Essay Review

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Human Development

Advancing Our Understanding of Early Perceptual and Cognitive Development

Essay Review of *Emerging Cognitive Abilities in Early Infancy* by F. Lacerda, C. von Hofsten and M. Heimann (Eds.)[1]

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Recent progress in understanding the perceptual and cognitive capacities of young infants is extremely impressive, especially since many of the new findings and theoretical developments are challenging long held beliefs about the origins of mind. This progress is no mean feat given that researchers are limited to studying a preverbal human with a limited repertoire of coordinated motor responses. It is testimony to the creativity and originality of researchers in this field that so much progress has been made in such a relatively short amount of time. In Emerging Cognitive Abilities in Early Infancy, readers are treated to a sampling of some of the new research and theories that characterize this field. The book, edited by Lacerda, von Hofsten, and Heimann, consists of 11 chapters focused on three general topics concerning object perception, speech perception, and perception of self and others.

In spite of this recent progress documenting multiple perceptual and cognitive capacities by infants, there is considerable disagreement with regard to how the evidence should be interpreted. For example, Spelke [1994] argues that core adult-like concepts about the physical world are present from birth, and development consists primarily of these concepts becoming enriched with experience. By contrast, Thelen and Smith [1994] claim that infants detect and respond to the regularities in the world with increasingly complex actions, but that cognitive concepts are not necessary or present in the young infant. Meltzoff and Moore [Chapter 10] claim a more middle ground and argue that infants do not possess adult-like concepts, but are endowed with discovery procedures for learning about the world and developing these concepts over time. Most contemporary researchers studying infant development have theoretical views that fall somewhere in between the extremes of this continuum.

[1] Hillsdale, NJ: Erlbaum, 2001, 263 pp.

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We believe that there is a logical impasse toward resolving these disagreements because most theories lack sufficient detail for establishing and testing specific predictions. For this reason, much of the current research appears more as phenomenal demonstrations of a particular theoretical stance than as empirical tests of a specific theory. Moreover, these theories tend to focus on what develops but often ignore the process by which they develop. As such, many of these theories are defined in terms of a set of principles or concepts that are available to infants at a given age [cf. Munakata, Chapter 2]. Each principle corresponds to some core property of knowledge or defining characteristic of a concept, but rarely includes boundary conditions for explaining the limits of infants' competencies. In this essay, we briefly consider some of the challenges confronting researchers who are developing theories of infants' perceptual and cognitive development.

Limitations of Discriminative Measures

It would be difficult to exaggerate the very large percentage of research on infants' perceptual and cognitive competencies that depends on measuring some discriminative response. Consider, for example, visual habituation [Bornstein, 1985]. Infants are presented with one stimulus over a series of trials until visual attention declines to some criterion level, and then one or more novel stimuli are presented on subsequent trials. If visual attention increases significantly following the presentation of a new stimulus, then discrimination is inferred. Many other paradigms, such as preferential looking, operant conditioning, spatial localization, and high amplitude sucking also rely on a discriminative response [Bower, 1966; Fantz, 1964; Bremner and Bryant, 1977; Jusczyk, 1985].

Although the putative goal is to test infants' perceptual or cognitive capacities, there are an indeterminate number of factors that could explain a discriminative response [Proffitt & Bertenthal, 1990]. Strictly speaking, the results from this paradigm simply indicate whether or not two stimuli are discriminable. If, however, the experimenter is sufficiently methodical in designing the pair or pairs of stimuli to be discriminated, it is possible to infer more general perceptual and cognitive capacities from the pattern of discrimination results. Nevertheless, it is difficult, if not impossible, to capture the complex interactions contributing to human behavior from a series of tests assessing dichotomous outcomes.

Let's consider some of the interpretive problems associated with discrimination studies in the context of research on infants' perception of object unity. The perception of object unity represents one of the foremost skills necessary to perceive a well-structured and veridical visual world. Human infants view a world that consists primarily of people and objects nested at multiple scales in a spatial layout. From any viewpoint, the projection of this information is fragmented: Most surfaces are not completely visible, objects and people are partially occluded, and boundaries are rarely delineated completely. Thus, the challenge for infants is to perceptually segment discrete objects while grouping related fragments into unitary objects. Condry et al. [Chapter 1] review a number of fascinating studies on this topic. Overall, these studies show that young infants are generally sensitive to the unity of partially occluded objects if the continuity of the visible surfaces are specified through properties such as common rigid motion, contour alignment, or surface

similarity. These findings thus provide *some evidence* for the perception of object unity, but we question whether this evidence is sufficient to support the broader theoretical claims presented in this chapter. In particular, the authors conclude that the findings on infants' perception of object unity favors the continuity position of Spelke [1994] suggesting that perception of object unity is inborn.

This interpretation is problematic for at least two reasons. The first concerns generalizing beyond the stimuli tested, a problem not limited to discrimination paradigms, but certainly applicable to them. The results reviewed by Condry et al. are based on the discrimination of a relatively limited set of stimuli, such as a partially occluded translating rod. There is nothing intrinsic to the logic of this paradigm to allow the authors to generalize beyond the sampled stimulus sets, yet, this is what they have done. At the very least, the claim of a general perceptual competence should imply that there is no evidence to refute this conclusion when infants of the same age are tested; but recent studies show that the perception of object unity does not even generalize to seemingly similar events, such as those involving rotary or nonrigid motions [Eizenman & Bertenthal, 1998; Booth, Pinto, & Bertenthal, in press]. Because of examples such as this, we must be extremely cautious in generalizing beyond the stimulus sets that were specifically tested.

The second problem associated with the conclusions by Condry et al. is that some of the evidence appears to contradict the claim that the perception of object unity is innate. The authors review a few studies showing newborn infants do not show evidence of object unity [Slater, Johnson, Brown, & Badenock, 1996], and 3- and 4-week-old infants show evidence only when the occluded portion of the surface is relatively small [Johnson & Aslin, 1995; Kawabata, Gyoba, Inoue, & Ohtsubo, 1999]. As an explanation for these seemingly contradictory results, the authors claim that the negative results with younger infants are more likely attributable to their sensory limitations than to their underlying capacity for perceptual organization. Although this is a plausible interpretation, it seems no more plausible than the alternative that perceptual organization develops gradually rather than all at once. In order to provide more direct support for the sensory limitations interpretation, we would recommend that the authors demonstrate discrimination using stimulus parameters that are detected by the limited sensory capacities of young infants.

Attainment of this goal may be problematic, however, because the failure to find discrimination could be a function of lacking many different factors, such as the necessary perceptual skill, the sensory capacities, or the requisite motivation to look at the visual stimuli for a sufficient period of time. Here again, we see the limitations of a discrimination paradigm for testing a specific theoretical prediction, because the results obtained with this paradigm cannot definitively reveal the basis for an infant's perceptual discrimination.

Necessity of Developmental Analyses

Another more general strategy for reconciling negative findings during early development with claims about innate competence is to appeal to a competence-performance distinction. Although this strategy is often embraced by neo-nativists, we question its utility, because as currently invoked it grants researchers license to

claim innate competence for any skill whether it is demonstrated in some primitive form at birth or at some later age. At the very least, a principled set of criteria are needed for claiming what skills constitute core or innate competencies and what skills are associated with the performance of these competencies. We believe that a more constructive approach is to view the infants' developing sensitivity toward object unity, and perceptual competence more generally, in terms of all the stimulus and response variables that contribute to performance. In so doing, the researcher can examine how multiple variables relating to the visual system, the stimulus, and the task interact and contribute to performance at various ages.

The more general challenge for the researcher is to begin to specify in some detail what develops at different ages and what factors contribute to this development. Some promising steps in this direction include distinguishing between early processing biases or predispositions and later perceptual discriminations that are shaped through more specific experiences [Johnson, Chapter 4; Kuhl, Chapter 6]. For example, young infants show categorical perception of speech sounds that are not limited to any specific language [Eimas, Miller, & Jusczyk, 1987]. By the end of the first year, infants fail to discriminate foreign language contrasts that they once discriminated [Werker & Tees, 1984]. A similar transition is observed with regard to speech production [de Boysson-Bardies, 1993]. Kuhl [Chapter 6] proposes that 'language input alters the brain's processing of speech, resulting in the creation of complex mental maps for speech' [p. 115]. It is hypothesized that phonetic prototypes (exceptionally good representatives of a phonetic category) function like perceptual magnets to make some speech sounds more salient than others. In her chapter, Kuhl reviews recent evidence to support this hypothesis and shows that the effect is a function of linguistic experience. Although Kuhl's definition of a prototype is not without its critics [see Davis & Lindblom, Chapter 7], the perceptual magnet effect merits serious attention because it offers a preliminary mechanism for explaining how specific forms of experience contribute to a critical developmental process.

Mechanisms of Developmental Change

As researchers begin to focus more precisely on developmental changes in perception and cognition, they will need to also address why as well as how specific perceptual and cognitive skills develop over time. One idea implicit in Kuhl's model of a perceptual magnet effect is that there is a dynamic interplay between the variation in the linguistic input and the selective mapping of those speech sounds that correspond to the best exemplars in the speech environment. Variation and selection represents a general process for explaining a wide range of developmental changes [Bertenthal, 1999; Bertenthal & Clifton, 1998; Siegler, 1994]. This process is predicated on the notion that self-produced or environmentally produced stimulation is much more variable than often acknowledged. As a consequence of this variability, the organism experiences new inputs and new responses that are variations of the previously produced behaviors. The likelihood of repeating these stochastically generated behaviors will depend on whether or not their consequences are associated with a positive valence.

For example, Freedland and Bertenthal [1994] observed that infants who crawled on their bellies could propel themselves by sequencing their arms and legs

in many different ways. Once infants began moving on their hands-and-knees, they quickly converged on one interlimb pattern (i.e., diagonal couplets in which the left hand and right leg moved together followed by the other two limbs moving together halfway through the crawling cycle), presumably because it was more stable and energy efficient. Clearly, it is critical to identify and evaluate the correct motive or drive responsible for the selection of a new behavior, but establishing criteria for doing so is extremely elusive. More research and more formal criteria for specifying this process [see, for example, Berthier, 1996] are necessary before the heuristic value of assessing variation and selection can be reliably assessed.

One implication emerging from this developmental perspective is that much of the research conducted on perceptual and cognitive development could benefit from a more careful consideration of individual differences. This suggestion was echoed by Heimann [Chapter 11] in his review of research on infants' imitation of modeled behaviors. Currently, the focus of the research literature is to establish competence at a particular age and not to address inter-individual or intra-individual differences. An important exception to this generalization is the work of Thelen and Smith [1994] who have emphasized the role of variation in development. If researchers begin to focus more on individual differences, we anticipate that the picture of early development will quickly become more complex and will challenge researchers to think more broadly about the multiple factors that contribute to the development of perceptual and cognitive skills.

Recommendations

Researchers studying early perceptual and cognitive development can contribute to the field of human development in multiple ways. Thus far, the principle contribution has been to describe specific capacities or skills that are available to infants at different ages. Clearly, these skills have implications for performance in a variety of contexts and situations, but performance is often judged within the limits of a very circumscribed laboratory situation. This is problematic for multiple reasons:

Even simple variations in testing, such as measuring the coupling between perception and action rather than measuring perception, per se, influence our assessment of infants. For example, von Hofsten's [Chapter 4] studies on the early development of visual tracking and visually-guided reaching show that behaviors that had been previously characterized as innately-released reflexes are, in fact, exploratory and goal-directed. Likewise, Lacerda and Sundberg [Chapter 5] show that the developing phonetic structure of vowel systems is the product of an interaction between perceptual and articulatory components. In addition, variations in previous perceptual experiences will affect performance. Cross-cultural studies on speech perception [Kuhl, Chapter 6] have been extremely important in showing when and how linguistic input begins to influence infants' sensitivities to phonetic contrasts in their perception of speech sounds.

For these reasons, we believe that there is much to be gained from expanding the toolbox of measures and the range of populations that are typically tested when studying perceptual and cognitive development. Over a decade ago, Proffitt and Bertenthal [1990] recommended that researchers adopt the principle of converging operations when studying perceptual development. It is now time to not only em-

brace that recommendation but to go beyond it and expand the inquiry to study not only multiple measures of infants' performance, but also the multifarious environmental factors that influence this performance.

As researchers expand the context of their inquiry and generate increasingly complex data, it becomes even more important to develop explicit models of hypothesized processes. The current volume by Lacerda et al. includes some promising developments with regard to modeling developmental processes. Meltzoff and Moore [Chapter 10] describe a flow chart model for showing how young infants determine the numerical identity of objects in the perceptual field based on the processing of spatiotemporal, featural, and functional information about objects. Although this model cannot simulate how numerical identity is learned, its specificity is a significant improvement over previous studies that appealed to the development of a single general principle to explain the development of numerical identity. A different approach to modeling is based on developing a neural network that can simulate the learning of a specific pattern or property. For example, Munakata, McClelland, Johnson, & Siegler [1997] showed that a recurrent network could learn to predict the reappearance of a ball that disappeared by maintaining some representation of the ball during the occlusion period.

The value of this type of modeling is not necessarily to prove that the simulated processes are used by the infant, but rather to provide something more basic, i.e., an existence proof to show that the hypothesized processes are sufficient to explain the learning of some new skill or concept. Currently, it is still quite rare for researchers studying infants to test their theories with neural network models, but the chapters by Munakata [Chapter 2] and by Johnson [Chapter 3] include some discussion of specific models that are noteworthy.

Postscript

In the preface to this book, the authors write that they hope their book will inspire new questions on the topic of perceptual and cognitive development. In view of how much our own ideas were stimulated by this book, we believe that the authors' expectations for this book will certainly be met. It is our further hope that new research will continue to strive to expand the range of studies that are viewed relevant to this field of inquiry, and also strive to improve the level of detail and specificity of mechanisms associated with the origins and early development of perception and cognition.

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