Commentary/Thelen et al.: The dynamics of embodiment

Plus ça change . . . : Jost, Piaget, and the dynamics of embodiment

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Abstract: The “A-not-B” error is consistent with an old memory principle, Jost’s Law. Quantitative properties of the effect can be explained by a dynamic model of habituation that is also consistent with Jost. Piaget was well aware of the resemblance between adult memory errors and the “A-not-B” effect and, contrary to their assertions, Thelen et al.’s analysis of the object concept is much the same as his, though couched in different language.

Critic John Horgan recently commented discouragingly about progress in psychology: “Theories of human nature never really die; they just go in and out of fashion” (1999, pp. 6–7). We are extremely sympathetic to the general theme of Thelen et al.’s system-theory approach to developmental psychology. But we now draw attention to two ways in which it conforms to Horgan’s critique. First, the theory ignores an older and simpler approach to memory reversals; and second, the theory is not as different from Piaget’s as its authors contend.

Old memories. Who has not had the experience of moving something—a book or a file, say—to a new location, then going away on holiday and, returning, looking fruitlessly for the object in its old location. This is an everyday example at a well-established but frequently forgotten memory principle, Jost’s Law: “Given two associations at the same strength, but of different ages, the older falls off less rapidly in a given length of time” (Howland 1951, p. 649, after Jost 1387). Before the vacation, memory-trace strength for the new location was higher than for the old, but after a delay, because of Jost’s Law, the two are reversed. The older “association” (we must forgive Howland the unfashionable language) decays more slowly than the newer. It seems to have gone unnoticed that the A-not-B error is strikingly consistent with Jost’s Law, albeit on a short time scale. What are the implications of this idea?

A simple dynamic model. To answer this question requires a dynamic model that instantiates Jost’s Law. Just such a model was proposed by one of us to account for the properties of habituation (Staddon, in press; Staddon & Higa 1996; 1999), and it is illustrated in Figure 1. Each occurrence of an event is input to a cascade of thresholded-input integrators whose output represents the strength of memory for the event. The light line in Figure 1 shows the response of the system to a series of inputs: memory strength increases with each stimulus presentation and then decays after the series. The important point for Jost’s Law is that the memory trace decays rapidly at first and then more slowly, allowing the situation illustrated by the heavy line in Figure 1, which shows the effect of a single presentation of object B. The trace stimulated by B is initially higher than the older light-line trace for A, but soon falls below it. If the infant’s reaching is controlled by the stronger trace, clearly he will respond correctly—choose B—to the left of the vertical line at the point of intersection of the two curves. But later, to the right of the line, he will show the A-not-B error because the older trace is now stronger than the newer one.

This model implies a number of quantitative relations:

1. The more occurrences of event A, the stronger the A-not-B error; in the limit, if A is presented only once, there should be no error.
2. The error should not occur at short delays (i.e., to the left of the vertical line in Fig. 1).
3. The point of transition from correct to incorrect reaching should decrease with the number of A presentations.
4. The delay after presentation of “B” necessary before the A-not-B error will occur should also depend on the time between B


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The A-not-B effect predicted by memory decay. Light line: Effect on the trace of four presentations of object A. Heavy line: Effect of a single presentation of object B. The “A” trace is stronger to the right of the vertical line, leading to the error. The traces were generated by a two-stage, feedforward (S-type) cascade model of the type discussed by Staddon and Higa (1996). Parameters for the two integrators: $a_1 = .5, a_2 = .99, b_1 = 4, b_2 = .1$.

and the last “A” presentation: the longer the A-B time, the longer the delay after B necessary to get the effect. This prediction is illustrated in Figure 2.

5. The transition time (i.e., the A-B delay that allows correct responding) should also depend on the spacing of A. Specifically, as the spacing of A increases while the number of A presentations and the A-B interval remains constant, the transition time should decrease, attain a minimum, and then increase. This prediction follows from the rate-sensitive property of habituation, the fact that habituation may be more persistent following spaced than massed training even though the level of habituation is greater with massed training.

Thelen et al. describe a series of studies consistent with the first three of these predictions: (1) “All A-not-B studies involve some, often unspecified, number of training trials” (sect. 2.2.1); (2) “infants do not err at short delays,” sect. 1.1, para. 4; and (3) In this case, time of transition has not been measured, but probability of choosing A has: “Smith, Thelen, and their associates have shown conclusively that commission of location errors with the B cue is strictly a function of the number of prior reaches to A” (sect. 2.2.5). But no one seems to have looked systematically at the effect of A-presentation spacing and A-B delay on the time of transition from correct to incorrect reaching – points 4 and 5. Parametric experiments are tough to do with infants, but these may be worth a try.

An obvious inference from this analysis is that the developmental changes indexed by the A-not-B error correspond to, if they are not entirely determined by, progressive changes in the memory system. One possible change is shown in Figure 3. Simply decreasing the value of the slower integrator, $A_2$, from 0.99 to 0.95 can abolish the error. No doubt other parameter changes would produce similar results, but the idea that the trace changes in such a way that different events become more clearly separated looks like the easiest way to duplicate the disappearance of the A-not-B error as the infant ages. Moreover, the change illustrated in Figure 3 implies correlated effects. For example, young infants should recover from habituation more slowly than older infants, another testable idea.

This is a dynamic analysis only. It makes no predictions about non-temporal manipulations such as the similarity, salience, and valence of the A and B objects and their locations. Moreover, the analysis is restricted to the acquisition of motor habits, which we (and Piaget) presume to be a large part of what is going on when infants engage in this simple task. We do not doubt that other, “higher” processes are also developing, so that the motor-learning component becomes less important as the child matures. But it never vanishes entirely, as Jost’s Law testifies.

Piaget redivivus: The object concept. And Thelen et al. agree: “it is incorrect however, to assume that perseverative reaching responses are unique to a particular stage in infancy” (sect. 2.2.6). But they go on to conclude:

Such diverse context effects pose a serious challenge to Piaget’s original interpretation. If the A-not-B error is a true measure of the status of infants’ representations of objects, how can it be that what they know depends on so many seemingly irrelevant factors? . . . The contemporary consensus is that Piaget’s account is incorrect, . . . we agree with some of our colleagues that the A-not-B error is not about an object concept per se. (sect. 1, last para., sect. 1.1)

Thelen et al.’s overall arguments and conclusions express two serious misunderstandings of Piaget: that contextual influences are incompatible with his theory, and that the A-not-B task measures the child’s object concept. As to context, we note that Piaget was quite aware of it. For example, he himself had evidence suggesting the type of object (e.g., people vs. toys) clearly makes a difference in the construction of the object concept. He also knew that even older children may revert to earlier reactions: for example, at 2 years and 4 months, “Lucienne, hearing a noise in my [Piaget’s] office, says to me (see are together in the garden): ‘That is papa up there’, Piaget 1954, p. 59, our emphasis). He was also aware that even adults on
occasion fall prey to the A-not-B error: 'I take my clothes brush out of the small bag in which it is usually kept and place it on a table, afterward when I want to use it I look for it in the bag and cannot understand its disappearance. I see my pipe on my desk put it in my pocket, then hunt for it on the desk' (p. 66). Finally, Piaget discovered the A-not-B error by exploring the influence of specific contextual changes on the way children search for hidden objects. Far from ignoring contextual effects, he exploited them.

The second thing to note is that contextual effects can be explained and predicted on the basis of Piaget's interpretation of the A-not-B error. For example, Thelen et al. report that small changes, such as varying the number of reaches to A, abolish the effect. This is perfectly consistent with Piaget, who argued that there is a period during which the child's search for hidden objects depends more on previous actions than on the displacements of the object. In other words, before it becomes something external to, and independent of, the self, the object is something at the disposal of the infant's actions. Lucienne, at 15-months-of-age, is in the garden. She has just greeted her father, Piaget, when her mother asks: 'Where is papà?' (Piaget 1954, p. 59). Although Piaget stands one meter away, in full view of the child, Lucienne looks at the window. Piaget explained his daughter's residual behavior by appealing to habit strength, the number of times in the past Lucienne had looked at the window and seen her father.

In summary, not only was Piaget well aware of content effects, but he also explained them by appealing to the same mechanisms invoked by Thelen et al. Although he used a less technical language, Piaget would certainly have agreed with Thelen et al.'s frequent claim that the A-not-B error emerges from the coupled dynamics of looking, planning, remembering, deciding, and reaching.

But if Piaget knew about many of the findings that Thelen et al. now hold against his theory of the construction of the object concept – and even explained them by invoking similar mechanisms – why then did he not concede that these findings undermine his theory? The answer is related to Thelen et al.'s second misunderstanding: that the A-not-B task measures the child's object concept. Thelen et al. attribute to Piaget the view that to have the object concept is to have "some causal structure [presumably in the brain] that generates a thought or a behavior." According to this view, a child will either have this structure in the brain, in which case she will not err in the A-not-B task, or she will lack it, in which case she will err. Therefore, the child's performance can be used to measure the presence or absence of this internal structure, the physical embodiment of the object concept.

But this was not Piaget's view. Nothing could be further removed from his epistemological and constructivist assumptions than the idea that to have a concept is to have a physical embodiment of it in the form of an internal causal structure, a functional entity, or even a representation that is distinct from action, operations, and interactions (Lourengo & Machado 1996). For Piaget, to know is to act and operate upon reality, and to have the object concept is to act in distinct ways toward objects, to search for them when hidden, to take note of their displacements and their temporal order whether the displacements are visible or invisible, and the like. In Piaget's view, therefore, the A-not-B error is not a measure of the object concept but a criterion of the child's level of understanding of objects as external, permanent realities. Differently stated, the object concept does not refer to an entity that is separate from, and causally related to, the child's acts, but to formal aspects of these acts (i.e., not their force or duration but their relatedness to the object's displacements, their order, etc.). Incidentally, this explains why the object concept is, for Piaget, inseparable from the concepts of space, time, and causality. Accordingly, Piaget's theory could not be closer to an embodied view of cognition, and it is simply wrong to attribute to him the notion that the child searches for hidden objects because of a "disembodied belief in the permanence of objects" (Thelen et al. sect. 7.1).

Piaget argued that to have a concept is to act and operate upon reality in distinct and organized ways. It follows that whatever fac-