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Commentary on **Esther Thelen, Gregor Schöner, Christian Scheier, & Linda B. Smith (2001). The dynamics of embodiment: A field theory of infant perseverative reaching. BBS 24(1):1–86.**

Abstract of the original article: The overall goal of this target article is to demonstrate a mechanism for an embodied cognition. The particular vehicle is a much-studied, but still widely debated phenomenon seen in 7–12-month-old-infants. In Piaget's classic "A-not-B error," infants who have successfully uncovered a toy at location "A" continue to reach to that location even after they watch the toy hidden in a nearby location "B." Here, we question the traditional explanations of the error as an indicator of infants' concepts of objects or other static mental structures. Instead, we demonstrate that the A-not-B error and its previously puzzling contextual variations can be understood by the coupled dynamics of the ordinary processes of goal-directed actions: looking, planning, reaching, and remembering. We offer a formal dynamic theory and model based on cognitive embodiment that both simulates the known A-not-B effects and offers novel predictions that match new experimental results. The demonstration supports an embodied view by casting the mental events involved in perception, planning, deciding, and remembering in the same analogic dynamic language as that used to describe bodily movement, so that they may be continuously meshed. We maintain that this mesh is a pre-eminently cognitive act of "knowing" not only in infancy but also in everyday activities throughout the life span.

Is the concept of object still a suitable notion?

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Abstract: The model and framework presented in the target article by Thelen et al. is an interesting effort that is able to account for the contextual variability in the A-not-B performance of 7–12-month-old infants. In the process of developing their framework, the authors discounted the concept of object as a useful notion in discussions of A-not-B performance. For Piaget and other developmentalists, the main evidence for the acquisition of the concept of object was the disappearance of A-not-B errors after age 12 months. However, the Thelen et al. model makes predictions of A-not-B outcomes over a much shorter, trial-to-trial time scale. Given the mismatch in the time scales over which analyses in the two approaches have been based, we wonder if the challenge to the concept of object has been misplaced.

Thelen et al. (2001) used the inconsistency of the results in the A-not-B paradigm, and the success of their model, to bring into question the utility of Piaget's (1954) *concept of object* as the predominant explanation for A-not-B performance. Nevertheless, we wonder whether the success of their model justifies rejection of the concept of object as an explanation for A-not-B performance. In addition to exploring this issue, we point out that although Piaget did not present a quantitative account of his empirical work, his framework can, at least in part, be considered dynamical. In other words, in many ways Piaget's outlook as a scientist of the developing mind may not differ as much from the viewpoint advocated by Thelen et al. as the authors portrayed.

What is the utility of the "concept of object"? The "concept of object" is generally defined as an awareness that an object continues to exist even when the actor no longer interacts with it, and when sensory input regarding the object has been removed. The A-not-B experimental procedure has been the predominant method used to study the concept of object and to track its changes with age. Briefly, the procedure requires participants to reach for a hidden object at a location A, and then to make a subsequent reach to an object hidden at a cued location B. Continued reaching at location A, committing the A-not-B error, has been taken as evidence of incomplete acquisition of the concept of object, whereas the acquisition of the concept of object has been reflected by the generation of cued reaches to location B. Thus, the level of A-not-B error provides a simple, parsimonious operationalization of the concept of object. Developmentalists, Piaget in particular, were interested in examining performance on this task because it reflected development toward adaptive, adult capabilities. In particular, a transition from the presence of A-not-B error to its disappearance became a landmark for identifying a critical transition in development. Namely, this transition marked the end of Piaget's stage IV to the beginning of stage V, during his sensorimotor period of development.

Between the ages of 7 and 12 months (Piaget's stage IV), variation in task parameters are related to variation in the degree of A-not-B error outcomes, but clearly there is evidence of the A-not-B error. Moreover, the A-not-B error disappears after about age 12 months (Piaget's stage V). Therefore, when considered over the course of development, and taking the literature as a whole, the basic effect and developmental trend *are* reproducible. Early in the Thelen et al. target article (sect. 2), the authors were apparently in agreement with this statement. However, in focusing on the between-experiment variability in A-not-B outcomes during the ages 7–12 months period, the authors (viz., their model) seem to have lost sight of the fact that the trend continues beyond that age, and in fact changes after about age 12 months. It is the appearance of this bifurcation in the developmental function, and not the pre-12-months-of-age between-experiment variability, that would seem to be the main evidence supporting the appearance of the concept of object. Therefore, if the concept of object is to be challenged from an analysis of the extant empirical data, then the authors have based their challenge on what seems to be a wrong view of the data.

In particular, the Thelen et al. model (e.g., Figs. 15–20 in the target article) accounts for how changes in task parameters and internal processes (e.g., memory) act on a short-term, trial-to-trial basis in the prediction of A-not-B performance. This time scale of analysis is much briefer than the time scale with which Piaget and other developmentalists were concerned. Given such a difference, we wonder if the authors were actually interested in addressing developmental processes regarding A-not-B performance. Perhaps Thelen et al. were more interested in adapting an already ex-

https://doi.org/10.1017/S0140525X04290161 Published online by Cambridge University Press

isting dynamical model (Schöner et al. 1997) to account for the processes related to the generation of motor output observed under the A-not-B paradigm.

This is not to say that the authors did not achieve success in the problem they considered: accounting for contextual variations in A-not-B outcomes during the age 7–12 months period. Indeed, they provided a quantitative framing of this problem that (1) reorganizes the range of A-not-B results; (2) holds the promise of making predictions of future experimental outcomes; and (3) is cast in a formal language where both the dynamics of mental life and observable behavior can be viewed in the same quantitative framework. The first and second achievements are tenets of good science, in general. The third is an achievement of a science where investigators consider that their subjects have minds, as well as bodies.

Is the concept of object a static construct? The second point of our commentary on Thelen et al.'s portrayal of the Piagetian concept of object is that it appears to have been misrepresented as a static mental structure. It is more reasonable to think of the object concept as representing a global variable that is subject to modulation by a number of sources of input. In Piaget's framework the development of object concept evolves over time through the integration and modification (e.g., assimilation, accommodation) of information coming from the interaction of the infant with the environment. This may also include information from multiple sources of sensory input from the environment, information that is a consequence of the infant's actions, and information available from past experience. In other words, the concept of object arises from the input of multiple, dynamically interacting sources of information. Therefore, we can conclude that Piaget's thinking on the concept of object, if not his general theoretical stance (e.g., see Fig. 11 in Varela 1989), was closer in spirit to the Thelen et al. framework than Thelen et al. have led readers to believe. Although Thelen et al. expressed their point of view with the help of sophisticated quantitative tools, when the Piaget and Thelen et al. approaches are considered together under a broadened view, we can see that the two approaches have common features.

Conclusion. Although there is no question that the Thelen et al. model works to account for the contextual variations in the data observed during ages 7 to12 months, these authors addressed phenomena that occur over a shorter-time scale than that in which Piaget and other developmentalists had interest. The model presented in the target article deals with shorter-term, trial-by-trial predictions. On the other hand, the concept of object is most clearly evidenced by the transition seen when a longer course of development is considered. As a result of the mismatch between the time scale of analysis that Thelen et al. were concerned with, and the time scale that was relevant for an understanding of object concept development, the challenge made by Thelen et al. to the concept of object seems misplaced. We conclude that when the concept of object is considered over the relevant developmental time scale, it, first, retains its usefulness for discussions on development, and, second, is not a static construct but instead evolves through the input from various dynamically interacting information sources.

ACKNOWLEDGMENT

This commentary was written while Andrew B. Slifkin was supported by a Fyssen Foundation fellowship.

There may not be an A-not-B error

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Abstract: In the A-not-B situation children reach toward location A when the object is at location B. Researchers interpret this as an error. I question this interpretation. Reaches are inaccurate only if the intention actually is to obtain the hidden object. If this is not the goal, then reaching for A may be accurate and there may be no error to be explained.

In the A-not-B situation the youngest children do not reach for hidden objects. Between 7 and 12 months of age, children often reach toward A when the object is hidden at B. Finally, older children reach for the hidden object, regardless of its location. Piaget interpreted the first two actions as errors, and the third action as correct. As reviewed by Thelen et al. (2001, sect. 2.1), subsequent accounts of the A-not-B situation also interpret the child's behavior in the second stage as an error. Piaget did not test this interpretation, and his successors do not appear to have done so either. But reaching toward A (when the object is at B) is incorrect only if the child actually intends to reach toward B.

It is risky to assume that we know the goals of prelinguistic children. It is particularly risky to assume that a 9-month-old has the same goals as the experimenter. This may be an example of the psychologist's fallacy (James 1890/1950): the inappropriate assumption that the experimenter's view of the situation is the same as that of the subject. Consider mealtime. At any age, some food may fall to the floor. Adults always consider this to be an error, but children may not. When the child first learns to put food in his or her mouth the skill is poorly developed and food is dropped due to lack of skill; an error. In the mature child (as in the adult), food reaches the floor only by accident. However, in an intermediate stage (at roughly two years of age) the child sometimes intends that the food land on the floor. Adults consider this to be an error but the child regards it as a resounding success. To be sure, there is a developmental change in the child's ability to move food by hand. However, there is also a developmental change in the child's goals (these goal changes are reflected in the fact that we sometimes refer to the food as being dropped, and at other times as being thrown). Researchers appear not to have considered the possibility that a sequential change of goals may occur in the A-not-B situation.

Thelen et al. have sometimes characterized the pattern of reaching as "perseverative," rather than as an error. However, this does not resolve the issue. The model offered by Thelen et al. predicts a divergence between intention (goal) and action (outcome). For all intents and purposes, this is an error, as is shown by the fact that in section 2.1 Thelen et al. have contrasted "perseverative reaching" with "accurate performance."

Perhaps over the course of development children do not make mistakes in the A-not-B situation. Instead, developmental changes in reaching might be produced by developmental changes in the child's goals. Six-month-old children may not want to retrieve the hidden object; maybe they are interested only in having things that they can see. If so, then not reaching is correct at this stage. Between ages 7 and 12 months, perhaps children do not want to retrieve the hidden object at B but do want to reach to A (I don't know why a child might want to do this, but that does not invalidate the point: As any parent knows, a child's goals often differ from the parent's goals, and it is often difficult to understand why children want what they want). If so, then reaching to A would be correct, or accurate, and the model of Thelen et al. would not apply. It is certainly the case that children's behavioral goals change as they develop, and these different goals lead to reliable differences in behavior. The question, then, is whether there might be a regular progression in children's goals that could produce the developmental pattern of reaching reported by Piaget.

Students of the A-not-B situation (including Thelen et al.) offer

https://doi.org/10.1017/S0140525X04290161 Published online by Cambridge University Press