A JOURNAL OF THE ASSOCIATION FOR PSYCHOLOGICAL SCIENCE aps

The "Humpty Dumpty Problem" in the Study of Early Cognitive Development

Putting the Infant Back Together Again

Lisa M. Oakes

Center for Mind and Brain, University of California, Davis

ABSTRACT—*In this article, I propose that the big question for the field of infant cognitive development is best characterized as the "Humpty Dumpty problem": Now that we have studied cognitive abilities in isolation, how do we put the developing cognitive system (and the infant) back together again? This problem is significant because cognitive abilities do not occur in isolation. Infants remember the items they have attended to and perceived, and their emotional state will influence their perception and representation of the events they encounter. Moreover, by examining the development of the whole cognitive system, or the whole child, we gain a deeper understanding of mechanisms developmental change. Thus, the big question for the study of infant cognition is like the question confronting all the king's horses and all the king's men: How do we put the infant's cognitive system back together again?*

Humpty Dumpty sat on a wall.

Humpty Dumpty had a great fall.

All the king's horses and all the king's men

Couldn't put Humpty together again.

Developmental scientists are, in a sense, in the same boat as all the king's horses and all the king's men. In an effort to understand the origins of cognition, the field has focused on dissecting cognitive abilities in infancy; our task now is to put those abilities back together again so that we can understand how they work together in development.

Address correspondence to Lisa M. Oakes, Center for Mind and Brain, 267 Cousteau Place, University of California, Davis, CA 95618; e-mail: lmoakes@ucdavis.edu.

THE BIG QUESTION

The study of cognition in infancy has made impressive progress over the last several decades. Despite the challenges of trying to understand a preverbal child with few motor skills, researchers have developed procedures and experimental designs that have provided understanding of infants' short-term memory (Ross-Sheehy, Oakes, & Luck, 2003), long-term memory (Rovee-Collier & Hayne, 1987), visual attention (Richards & Casey, 1992), face perception (Turati & Simion, 2002), and many other cognitive and perceptual abilities. Studies have used visual habituation, visual preference, reaching tasks, eye-tracking, ERP recordings, heart-rate measures, and so on, to provide critical insights into cognitive functioning and its development in infancy.

Everyone knows that, despite being isolated in tight experimental designs, cognitive abilities actually work in concert. As an example, consider the processes necessary for an infant to categorize a currently visible animal as a *dog*. The infant must perceive the dog, attend to and encode features relevant for comparing the dog with other dogs, recall previously encountered dogs in enough detail to make the comparison of those features, and detect similarities and differences among the dogs. A complete picture of categorization (and any aspect of cognitive development) therefore requires understanding not only how categorization works in isolation, but also how processes work together. Thus, the "Humpty Dumpty problem" (the problem of putting the separately studied pieces of cognition together again) is critical for a full understanding of early cognitive development.

PERSPECTIVES on Psychological Science

This issue is particularly a problem when we consider how cognitive abilities such as categorization are studied in infancy. For example, almost all of our knowledge of infants' developing categorization abilities comes from studies using some form of habituation or familiarization procedures. In these procedures, infants are presented with a collection of objects from one category (e.g., dogs, pieces of furniture) and then their reaction to novel items from a different category (e.g., cats, vehicles) is measured. Infants are assumed to have detected the relevant category if they show renewed interest in a novel item from the contrasting category and remain familiarized to the novel item from the familiar category. In this task, conclusions are generally drawn only about categorization abilities, despite the fact that infants' performance requires that they perceive the one or two items presented on each trial, selectively attend to relevant dimensions (ignoring irrelevant ones), store information about the items in memory, compare items encountered at different times, inhibit responding to irrelevant or distracting stimuli or feature dimensions, and (perhaps) maintain a representation of one or more stimuli in working memory for several seconds. Thus, infants may not recognize a category in this task because they have failed to categorize the items, perceive the relevant features, selectively attend to the commonalities, remember instances across trials, and so on. In addition, if infants do successfully recognize the category in this context, then they must have perceived the relevant features, selectively attended to the commonalities, ignored distractors, and so on. Infants' performance on this task tells us much more than simply whether or not they have categorized the items.

For example, 4-month-old infants are sensitive to the distinction between dogs and cats when presented with two pictures side by side; it is not until 6 months, however, that infants are sensitive to the same distinction with the same stimulus items when those pictures are presented one at a time (Oakes & Ribar, 2005). This discrepancy is puzzling if one assumes that each variation of the task isolates infants' categorization. The discrepancy is not surprising, however, when one considers the differences in how other cognitive processes are engaged in the two versions of the task. The information relevant for categorizing the stimuli is the same whether items are presented one or two at a time—the items have the same commonalities and differences. When items are presented one at a time, infants must store each item in memory, and they can detect commonalities only by comparing items stored in memory with a single currently available item. When items are presented side by side, in contrast, comparing them does not require the same engagement of memory processes. Thus, the difference in performance in these two tasks reflects the interaction of memory, comparison, and categorization. Indeed, we have argued elsewhere (Oakes & Kovack-Lesh, 2007) that, in such tasks, infants' categorization and memory are inextricably intertwined, and conclusions about categorization cannot be separated from conclusions about the contribution of memory processes. Clearly, therefore, a deeper understanding of infants' categorization and its development is gained by considering how multiple cognitive systems contribute to the performance on such tasks than by drawing conclusions about only a single process. Therefore, addressing the Humpty Dumpty problem with respect to the infants' cognitive abilities is critically important.

It is interesting to note that progress has been made at addressing the Humpty Dumpty problem at a larger scale: by examining the development of psychological processes such as cognition in the context of the development of other psychological processes such as motor, emotional, and social abilities (see, e.g., Campos, Bertenthal, & Kermoian, 1992; Needham, 2000; Tamis-LeMonda & Adolph, 2005). Infants attend to, perceive, and remember stimuli that also elicit emotional reactions (e.g., a happy face) as they manually explore objects and during interactions in which they are more or less motivated to learn about the object (e.g., an attractive new toy versus a barking dog). Thus, developmental scientists must also grapple with how developing cognition fits within the context of the whole infant. The influential work of Thelen and Smith (1994) introducing the dynamic systems approach to the study of psychological development reminded developmental scientists that "everything counts." In this spirit, Smith and Thelen (2003) uncovered the motor and perceptual contributions to infants' performance on the A-not-B error. Other researchers have also examined relations among developing systems. Tamis-LeMonda and Adolph (2005), for example, have examined the connection between developing social relations and the emergence of motor actions. Campos and colleagues (Campos et al., 1992) have studied the codevelopment of motor, perceptual, cognitive, and social development. Such research programs focus on development in the context of the whole child, and they serve as a model for focusing on development in the context of the whole mind (or the whole cognitive mind); we can apply the approaches adopted in these research programs to put the pieces of cognition (e.g., perception, memory, categorization) back into an integrated cognitive system.

UNCOVERING MECHANISMS OF DEVELOPMENTAL CHANGE

Solving the Humpty Dumpty problem is important because it may be key to uncovering mechanisms of developmental change in cognitive abilities. Identifying such mechanisms of change is one of the major challenges that face developmental scientists. Despite the fact that a number of researchers and theorists have argued that identifying such mechanisms should be of central importance to the study of development, relatively little progress has been made in this area. Our focus on isolating individual skills may contribute to this lack of progress. Studying infants' sensitivity to different kinds of categories, for example, can reveal how that sensitivity changes—for example, younger infants tend to respond to broader categories (such as *animal*) and older infants tend to respond to narrower categories (such as *dog*; Mandler, 2004). Even if this developmental change is observed in different labs using several different experimental procedures, stimuli, samples, ages, and so on, descriptions of such changes in sensitivity tell us little about why this change occurs. Theorists speculate about the cause of this change—one theory is that infants gain a greater conceptual understanding of the categories (Mandler, 2004) and another is that their categories narrow with more experience (Quinn, 2002). However, such conclusions are drawn from descriptions of change, not from directly examining mechanisms of change. We cannot directly assess the mechanisms of change by documenting changes in one isolated ability.

Our focus on isolating cognitive abilities clearly reflects kinds of mechanisms of cognitive development that have been proposed. Many views argued for changes in general abilities or skills that underlie the specific behaviors we observe and measure. For Piaget (1954), infants' cognitive behaviors (searching for hidden object, imitation, emergence of language, and so on) changed as a function of their gradual shift from sensorimotor to symbolic representations. Information-processing theorists argued that changes in cognitive behavior derived from general changes in processing speed (e.g., Kail, 1995). According to such perspectives, individual, isolated cognitive abilities reflect general underlying capabilities, and changes in the observed abilities or behaviors reflect changes in that underlying system. Similarly, according to researchers proposing that cognitive development is driven by innate modules (Spelke & Kinzler, 2007), understanding cognitive development requires identifying core cognitive skills and knowledge and thus isolating cognitive abilities. Isolating specific cognitive abilities therefore addresses questions central to such views of cognitive development.

However, our view of cognitive development is changing. Rather than assuming that observed changes in specific cognitive behaviors reflect changes in a general underlying system or the maturation of domain-specific modules, cognitive development is thought to be multi-determined, reflecting ch changes at different levels or in different systems (e.g., Smith & Thelen, 2003; Westermann et al., 2007). Therefore, changes in one skill or ability may induce changes in other skills or abilities. For example, changes in reaching may cause changes in infants' visual interest in objects (Needham, Barrett, & Peterman, 2002), and changes in visual acuity may cause changes in how visual stimuli are categorized (French, Mermillod, Quinn, Chauvin, & Mareschal, 2002). Examining the isolated (and correlated) development of individual cognitive skills cannot reveal mechanisms of development. Uncovering such mechanisms requires that we directly examine the codevelopment of different abilities, as well as how changes in one ability induce changes in a different ability.

Consider, for example, evidence provided by French and his colleagues (French et al., 2002) using connectionist simulations showing that very young infants' attention to broad category boundaries may be the result of poor visual acuity. Thus, changes in the breadth of infants' categorization of visually presented stimuli are directly related to changes in their ability to see and detect the details of those stimuli. When infants' acuity is poor and they have difficulty detecting and resolving fine details, they recognize general commonalities, such as those that specify global categories (e.g., a category that includes dogs, cats, lions). As infants become able to make out finer visual detail of images and objects in their world, they can detect subtler similarities that define narrower categories (e.g., forming separate categories for dogs and cats).

The point is that by putting relatively well-understood pieces back together, we begin to answer questions about the causes of development. Changes in one skill or ability likely cause changes in other skills or abilities, or they at least create opportunities for such changes. Some such connections are obvious. For example, it is obvious that the ability to sit upright gives the infants' a different view of the world as well as the freedom to use her hands to explore objects around her. Connections among different cognitive skills and abilities are less obvious. As described above, categorization requires perception, attention, memory, comparison, and so on. Thus, changes in those abilities will result in changes in how infants categorize. For example, changes in infants' ability to encode and maintain more information in visual short-term memory must facilitate their comparison of visual images (e.g., two pictures, two animals, two objects) separated in time and space (e.g., at two ends of a room). As infants become able to make comparisons based on more subtle featural correspondences or deep structural commonalities (such as overall color), they will detect and encode different kinds of similarities and differences, and as a result they will form different kinds of categories (e.g., categories based on large similarities in shape vs. those based on a less salient, but important feature, such as the shape of the ears). Thus, changes in infants' categorization may be best thought of in terms of changes in visual short-term memory, comparison, and perceptual processes, rather than in terms of changes in general underlying conceptual abilities.

Similarly, changes in infants' representation of objects might be considered to reflect (in part) changes in selective attention abilities. When infants are poor at controlling their attention, they will attend to, perceive, and remember stimulus factors that capture attention automatically—for example, movement. When they are better at controlling attention, infants will be able to select other dimensions to attend to and perceive. For example, we observed that 6- to 7-month-old infants selectively attend to the action performed on an object by a human hand, while failing to encode the surface features of that object (such as its color or shape; Perone, Madole, Ross-Sheehy, Carey, & Oakes, 2008). By 10 months, infants do not have this bias (Perone & Oakes, 2006). What underlies this developmental change? One possibility is that young infants do not understand the relevance of the surface feature of the objects, and they "choose" to attend to the action. Alternatively, poorly developed selective attention abilities may cause younger infants to attend to, perceive, and learn only transient features, whereas older infants who have better selective attention abilities can more effectively divide their attention to different dimensions. Or, this developmental change may reflect young infants' bias to attend to human action, perhaps due to developments in the mirror neuron system or the precursors to theory of mind. The point is that although we can design experiments and procedures to isolate infants' attention to the action versus the surface features of objects in these events, focusing on just this behavior limits our understanding of why younger and older infants learn about these events differently. By examining the changes in infants' attention to and memory for such events while at the same time examining changes in imitative skills, understanding of human action in other contexts, general selective attention abilities, and so on, we both document developmental changes in infants' attention to one type of event and begin to build an understanding of the how and why of those changes.

EXPERIMENTAL STRATEGIES FOR PUTTING HUMPTY DUMPTY TOGETHER AGAIN

These two examples illustrate two ways we can begin to address the Humpty Dumpty problem. It is easy to say that researchers should "study cognitive abilities together," but we have spent decades developing tasks and experimental designs to isolate abilities so that we can identify the development of those abilities without the confounding effects of other variables. Clearly, such an approach is an important step. The task before us now is to develop tasks and experimental designs that will uncover the codevelopment of different abilities.

How do we do this? Developing experiments to seriously examine such codevelopment may at first seem daunting. Models for empirically addressing this problem come from the examples described earlier considering development in the context of the whole child. One approach has been to examine how changes in social, motor, or emotional abilities change infants' experiences, which presumably induces changes in cognitive abilities. Needham (2000), for example, found that infants who were more active with one set of objects were more sophisticated in their visual perception of the surfaces of a different set of objects. We observed that infants' activity with objects in free play was associated with their attention to the surface features of different objects in dynamic events (Perone et al., 2008). Cicchino and Rakison (2008) observed differences in infants' differentiation of self-propelled and caused motion as a function of whether or not infants were able to crawl.

Each of these studies provides important insight into how different abilities codevelop. In particular, they show how infants' action on the world is associated with their visual perception of events. However, we must go beyond such documentations and ask how experience influences development. For example, an infant learns about a spoon through his action on that spoon. He explores it with his hands as it sits at rest on his high-chair tray, puts it in his mouth, and interacts with his caregiver. The infant's learning about the spoon is not simply about the ability to perceive the shape and color and to associate those features with other nonobservable features. Rather, how the infant acts on the spoon will determine what information he has access to or what is most salient and, as a result, what he will learn. An infant who can deftly pick up the spoon and get it to her mouth will learn about the object's weight, the sound it makes when banged on the high-chair tray, what it looks like from different angles, etc. An infant who grasps at the spoon only with effort, never actually lifting it off the surface, in contrast, will not have access to any of that information, perhaps focusing instead on its smooth texture, the sound it makes while being pushed across the tray, etc.

In fact, Needham and her colleagues (Needham et al., 2002) have shown a causal connection between infants' manual exploration and their visual perception. Prereaching infants were given 2 weeks of enhanced reaching experience with "sticky mittens" (mittens with Velcro attached, allowing prereaching infants to experience successfully picking up objects). Infants who had this experience engaged in more visual exploration of objects than did infants who had not received this experience. Thus, experience picking up objects causes infants to be more visually engaged when exploring objects. This example is important because it shows how experience in one domain—in this case manual object exploration skills—can influence development in a different domain—in this case, the visual perception of objects.

How can we can use such studies as a model for understanding the causal influence of development in one cognitive ability on the development of other cognitive abilities? The empirical approach to understanding this problem requires several distinct steps. First, we must identify how apparently independent (or isolated) cognitive abilities are related. Earlier, I described possible relations between cognitive abilities, such as how changes in visual acuity and memory cause changes in categorization and how increased control over selective attention causes changes in how infants represent objects and events. It is possible to measure changes in different domains and see whether correlations exist for development across domains.

However, identifying such correlations will not allow us to determine whether causal connections exist between those abilities. Thus, a second step is to study how an observed behavior reflects the coordination of multiple skills and abilities. Specifically, we can create situations that help infants overcome their limitations in some abilities, essentially "scaffolding" those abilities; such situations help us identify factors that cause observed behaviors. Moreover, if those factors develop at different rates, such investigations generate hypotheses about how the interaction of those factors over time—that is, as the factors themselves develop—contribute to the emergence and development of behaviors. In the terms of dynamic systems analysis, we can develop hypotheses about which cognitive ability is the "rate limiting" factor (Thelen, 1986) that makes it difficult for infants to perceive a feature, make a comparison, recognize a category, and so on. Then, we can test infants in contexts that provide support for those hypothesized factors. This was essentially our goal when we tested 4-month-old infants' categorization when items were presented one at a time versus side by side (Oakes & Ribar, 2005); we induced 4-month-old infants to engage in more sophisticated comparisons and to detect more subtle commonalities and differences between dogs and cats when items were presented side by side by reducing the need for memory in making those comparisons. Thelen and colleagues' work on the development of independent walking provides a model for taking this approach. By scaffolding infants' lack of strength to support their weight by submerging them in water (Thelen, Fisher, & Ridley-Johnson, 1984) or their inability to control the swing of their legs by testing them on a treadmill which engages reflexes and/or provides a boost to help them overcome the forces of gravity (Thelen, 1986), Thelen and her colleagues gained important understanding into how the different systems that contributed to walking developed together.

This scaffolding approach is not precisely the same as understanding how developmental changes in one ability cause developmental changes in a different ability. Rather, this approach gives us insight into how the abilities work together to create observed behavior by essentially isolating individual abilities and determining whether the development of those processes is masked by the immaturity of other processes. For example, one conclusion from our work on categorization is that 4-month-old infants could categorize the cats and dogs, but their immature memory abilities made it difficult for them to demonstrate that they could categorize those items.

However, what does it mean to categorize or to make sophisticated stepping movements only under specific conditions that support or scaffold immature aspects of the system? In a sense, infants' competence at categorizing (or stepping) is masked by other skills. But, what is important is not simply how the development of those other skills unmask infants' underlying competence, but how this skill development actually changes behavior. That is, the stepping of infants under water or on treadmills is similar in many ways to adult stepping, but it is not identical to it. As infants gain physical strength, coordination, and balance and step on their own, the stepping movements change in response to those experiences. Similarly, as infants become able to compare under a broader set of conditions, those experiences cause changes in infants' comparison abilities—perhaps they recognize deeper commonalities or they become better at aligning the instances to be compared. Competence and performance are inseparable components of behavior, and changes in factors that contribute to the infants' ability to perform may create changes in experience that shape infants' underlying competence.

The third step to creating a model for understanding the causal influence of development in one cognitive ability on the development of other cognitive abilities is to directly test hypotheses about how developmental mechanisms actually induce change. Just as Needham and her colleagues (Needham et al., 2002; Sommerville, Woodward, & Needham, 2005) showed that "artificial" reaching experience influenced infants' perception of objects and events, we can ask whether artificial experience using one cognitive ability induces changes in a different aspect of cognition. It is much more difficult to consider how we can experimentally manipulate infants' cognitive experience in the ways we can alter infants' motor experience to test the causal role of a cognitive achievement on other cognitive skills. We can put "sticky mittens" on prereaching infants and we can put prewalking infants in walkers, but how do we give infants a boost in remembering, perceiving, or controlling attention? That is, how do we create "cognitive sticky mittens"?

This is the main experimental challenge for developmental scientists interested in cognitive development in infancy. However, it is a solvable problem. Consider the following hypothetical example. We observed that 4-month-old infants' attention to the categorical distinction between dogs and cats when items were presented side by side was determined (in part) by the number of times infants glanced back and forth between the two stimuli presented on each trial (Kovack-Lesh, Horst, & Oakes, 2008). Infants who looked back and forth more often were better able to remember and categorize the stimuli (at least if they had pets at home) than did infants who looked back and forth less (this effect was recently replicated by Kovack-Lesh, 2008). It is important to note that infants at 4 months of age are just developing the ability to control their visual attention; infants younger than 4 months often get "stuck" when fixating and have difficulty disengaging once they have fixated (Hood, 1995). Therefore, 4-month-old infants' categorization when items are presented side by side may be determined by their ability to control their fixations to the two simultaneously stimuli, which influences their opportunities to compare those two stimuli. Providing artificial experience engaging and disengaging stimuli (i.e., inducing infants to glance back and forth between two simultaneously presented stimuli) should increase infants' attention to subtle categorical contrasts. Infants who do not yet spontaneously shift their attention between two simultaneously presented stimuli can be induced to shift their attention (Jankowski, Rose, & Feldman, 2001). Moreover, inducing switching behavior in young infants on several sessions over a period of time and may facilitate the development of spontaneous shifting behavior and/or their comparison abilities, just as increasing infants' experience picking up toys induced changes in infants' visual exploration (Needham et al., 2002). The point is that studies examining cognition on the context of other developing abilities (i.e., how reaching is related to visual perception) can serve as a model for designing research programs to address the Humpty Dumpty problem as it relates to the interaction among cognitive abilities.

CONCLUSIONS

The idea that development will be understood by examining the codevelopment of different psychological abilities is not new. The interaction of cognition and action is central to Gibson's (1988) hypotheses about development. Piaget (1954) argued for a central role of interaction with the physical world on the growth of cognition. More recently, the dynamic systems view of development has advocated this approach (Thelen & Smith, 1994).

Increasingly, researchers from different theoretical perspectives are examining the interaction of different abilities. A forthcoming special section of *Developmental Psychology* will highlight work examining the connections between action and cognition (Rakison & Woodward, 2008). These studies involve identifying correlations across developing abilities and examining the effects that enhancing infants' experience with one kind of ability has on the emergence of another kind of ability. Others have systematically examined connections between different aspects of cognition. Wilcox and Chapa (2004), for example, examined how demonstrating functional information for infants helped them use another object attribute (color) to individuate objects—presumably scaffolding infants' attention to color in the original context. Graf Estes and colleagues (Graf Estes, Evans, Alibali, & Saffran, 2007) showed how infants' detection of statistical regularities in one context influenced their interpretation of novel words in a different context, showing how one kind of ability (detection of statistical regularities in speech in this case) can directly influence other abilities (the linking of labels to references in this case). Each of these studies investigated the effect of one kind of cognition on another or the interaction of different cognitive abilities.

Therefore, solving the Humpty Dumpty problem need not be overwhelming. In addition to isolating individual cognitive abilities, researchers need to develop programs of research to investigate interactions between abilities. Thus, we can examine how infants perceive, attend, categorize, remember, and compare together. Research programs can have as their main goal understanding the interaction of cognitive functions, and this type of experiment would not be the end of a grant proposal, but rather it would be the starting point that frames the whole undertaking. Clearly, we need to continue to examine cognitive abilities in isolation. But, such studies should be conducted as an explicit first stage, which will ultimately lead to studies examining those same abilities in the context of other abilities. Such an approach will not only provide a deeper understanding into how infants engage in cognitive activity in the lab, it will also make a closer connection to how infants engage in such activity in their everyday life.

The study of infant cognition has made impressive progress in 30 years. We have an understanding of basic processes such as perception, attention, memory, and categorization. However, this progress has been gained by dissecting the cognitive system and studying each process—or subprocess—in isolation. Thus, we know how infants perform in tasks designed to tap, for example, color perception, short-term memory, or basic-level categorization, but we know much less about how the short-term memory demands of a task influences categorization or how providing competition for visual attention influences infants' ability to perceive the features of the stimuli, nor do we know how changes in one domain actually cause or induce changes in a different domain. In their everyday activity in the world, infants must perceive, attention, remember, categorize all at the same time. Thus, in the next 30 years, we should focus our research questions on solving the Humpty Dumpty problem and study cognitive abilities in the context of other cognitive processes or even other psychological functions. This approach will allow us to gain a complete understanding of the cognitive system in infancy and how it develops.

Acknowledgments—Preparation of this article was made possible by NIH Grant HD49840. Steve Luck, Ian Messenger, and Karinna Hurley provided helpful comments on drafts of this article.

REFERENCES

Campos, J.J., Bertenthal, B.I., & Kermoian, R. (1992). Early experience and emotional development: The emergence of wariness of heights. *Psychological Science*, *3*, 61–64.

Cicchino, J.B., & Rakison, D.H. (2008). Producing and processing self-propelled motion in infancy. *Developmental Psychology*, *44*, 1232–1241.

French, R.M., Mermillod, M., Quinn, P.C., Chauvin, A., & Mareschal, D. (2002, August). *The importance of starting blurry: Simulating improved basic-level category learning in infants due to weak visual acuity.* Paper presented at the Proceedings of the 24th Annual Conference of the Cognitive Science Society, Fairfax, VA.

Gibson, E.J. (1988). Exploratory behavior in the development of perceiving, acting, and the acquiring of knowledge. In M.R. Rosenzweig & L.W. Porter (Eds.), *Annual review of psychology* (Vol. 39, pp. 1–41). Palo Alto, CA: Annual Reviews.

Graf Estes, K., Evans, J.L., Alibali, M.W., & Saffran, J.R. (2007). Can infants map meaning to newly segmented words? Statistical segmentation and word learning. *Psychological Science*, *18*, 254–260.

Hood, B.M. (1995). Shifts of visual attention in the human infant: A neuroscience approach. In C. Rovee-Collier & L.P. Lipsitt (Eds.), *Advances in infancy research* (Vol. 9, pp. 163–216). Norwood, NJ: Ablex.

Jankowski, J.J., Rose, S.A., & Feldman, J.F. (2001). Modifying the distribution of attention in infants. *Child Development*, *72*, 339–351.

Kail, R. (1995). Processing speed, memory, and cognition. In F.E. Weinert & W. Schneider (Eds.), *Memory performance and* *competencies: Issues in growth and development* (pp. 71–88). Hillsdale, NJ: Erlbaum.

Kovack-Lesh, K.A. (2008). *Exploring joint influences on infant categorization: Previous experience and how infants compare on-line*. Unpublished dissertation, University of Iowa, Iowa City.

Kovack-Lesh, K.A., Horst, J.S., & Oakes, L.M. (2008). The cat is out of the bag: The joint influence of previous experience and looking behavior on infant categorization. *Infancy*, *13*, 285–307.

Mandler, J.M. (2004). *The foundations of mind: Origins of conceptual thought*. New York: Oxford University Press.

Needham, A. (2000). Improvements in object exploration skills may facilitate the development of object segregation in early infancy. *Journal of Cognition & Development*, *1*, 131–156.

Needham, A., Barrett, T., & Peterman, K. (2002). A pick me up for infants' exploratory skills: Early simulated experiences reaching for objects using "sticky" mittens enhances young infants' object exploration skills. *Infant Behavior & Development*, *25*, 279–295.

Oakes, L.M., & Kovack-Lesh, K.A. (2007). Memory processes and categorization in infancy. *Cognition, Brain, and Behavior*, *11*, 661–667.

Oakes, L.M., & Ribar, R.J. (2005). A comparison of infants' categorization in paired and successive presentation familiarization tasks. *Infancy*, *7*, 85–98.

Perone, S., Madole, K.L., Ross-Sheehy, S., Carey, M., & Oakes, L.M. (2008). The relation between infants' activity with objects and attention to object appearance. *Developmental Psychology*, *44*, 1242–1248.

Perone, S., & Oakes, L.M. (2006). It clicks when it is rolled and squeaks when it is squeezed: What 10-month-old infants learn about object function. *Child Development*, *77*, 1608–1622.

Piaget, J. (1954). *The construction of reality in the child*. Oxford, United Kingdom: Basic Books.

Quinn, P.C. (2002). Beyond prototypes: Asymmetries in infant categorization and what they teach us about the mechanisms guiding early knowledge acquisition. *Advances in Child Development and Behavior*, *29*, 161–193.

Rakison, D.H., & Woodward, A. (2008). New perspectives on the effects of action on perceptual and cognitive development. *Developmental Psychology*, *44*, 1209–1213.

Richards, J.E., & Casey, B.J. (1992). Development of sustained visual attention in the human infant. In B.A. Campbell & R. Richardson (Eds.), *Attention and information processing in infants and adults: Perspectives from human and animal research* (pp. 30–20). Hillsdale, NJ: Erlbaum.

Ross-Sheehy, S., Oakes, L.M., & Luck, S.J. (2003). The development of visual short-term memory capacity in infants. *Child Development*, *74*, 1807–1822.

Rovee-Collier, C., & Hayne, H. (1987). Reactivation of infant memory: Implications for cognitive development. In H.W. Reese (Ed.), *Advances in child development and behavior* (Vol. 20, pp. 185–238). Orlando, FL: Academic Press.

Smith, L.B., & Thelen, E. (2003). Development as a dynamic system. *Trends in Cognitive Sciences*, *7*, 343–348.

Sommerville, J.A., Woodward, A.L., & Needham, A. (2005). Action experience alters 3-month-old infants' perception of others' actions. *Cognition*, *96*, B1–B11.

Spelke, E.S., & Kinzler, K.D. (2007). Core knowledge. *Developmental Science*, *10*, 89–96.

Tamis-LeMonda, C.S., & Adolph, K.E. (2005). Social referencing in infant motor action. In Bruce D. Homer & Catherine S. Tamis-LeMonda (Eds.), *The development of social cognition and communication* (pp. 2145–2164). Mahwah, NJ: Erlbaum.

Thelen, E. (1986). Treadmill-elicited stepping in seven-month-old infants. *Child Development*, *57*, 1498–1506.

Thelen, E., Fisher, D.M., & Ridley-Johnson, R. (1984). The relationship between physical growth and a newborn reflex. *Infant Behavior & Development*, *7*, 479–493.

Thelen, E., & Smith, L.B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.

Turati, C., & Simion, F. (2002). Newborns' recognition of changing and unchanging aspects of schematic faces. *Journal of Experimental Child Psychology*, *83*, 239–261.

Westermann, G., Mareschal, D., Johnson, M.H., Sirois, S., Spratling, M.W., & Thomas, M.S.C. (2007). Neuroconstructivism. *Developmental Science*, *10*, 75–83.

Wilcox, T., & Chapa, C. (2004). Priming infants to attend to color and pattern information in an individuation task. *Cognition*, *90*, 265–302.