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Indexing Individual Objects in Infant Working Memory

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Currently there are disputes in the infancy literature concerning when infants are first able to individuate physical objects by their features or properties. This issue has taken on new significance following claims that individuation by feature is linked to the emergence of object kind concepts toward the end of the first year. Needham (2001, this issue) presents evidence that infants as young as 4.5 months old can individuate objects by feature. We locate this controversy within the framework of brain mechanisms that *index* or track individual objects, drawing upon theories of attention and working memory developed in the study of adults. We find that Needham's work contributes to two issues: categorization and the effect of object history on the individuation of objects in a complex display.

Key Words: object working memory; individuation; identification; infants.

It used to be thought that infants were incapable of mentally representing physical objects. For Piaget (1955) this incapacity was a hallmark of the entire period of infancy, a cognitively primitive stage in which the mind could only grasp that which was currently "present to the senses." The problem with objects is that they are three-dimensional volumes in three-dimensional space. This means, given the laws of physics and probability, that most of the time most of the objects in the world are bound to be out of reach, out of ear shot, and invisible. The odd, idiosyncratic object will cohabit our arbitrary, personal sector of time and space but even these will only occasionally emerge into view or come within reach. Despite this unpromising backdrop, we all rapidly converge on identical views concerning the objective and universal nature of physical objects, their mode of existence, their kinds and causal powers, assigning to each an individual and enduring identity. The problem of how this rapid convergence takes place has exercised thinkers for many generations but it is only within the past several decades that we have begun to make real empirical progress.

Piaget believed that the key to this problem was the capacity to conceive of objects as enduring through their periods of concealment. The trick was to represent an image of the object to yourself in its absence so as to mimic its continued presence. Bower (1967, 1974) rejected Piaget's focus on permanence and

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replaced it with the problem of *identity*. Even if the young brain can “*re*-present” an absent object, the deeper problem remains as to how the brain can represent “self-same object” as opposed to merely “similar object.” If “re-presenting” is simply a matter of entertaining a mental image or picture of the object, there can be no difference between “self-same one” and “very-similar-looking one.” But there is all the world of difference between *my mother* and *very-similar-to-my-mother*! At the same time, recognizing identity for an object carries with it the need to recognize individuality, since the question of identity concerns identity of an *individual*. Individuality in turn raises the question of *how many* objects one is dealing with, even if “exactly *one*” is the answer. The twin problems of object individuation and identity have rightly come to dominate current work on the “object concept.”

Bower’s rejection of the permanence problem received support from the finding that the infant visual system is designed from the bottom up for a 3D world (Yonas, Arterberry, & Granrud, 1987; see Kellman & Arterberry, 1998, for a recent review). More especially, it received support from work showing a surprisingly rich set of infant expectations about life behind occluders (Baillargeon, 1986, 1995; Baillargeon, Spelke, & Wasserman, 1985). Recently, attention has come to focus on infants’ ability to individuate objects, both through studies of infant counting (Wynn, 1992) and through studies of inferences based on spatiotemporal and property information (Kellman, Spelke, & Short, 1986; Spelke, Kestenbaum, Simons, & Wein, 1995; Xu & Carey 1996). Spelke has produced a compelling body of evidence that infants have a fundamental sense of physical objects as discrete, cohesive, bounded volumes that exist in a continuous fashion in time and space (e.g., Spelke, 1982, 1988, 1994; Spelke, Kestenbaum, Simons, & Wein, 1995). The “Spelke object” derives its unique identity by tracing a unique “world line,” to use the physicists’ phrase.

Objects and Kinds of Objects

Xu and Carey (1996) asked about the impact of *kind* concepts on infants’ individuation judgements. According to Xu and Carey, the infant begins with only a concept of the Spelke object, undifferentiated with respect to categories. That is, younger infants have the concept, THING, but not, for example, the concepts, BALL or CUP. This means that when the younger infant observes objects emerging from and returning behind an occluder one at a time, the infant has no way of determining how many objects are in the parade. This is because both objects share part of their world lines (the part behind the occluder). This renders the spatiotemporal information ambiguous. Since the infant cannot determine the distinctness of the world lines, the younger infant cannot determine the distinctness of the objects.

Older infants around 12 months, however, have, according to Xu and Carey’s account, begun to acquire differentiated kind concepts. Differentiated kind concepts give the older infant a new ability to use the property differences exhibited by the successive objects in the parade to determine their distinctness as individuals. Although the infant had been able to perceive and discriminate the properties for a long time, she was previously unable to infer distinct identity on their basis. Why do differentiated kind concepts confer this power? According to Xu and Carey's account, this follows from the nature of kind concepts. Borrowing the philosophical theory of *sortals* (Wiggins, 1980), they propose that a given kind concept provides criteria for how to individuate and identify objects belonging to that kind. The undifferentiated kind concept, THING, provides only criteria referring to spatiotemporal factors. But a differentiated sortal, like CUP, will include criteria referring to other properties of the object, such as shape, by which a *cup* can be distinguished from a non-cup and be identified as self-same (or different) individual *cup*. Hence, the older infant, armed with knowledge of the individuation and identity criteria for something being a *cup*, no longer has to rely upon spatiotemporal factors alone and knows how to count *cups* when spatiotemporal information is ambiguous.

Xu and Carey's intriguing hypothesis is controversial and has been challenged by results from a number of experiments, including those reported in this issue by Needham (see also Needham & Baillargeon, 1997, 1998; Wilcox, 1999; Wilcox & Baillargeon, 1998a, 1998b). These authors have argued that with certain simplified displays, infants as young a 4.5 months will use featural differences to individuate objects, long before the infants in Xu and Carey's experiments. Baillargeon and colleagues agree that when infants are required to make judgements across events involving the removal of an occluder ("event mapping" tasks), infants will fail to individuate by feature until around 12 months. But they also argue that if younger infants are required to make judgements about simpler events in which, though an occluder is present, it is never removed ("event monitoring" tasks), then they can show quite good performance individuating objects by feature. Needham (2001, this issue) uses events that do not involve full occlusion and do not involve making judgements across events in which an occluder is removed. Arguably then, she uses an "event monitoring" task and finds (in some cases) that young babies can use object features in making individuation judgements.

The "Object Concept" as an Information Processing System

The above dispute follows a pattern that is familiar from research on cognitive development. A claim that the younger child lacks a competence is met by a counterclaim that the competence can be detected by more sensitive methods. Do young infants lack the ability to individuate by feature? Do they lack differentiated kind concepts? If so, is the former the result of the latter? Or do infants possess either or both but but fail to demonstrate their competence because the measures we employ are not sensitive enough at younger ages? Determining the competence of a cognitive system at different points in development is a fundamental task of cognitive science and essential if we are ever to gain insight into the "mechanisms of development." However, it is seldom possible for us to fruitfully investigate competence without also developing serious ideas regarding *performance*. By “competence,” we mean in this context the representational resources the infant has, for example, the available concepts, regardless of whether or how the infant can actually use those resources in particular situations (cf. Chomsky, 1965, pp. 3–15). By “performance,” we mean all those factors that enter into determining whether and how the competence is used in particular situations, for example, the nature of working memory, executive functioning, and attention.

We have been developing a theoretical framework that we believe is useful for formulating the different competence and performance aspects of the object concept (Leslie, Xu, Tremoulet, & Scholl, 1998; Scholl & Leslie, 1999). Our aims in formulating this framework have been twofold: to understand the relation between competence and performance in the object concept and to do so in a way that makes use of ideas that are independently motivated by studies of object cognition in adults. It is always possible that the organization of infant cognitive systems will turn out to be so radically different from that of adults that completely different ideas are needed in the two cases. However, this seems unlikely. A better working assumption is that the major systems present in the adult are the very systems we see developing in the infant. If so, it is useful to align infant and adult studies.

One of the most important insights from the study of object cognition in adults is that traditional models which incorporate only sensory processing and long-term memory stores are inadequate. The traditional model assumes that sensory codes describing the featural properties of an object activates the long-term memory representation best matching that set of features. This long-term representation allows access to more information (e.g., by association or inference) than is contained in the activating feature set. The extra information might include, for example, the kind to which the object belongs, functional information, and, in the case of the adult, the word for this type of object. The activation of a long-term representation identifies the distal object that corresponds to the proximal sensory input. If the sensory input carries “bottom-up” information, then long-term memory provides further information that can be used “top-down.” For example, the sensory input from the sight of a dog’s head poking out of bushes will bottom-up active a long-term representation, DOG (e.g., by matching a stored visual template of a dog-head). This activation of DOG makes further information available, e.g., information about *tails*. The stored and now activated information about *dog tails* might in turn be used “top-down” to enhance the parsing of the sensory input—so, for example, only now, for the first time, from among the tangle of branches, the dog’s tail is discerned.

Both Needham and colleagues and Xu and Carey implicitly assume this traditional model. For example, Xu and Carey postulate that long-term stored-object kind concepts (or sortals) are used top-down to individuate and identify objects in sensory input. Kind concepts have to be stored in long-term memory, but, once activated by sensory input, will influence how that input is interpreted. So, to use an example from Xu, Carey, and Welch (1999), if the sensory input produced by a display in which a toy duck sits atop a toy truck best matches two distinct long-term kind representations, DUCK and TRUCK, then the infant will successfully identify the input as "duck on top of truck." On the other hand, if the infant lacks the appropriate long-term representations, then she will fail to identify the sensory input appropriately and fail to individuate the objects involved. Needham (this issue) demonstrates another type of top-down effect, in which infants' individuation judgments are influenced by prior experience from a brief exposure, and Needham and Baillargeon (1998) show the effect can persist as long as 24 h. But, important though they are, sensory input and long-term memory are not the only two things we need to consider.

Following Kahneman and Treisman (1984) and Treisman (1988), it is now widely acknowledged in the study of adult object cognition that the twin pillars of sensory input and long-term representation need to be supplemented by a third set of representations and mechanisms. In addition to sensory codes and iconic memory (Sperling, 1960), on the one hand, and generic object kind representations and long-term memory, on the other, attended objects are also coded episodically and these codes maintained temporarily in working memory. Although there is a wealth of experimental support, the idea is most easily conveyed by the following *gedanken* offered by Kahneman and Treisman. You see a dark blob in the distance and think, "a bird!" Then you change your mind, and think, "no, a plane!" before finally settling on "Superman!" Despite these changes of mind, we do not experience three distinct individuals. Each of these activated long-term representations, BIRD, PLANE, SUPERMAN, is used to refer to the *same* individual; we experience that individual as maintaining a constant identity despite the succession of radically different descriptions of it that we entertain. So the brain must have some way, other than by long-term generic representations, to refer to and track individuals through particular episodes. For this purpose, Kahneman and Treisman introduced the notion of an *object file* as an intermediate representation between sensory input and long-term representation. An object file indexes a particular individual by way of its locations-through-time without regard to its other properties.

A long-term object kind representation is a generic representation. For example, CUP represents the generic category that has *cups* as members: it does not by itself represent an individual. To represent an individual, CUP requires something additional, for example, a quantifier like "*a*" or "the" to represent *a cup* or *the cup*. Even a quantified long-term representation like this does not yet refer to a specific individual, since it can represent *any* cup. Though "*the* CUP" implies a particular individual, it requires some further mechanism to tie the representation to a particular contextual *cup*. If there are two cups present, for example, THE CUP could refer to either one. How does the brain know which of the two cups its own representation refers to? This is where the indexing function of an object file representation comes in. Typically, the way infants are tested is by introducing one or two individual objects into the here-and-now context and then asking the infant to track *this* individual and *that* individual as they undergo an occlusion. The type of occlusion typically used will produce a perceptual masking and banish the object related sensory and iconic memory codes (e.g., Palmer, 1999).

Following this, the infant is asked to make individuation or identity judgements when *this* and/or *that* individual appears once more. We therefore owe an account, not only of how objects come to be represented as belonging to kinds, but also of how particular individuals can be tracked and *referred to* by the cognitive system.

Indexing Individual Objects

A key construct in our theoretical framework for object tracking by infants is the *object index* (Leslie et al., 1998). We hypothesize that when one attends to an object, the brain assigns a mental "pointer" or index to that object. The index "sticks" to, and thus tracks, the object as it moves, even if it moves behind an occluder. The sticky index allows the infant to continue to attend to the object while occluded, though, inevitably, this demands working memory resources. The construct of an object index is drawn from studies of adult attention and, specifically, as already noted, has much in common with the idea of an "object file" (Kahneman & Treisman, 1984; Kahneman, Treisman, & Gibbs, 1992; see also Pylyshyn, 1989, 1994, on visual indexing). Each of the key properties attributed to object indexes in our model is independently motivated by studies of adult attention. See Leslie et al. (1998) and Scholl and Leslie (1999) for details. We hypothesize that an index forms the core of the object representation that an infant constructs in working memory while attending to a physical object.

One analogy to the notion of an object index is a mental finger that points at an object in the world. Although a pointing finger contains no information about the object at which it points, it allows rapid access to the object, without an exhaustive search. Straining the analogy somewhat, a note containing descriptive information about the object pointed at (e.g., color, shape, or size) might optionally be glued to the pointing finger. Another—perhaps more useful—analogy can be drawn between the nonverbal index and demonstrative words in language. A bare index (one without descriptive information attached) might be thought of as analogous to indicating an object by uttering, "THAT!" Two objects might be indicated by "THIS!" and "THAT!" Descriptive information might optionally be added: "THIS is RED!" and "THAT is GREEN!"

An object index constructed in working memory can serve to interface bottom-up sensory information with information stored in long-term memory, e.g., object kind information. As we saw, a representation of object kind, e.g., CUP, cannot by itself be used as the representation of a particular individual object because kind representations are generic. However, this long-term representation might be combined under appropriate circumstances with an object index to yield the working memory representation, "THIS is a CUP." Since the sticky index, THIS, will continuously point to a particular object through changes of location, it allows the infant to track a particular *cup* throughout an episode.

Working Memory for Objects

We have elsewhere reviewed at some length the parallels and differences between the infant and adult literatures relevant to indexing (Leslie et al., 1998;

Scholl & Leslie, 1999) and we do not repeat that here. Instead we want to highlight the role of object working memory in indexing. There are obvious reasons for assuming that working memory plays a key role in the on-line tracking of small sets of objects through occlusion. Information about the objects needs to be maintained through the period of occlusion. The effect of occlusion is not simply the absence of sensory input from the occluded objects, but also that sensory input from unrelated surfaces and objects continues to be processed and overwrites the older information in the sensory system (Sperling, 1960). There are therefore severe spatiotemporal constraints on what information about occluded objects the visual system can maintain on its own, without the assistance of attention and working memory.

Information gleaned from attending to an object and to its behavior throughout an episode will often find its way into long-term memory. This means that object indexing in working memory will be an important conduit for information in the process of learning about object kinds.

Working memory appears to comprise a set of behaviorally and neurally specialized components in prefrontal cortex. Among those commonly recognized are verbal, visual, spatial, and object short-term stores plus an executive control component (Baddeley, 1986, 1998; Baddeley & Hitch, 1974; Goldman-Rakic, 1996; Luck & Vogel, 1997; Rainer, Asaad, & Miller, 1998; Rao, Rainer, & Miller, 1997; Smith et al., 1995; Ungerleider, Courtney, & Haxby, 1998). It has been known for almost 2 decades that the lateral prefrontal cortex has a central role in working memory functions. Recent neurophysiological and imaging studies have revealed several distinct subsystems within this area. Some researchers assume that the subsystems reflect a *functional* division of labor, for example, that there are separate circuits for the maintenance of memory codes and for the manipulation of memory codes (D'Esposito, Postle, Ballard, & Lease, 1999; Owen, 1997; Postle & D'Esposito, 1999). Others have found evidence for a complex *stimulus-dependent* segregation: first, between verbal and visual working memory (e.g., McCarthy et al., 1996; Mecklinger & Pfeifer, 1996) and more recently within the visual domain; working memory for *objects* appears to be mediated by more ventral frontal regions, while *spatial* working memory is mediated by more dorsal frontal regions (Courtney, Ungerleider, Keil, & Haxby, 1996; Wilson, Scalaidhe, & Goldman-Rakic, 1993). Object- and space-based systems of the frontal lobe are presumed to correspond to the functional segregation of earlier processing stages, such as the ventral (object discrimination or "what") and the dorsal (spatial localization or "where") visual pathways.

A general feature of working, as opposed to long-term, memory is that it is capacity limited. Capacity limitations in visual working memory have not been so extensively studied as those in verbal working memory. However, early work suggested that visual working memory capacity is severely limited (Phillips, 1974; Phillips & Christie, 1977). A recent study by Luck and Vogel (1997) suggests a limit of 4 objects in visual or object working memory in adults, contrasting with the well-known verbal limit of 7±2 "chunks" (Miller, 1956). Luck and Vogel claim that each working memory object representation can hold at least four conjoined features with no cost in terms of storage capacity. Rao, Rainer, and Miller (1997) recorded from cells in monkey lateral prefrontal cortex during a delay task which required the monkey to hold in memory both object location and object feature information. Cells in the dorsolateral prefrontal cortex receive inputs from the parietal dorsal visual system (“where”), while cells in the ventrolateral prefrontal cortex receive inputs from the inferotemporal ventral visual system (“what”). Rao et al. found neurons with delay activity in lateral prefrontal cortex that were selective for either object location or for object feature information. Interestingly, around half the neurons with delay activity showed tuning to both location and feature information, suggesting that the prefrontal working memory systems are an important site for integrating such information. It is likely, then, that these systems play an important role in the binding of features to the object representation. There is also behavioral evidence that the prefrontal cortex undergoes major maturational changes during the second half of the first year (Bell & Fox, 1992; Diamond, 1988; Diamond & Doar, 1989; Goldman-Rakic, 1987), a finding which is also supported by anatomical data (Koenderink & Uylings, 1995; Koenderink, Uylings, & Mrzljak, 1994). We hypothesize then that the maturation of these frontal, integrating, working memory systems plays an important role in the increasingly robust individuation and identification abilities infants display toward the end of the 1st year.

The Two Goals of Needham’s Research

The way Needham formulates her main question is as follows: What kinds of information from prior experience do infants use in segregating objects? In other words, if a baby sees an object, can she use later the information she extracted earlier to tell that a similar part of a complex display she sees would also likely be an individual object? Does the infant learn something useful from this prior experience with regard to individuation? The question is of great importance, since it lies at the center of object recognition. Re-cognition, as the word suggests, presumes some prior processing. How does this learning process work in early development?

More specifically, Needham’s article in this issue can be described as a study in *perceptual categorization*. Categorization is a process in which distinct entities come to be treated as equivalent. We can reformulate Needham’s question as: What are the boundaries of a given object category in young infants? Following prior experience with an individual object in one scene, what similarity metric will the infant apply when parsing objects in another scene? When for the infant are two objects considered equivalent or sufficiently similar so that the first object influences the top-down parsing of the new scene? The structure of her several experiments is the following (see Table 1). The baby sees an object, X_1, for example, a blue box with *red* squares on it, which differs along certain dimensions from, but is otherwise similar to, the target object, X_2, always a blue box decorated with *white* squares. The target object, however, is only seen in a new scene in

TABLE 1
Summary of Needham and Colleagues' Segregation Experiments

Exp. No.	Familiarization 1 (5 sec)	Familiarization 2 (infant-controlled)	Test	Result
Needham and Baillargeon (1998)				
1	—	—		U = E
	—	target box (blue box w/ white squares) + cylinder	Move-together (U) or Move-apart (E)	U = E
2	Target box	—	"	U > E
3	Cylinder	—	"	U = E
4	Cylinder (15 sec)	—	"	U > E
5	Target box (2 min) 24 h before test	—	"	1st block: U = E 2nd block: U > E
Needham (this issue)				
1	Blue box w/ white circles	—	"	U = E
2	Blue box w/ white circles	Target box + cylinder	"	U > E
3	Target box horizontally	Target box + cylinder	"	U > E
4	Purple box w/ yellow circles	Target box + cylinder	"	U = E
5	Blue box w/ red squares	Target box + cylinder	"	U = E
6	Blue box w/ yellow squares	Target box + cylinder	"	U = E
Needham and Lockhead (cited in Needham, this issue)				
1	Three different boxes	Target box + cylinder	"	U > E
2	Three identical boxes	Target box + cylinder	"	U = E
3	Two different boxes	Target box + cylinder	"	U = E

Note: The target box is always an upright blue box with white squares on it. Uppercase letters indicate when an attribute is different on the familiarization object. The test event is always either a Move-together (Unexpected) or Move-apart (Expected) event. U (unexpected) and E (expected) represent looking times in the Result column.

which it is in contact with a third object, Y, always a yellow cylinder. Does the baby infer that since X_1 was a distinct bounded individual, X_2 is likely to be a distinct bounded individual too and therefore not mechanically attached to Y?

The different experimental variations that Needham introduces address a number of different perceptual dimensions along which X_1 and X_2 differ from one another: orientation, shape, and color of decorative elements, and background color of object (and, in Needham, Dueker, & Lockhead, cited in Needham, 2001, this issue, number of objects in the X_1 displays). However, the variations she uses are not, as far as we can see, theoretically systematic, and, unfortunately, this makes the results somewhat hard to interpret. For example, Experiment 2 shows that the *shape* of the decorative elements can vary while the infant will still consider X_1 and X_2 to be equivalent or similar—that is, he will infer, based on exposure to X_1, that X_2 is also a distinct object, distinct in particular from Y. So shape of decorative elements does not matter to the infant. However, the *color* of these same decorative elements *does* matter (Experiment 5 vs Experiment 6): If the color of the surface decorative elements differs then the infant judges the objects to belong to different categories and concludes that X_1 is not a reliable guide to X_2 in the matter of how likely it is that X_2 is attached to Y. This seems to be a clear empirical finding. But we are not sure what it means. Why were these particular dimensions chosen and why these particular values along these dimensions? Was it that the shape and color of the decorative elements were thought to be related to the notion of visual texture? It seems likely that, for purposes of individuating physical objects, three-dimensional surface texture would be more important than the properties of decorative elements. However, Rakison and Butterworth found that older babies (14–22 months olds) attend to objects' spatial structure but not to object texture in categorization (Rakison & Butterworth, 1998). So we remain puzzled by the finding that the color but not shape of decorative elements should play a role in object categorization and generalization of individuation. Our point really is that Needham's interesting research program would be enhanced by a theoretically judicious choice of dimensions and values along those dimensions.

A theoretical basis for this part of Needham's research could be provided by the associative category formation framework (for a recent developmental interpretation, see Elman et al., 1996). According to this framework, the target object (X_2) represents one point in an *n*-dimensional similarity space. The category "box" is a set of the points in this space with certain coordinates on these *n* dimensions. The category "blue box" is a subset of this set, with *n*-1 other dimensions. The empirical question from this standpoint is to explore where are those points in this space (X_1) which are sufficiently close to X_2 for the baby to infer that X_2 is going to behave the same way as X_1 did, that is, be unattached to Y. So far, however, the exploration of this space in Needham's experiments has not been as systematic as in similar work in the connectionist literature (e.g., Quinn & Johnson, 1998). Choosing one simple dimension to start with—for example, the well-studied dimension of color—would have made Needham's findings more easily interpretable. In Experiment 4, background color was manipulated, but only together with two other dimensions. If well-chosen values along a single dimension were compared, the relative positions of X_1 and X_2 along this dimension could be described and quantified, and the results could be placed within the framework of the existing categorization literature.

Another intriguing result in Needham's paradigm is that babies require 15 s prior familiarization to the yellow cylinder in order to individuate or segregate it from the box in the second display. However, if the familiarization display shows the blue box, only 5 s is required to allow the infants to segregate it from the yellow cylinder in the second display (Needham & Baillargeon, 1998, Experiment 2 vs Experiment 4). Why there should be this striking asymmetry in the familiarization period required to show the effects of prior experience is not clear. Needham suggests that the objects have a differential salience. If so, it could be measured independently of these other effects or controlled for. Why should differential salience play a role in the effect of prior experience on individuation judgements? Perhaps salience in this context stands for how much attention the object and its properties attract. With increased attention, there is an increased chance that information is bound to the object representation in working memory and consequently more chance that this information finds it way into long-term memory. As things stand, however, the salience explanation remains an interesting but post hoc explanation.

Needham finds that the boundaries of the studied category are highly stimulus dependent (cf. color versus shape of decorative elements). Perhaps there is no simple rule which appropriately describes what counts as a "good" X_1 in these experiments. We can propose the following variation. In Needham's Experiment 5 the box with the different colored surface elements (X_1: red squares, X_2: white squares) did not "work," meaning, the babies did not infer that if X_1 is an individual, then X_2 is also one. In our modified version, the familiarization to the original static display (X_2 + Y, target box and cylinder) is preceded by a brief familiarization to the Move-apart event with X_1 + Y (box with red squares and cylinder moving apart). Will the baby still think that X_1 and X_2 are too different to use X_1 as a guide to X_2? Our gut feeling is that this simple variation *will* enable the babies to infer that X_2 is an individual object.

We think that there are several questions raised in Needham and Baillargeon (1998) which would be interesting to follow up. Needham's present article departs somewhat from the original question of on-line individuation of objects in a complex display. We would like to see Needham going back to that question. Instead of exploring the structure of a category presumably stored in long-term memory, we would like to see further investigations where the baby's task is to tell if a complex display consists of one object or two adjacent objects based on prior information picked up about the *same* objects. What is the crucial information the baby needs to know about the same objects before seeing the static display to be able to infer that she sees two objects? From Table 1 (Needham & Baillargeon, 1998; Experiments 2, 4, and 5), seeing one of the two objects by itself can be enough. But what happens if baby first sees both objects with a slight separation? It might have just the same effect or it may possibly prove a more demanding condition. Finally, it would be reassuring to see that these effects can be obtained with a different set of stimulus objects, not just the box and cylinder.

Final Reflections

The current literature contains disputes and discrepant findings surrounding the age at which infants can individuate objects by feature. While it may take some considerable time to resolve these questions, we want to argue that there is considerably more theoretical space that is usually assumed. We should pay more attention to the question of mechanism and cognitive architecture and be more mindful of performance systems as well as of competence and representational systems. There are many properties that over the past 20 years or so infants have been shown to represent, properties such as solidity, causal role, rigidity, compressibility, shape, color, and so forth. But showing that such properties are representable is not the same thing as showing under what circumstances such property representations find their way into particular object working memory representations. Nor have we measured the limits on infant object working memory, the role of attention in processing different object properties, or the limits on parallel individuation and identity judgements. Until we do, we shall be missing an important part of the story of how infants pick up information from the world and acquire long-term object kind representations.

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