions can be used as constructive units in future constructions,[4] and second, as previously constructed loci within which variations can be induced [Campbell & Bickhard, 1992]. For humans, the constructive processes will themselves undergo learning and development. Accordingly, human forms of learning involve a meta-recursive constructivist process in which a major aspect of development involves learning to learn [Bickhard, 2006].

Learning as scaffolded construction is modeled in terms of particular kinds of influences on the variation and selection process [Bickhard, 2005]. Specifically, scaffolding is understood as the suspension of potential selection pressures related to the construction processes. Consider a situation in which the complete construction process for success on some task is outside the range of the child's current capabilities: perhaps successful constructions are simply too complex relative to the constructive resources currently available to the child. That is, the child's attempted constructions are selected out because they do not fulfill the task requirements for success. Now, if the "normal" selection processes could somehow be blocked, then the prior attempts could remain as temporary resources for subsequent constructions (i.e., if the selection process could be suspended, then the recursivity could manifest). Scaffolding as the blocking of selection pressures is convergent with how Abrahamson and colleagues enabled children to succeed on the sensorimotor versions of the proportion tasks that could then serve as a resource for the subsequent reflective understanding. Importantly, their procedure also used techniques to highlight selection pressures that children were ignoring through the use of the number grid or questioning that had the effect of falsifying the child's current idea about the mathematical principle involved.

Scaffolding as the blocking of selection pressures fits with standard ways of thinking about scaffolding as adult guidance, but adult guidance is not the only way in which selection pressures can be blocked. Children themselves can learn strategies and heuristics to block some types of selection pressures. That is, children can develop abilities for self-scaffolding [Bickhard, 2005], for example, breaking problems down into sub-problems, going to extreme cases that are exaggerated or idealized, etc. Accordingly, self-scaffolding skills are central to children's learning to learn and pedagogical practices can target both learning and learning to learn.

[4] Nativist and empiricist positions may also appeal to a recursive constructivism in this sense but they will be restricted to the combinatorial space of whatever the foundational representations are supposed to be – i.e., no emergent representations, only "molecular" representations constructed out of a foundational base of "atomic" representations [Allen & Bickhard, 2011a].

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In sum, interaction is always with environments, and this includes social environments. Environments constitute both the primary loci of interactions and the primary loci of constraints on learning and development, including functional scaffolding. Again, however, agent-level processes, such as those of self-scaffolding, are of essential importance.

Evidential Relations to Hypothesized Cognitive Constructive Processes

Finally, a note of caution about issues concerning evidential warrant for theoretical constructs and processes. In general, hypothesized theoretical constructs and processes will be open to both theoretical and empirical constraints. Such constraints operate to rule out alternative ideas (they constitute differing kinds of selection constraints on model constructions). Finding empirical results that are consistent with hypothesized cognitive processes is important, but the empirical warrant for those hypotheses is only as good as the alternatives that are ruled out. If the empirical "facts" are consistent with multiple hypothesized theories or models, then the evidential warrant will rest more heavily on theoretical constraints that rule out alternatives. While it may be a step too far to claim "literally seeing reflective abstraction," Abrahamson and colleagues have provided substantial warrant for the contemporary relevance of Piagetian theory.

Conclusion

We applaud Abrahamson and colleagues' theoretical integrations and their methodological innovations that allow them to put those integrations to empirical test. We have argued that the DS, Piagetian, and Vygotskian frameworks made use of in these integrations are the right ones, but that they are in need of four extensions and clarifications: (1) The addition of thermodynamic considerations to a dynamic systems framework, thus permitting the modeling of emergence, normative emergence, and, in particular, the emergence of representation. (2) The modeling of internal processes, such as reflective abstraction, in addition to externally observable "embodied" behaviors. (3) An explicit model of the relationships between internal developmental processes and external environmental, especially social, contexts. We have outlined one such model, in terms of functional scaffolding and self-scaffolding. (4) And a caution concerning the evidential relationships between empirical and theoretical constraints and particular models.

References

Allen, J.W.P., & Bickhard, M.H. (2011a). Emergent constructivism. *Child Development Perspectives, 5,* 164–165. doi:10.1111/j.1750-8606.2011.00178.x

Allen, J.W.P., & Bickhard, M.H. (2011b). You can't get there from here: Foundationalism and development. *Behavioral and Brain Sciences, 34,* 124–125. doi:10.1017/S0140525X10002311

Allen, J.W.P., & Bickhard, M.H. (2011c). Normativity: A crucial kind of emergence. *Human Development, 54,* 106–112. doi:10.1159/000327096

Allen, J.W.P., & Bickhard, M.H. (2013). Stepping off the pendulum: Why only an action-based approach can transcend the nativist empiricist debate. *Cognitive Development, 28,* 96–133. doi:10.1016/j.cogdev.2013.01.002
Bickhard, M.H. (1993). Representational content in humans and machines. *Journal of Experimental and Theoretical Artificial Intelligence, 5,* 285–333. doi:10.1080/09528139308953775
Bickhard, M.H. (2005). Functional scaffolding and self-scaffolding. *New Ideas in Psychology, 23,* 166–173. doi:10.1016/j.newideapsych.2006.04.001
Bickhard, M.H. (2006). Developmental normativity and normative development. In L. Smith & J. Voneche (Eds.), *Norms in human development* (pp. 57–76). Cambridge, UK: Cambridge University Press. doi:10.1017/cbo9780511489778.003
Bickhard, M.H. (2008). Is embodiment necessary? In P. Calvo & T. Gomila (Eds.), *Handbook of cognitive science: an embodied approach* (pp. 29–40). Amsterdam, The Netherlands: Elsevier. doi:10.1016/B978-0-08-046616-3.00002-5
Bickhard, M.H. (2009a). Interactivism: A manifesto. *New Ideas in Psychology, 27,* 85–95. doi:10.1016/j.newideapsych.2008.05.001
Bickhard, M.H. (2009b). The interactivist model. *Synthese, 166,* 547–591. doi:10.1007/s11229-008-9375-x
Bickhard, M.H. (2016). Inter- and en-activism: some thoughts and comparisons. *New Ideas in Psychology, 41,* 23–32.
Bickhard, M.H. (in preparation). *The whole person: toward a naturalism of persons – contributions to an ontological psychology.*
Campbell, D.T. (1974). Evolutionary epistemology. In P.A. Schilpp (Ed.), *The philosophy of Karl Popper* (pp. 413–463). LaSalle, IL: Open Court.
Campbell, R.L. (2001). Reflecting abstraction in context. Translator's introduction in J. Piaget *Studies in reflecting abstraction*. Edited and translated by Robert L. Campbell (pp. 1–27). Hove, UK: Psychology Press.
Campbell, R.L., & Bickhard, M.H. (1986). *Knowing levels and developmental stages: Contributions to human development.* Basel, Switzerland: Karger.
Campbell, R.L., & Bickhard, M.H. (1992). Types of constraints on development: An interactivist approach. *Developmental Review, 12,* 311–338. doi:10.1016/0273-2297(92)90012-Q
Fodor, J.A. (1968). The appeal to tacit knowledge in psychological explanation. *The Journal of Philosophy, 65,* 627–640. doi:10.2307/2024316
Fodor, J.A. (1998). *In critical condition.* Cambridge, MA: MIT Press.
Karmiloff-Smith, A. (1992). *Beyond modularity: A developmental perspective on cognitive science.* Cambridge, MA: MIT Press.
Müller, U. (2009). Infancy. In U. Müller, J.I.M. Carpendale, & L. Smith (Eds.), *The Cambridge companion to Piaget* (pp. 200–228). Cambridge, UK: Cambridge University Press.
Piaget, J. (1954). *The construction of reality in the child.* New York, NY: Basic. doi:10.1037/11168-000
Piaget, J. (1962). *Play dreams and imitation in childhood.* New York, NY: W.W. Norton & Co.
Port, R., & van Gelder, T. (1995). *Mind as motion: Exploration in the dynamics of cognition.* Cambridge, MA: MIT Press.
Simon, H.A. (1976). From substantive to procedural rationality. In S.J. Latsis (Ed.), *Method and appraisal in economics* (pp. 130–131). Cambridge, UK: Cambridge University Press. doi:10.1017/CBO9780511572203.006
Spencer, J.P., & Schöner, G. (2003). Bridging the representational gap in the dynamic systems approach to development. *Developmental Science, 6,* 392–412. doi:10.1111/1467-7687.00295
Stanovich, K.E., & West, R.F. (2000). Individual differences in reasoning: Implications for the rationality debate? *Behavioral and Brain Sciences, 23,* 645–665. doi:10.1017/S0140525X00003435
Stich, S. (1983). *From folk psychology to cognitive science: The case against belief.* Cambridge, MA: MIT Press.
Thelen, E., & Smith, L.B. (1994). *A dynamic systems approach to the development of cognition and action.* Cambridge, MA: MIT Press.
Tulving, E. (1972). Episodic and semantic memory. In E. Tulving and W. Donaldson (Eds.), *Organization of memory* (pp. 381–402). New York, NY: Academic Press.
Tversky, A., & Kahneman, D. (1974). Judgment under uncertainty: Heuristics and biases. *Science, 185,* 1124–1131. doi:10.1126/science.185.4157.1124
Witherington, D.C. (2011). Taking emergence seriously: The centrality of circular causality for dynamic systems approaches to development. *Human Development, 54,* 66–92. doi:10.1159/000326814
Witherington, D.C. (2014). Self-organization and explanatory pluralism: avoiding the snares of reductionism in developmental science. *Research in Human Development, 11,* 22–36. doi:10.1080/15427609.2014.874763