comes from the type of sensory information that infants are believed to use when adjusting their reaching response. According to some researchers, infants initially rely on haptic information (the sense of touch) to adjust their grip configuration (fingers and hands) to the size of the objects and only later rely on anticipatory visual information alone to configure their arm and hand movement before contacting the target. Other researchers, in contrast, found that both haptic and visual information in the shaping and planning of reaching movements for objects of different sizes emerge later, when infants are freed from pervasive motor constraints influencing the coupling and decoupling of their arms. Some of these motor constraints arise from infants' successive postural reorganizations over the first year of life as they learn to sit, crawl, and walk. For instance, poor sitting and walking abilities at around 6 and 12 months old have been found to alter infants' upper arm movement decoupling. As a result, they respond more bimanually to small and large objects alike.

Despite these discrepancies, the previously mentioned studies as a whole clearly reveal that infants become more proficient at increasing their visuomotor mapping to objects' physical characteristics as they gain better control of their arms and body. Most of the work reported here relied mainly on infants' motor responses to infer their visual and movement-planning abilities. Little is known about how closely infants pay attention to and scan the visual characteristics of objects when preparing to reach. Very recent work is beginning to address this question by pairing eye-tracking technology with motion analysis during reaching. Preliminary results seem to suggest that infants' varying degrees of attention to the target object have direct implications for the manner in which they reach for objects.

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See also Action and Vision; Embodied Perception; Perceptual-Motor Integration; Proprioception; Reaching and Grasping

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Perceptual Development: Visual Object Permanence and Identity

Two of our most basic cognitive capacities, and milestones in early cognitive development, are *object permanence and object identity.* Object permanence refers to the ability to understand that objects continue to exist even when perceptual contact is lost (e.g., recognizing that a favorite rattle still exists even when it is covered with a blanket). Object identity refers to the ability to determine whether an object currently in view is the very same object or a different object than seen before (e.g., deciding whether the rattle currently in view is the very same rattle played with yesterday). Object identity should not be confused with object recognition; these two processes differ in important ways. Object recognition refers to the ability to recognize whether the object currently in view looks the same or different as an object seen previously. Object identity refers to the ability to determine whether two perceptual encounters involve the same object (the same rattle seen twice) or numerically distinct objects (two different

rattles). It is possible to recognize an object as looking novel (or familiar) without making inferences about its identity.

Understanding the development of object permanence and object identity, the subjects of this entry, are critical to theories of object knowledge in infancy. These two capacities lay the foundation for more complex thought and behavior. For example, whether an infant perceives a toy as the same toy as played with previously determines how the infant will think about and act on that toy.

Object Permanence

Early developmental psychologists, like Jean Piaget, believed that infants lacked object permanence until the end of the first year. Most of these studies relied on search methods, and infants' failure to search for hidden objects was believed to be indicative of their lack of knowledge that objects continue to exist when out of view. The rationale was that if infants knew that an object continued to exist when placed under a cover or a blanket, they would search for it. However, with the development of more sensitive research methods, including looking time, reaching in the dark, and simplified search tasks, there is now converging evidence from different laboratories using many different methods indicating that infants as young as 2.5 months possess object permanence, even though infants fail to search for hidden objects until about 8 months. Evidence that infants represent the existence of hidden objects has shifted the focus of research away from the question of whether infants possess object permanence to questions about the nature and content of infants' object representations. Current research suggests that infants possess some basic (or core) information about objects, but that this knowledge changes appreciably with time and experience. For example, even very young infants recognize that objects maintain their numerical identity across space and time, but there are age-related changes in the kind of information (e.g., the spatiotemporal or featural properties of the objects) that infants use to track objects.

Object Identity

Object identity was previously defined as the ability to determine whether two perceptual instances involve the same object or two different objects. However, object identity can be conceptualized as two distinct processes. One process, object individuation, is that of determining numerical identity (how many objects are involved) and the other, object identification, is that of identifying each object by its perceptual attributes (e.g., which objects are involved). Identifying objects on the basis of perceptual attributes requires binding specific features to generic entities. The development of each of these processes is described separately.

Object Individuation

Spatiotemporal information is fundamental to the individuation process. By 3.5 months, infants use discontinuities in speed or path of motion to signal the presence of distinct objects. For example, if a object moves behind one edge of an occluder and then immediately reappears at the other edge too quickly to have traveled the width of the occluder, infants use the discontinuity in speed of motion to conclude that two objects were involved in the event. Young infants can also use spatial information to individuate objects, but this develops later than their ability to use featural information. For example, by 4.5 months infants use form features (e.g., shape, size), but it is not until much later that infants use surface features (e.g., color, luminance) as the basis for individuating objects.

There are probably several factors that contribute to infants' earlier sensitivity to form features. One factor has to do with the nature of the developing visual system. Because color vision is initially quite poor, young infants have difficulty getting good information about color. In contrast, infants' sensitivity to areas of high contrast and to motion-related information presents even young infants with many opportunities to gather information about object form. However, visual maturation cannot fully explain the developmental hierarchy favoring form features. Infants are sensitive to surface features long before they use those differences to individuate objects. Another factor has to do with the perceptual nature of form features. Because form features are amodal, they can be experienced in many different modalities and provide redundancy in information across modalities. Finally, form features are deeply embedded in the physical world, are intimately tied to objects

(i.e., they specify the physical nature of objects, the space they occupy, their substance, and how they will move and interact with other objects), and are stable over time. In contrast, surface features, such as color and luminance, are not unambiguously linked to objects or relevant to understanding the way in which the physical world operates (e.g., the color of an object does not predict whether it will fit into a container or support another object). In addition, these features are often perceived by infants as unstable across viewing conditions. Because of these factors, infants do not view color information as particularly salient when tracking objects across space and time.

However, this does not mean that infants can never use surface features as the basis for individuating objects. There is evidence that young infants can be primed, through select experiences, to use surface features at an age younger than they do spontaneously. For example, young infants demonstrate greater sensitivity to color differences in an individuation task if they are first shown events in which color predicts the function of an object. That is, making color functionally relevant can increase infants' sensitivity to color information when individuating objects. There is also evidence that increasing the perceptual salience of surface features can facilitate infants' use of those features in an object individuation task. This suggests that infants' object representations are relatively fluid and may depend on the demands of the task and/or the nature of the situation.

Language plays an important role in infants' capacity to individuate objects. For example, infants who are just beginning to learn count nouns (age 9 to 12 months) demonstrate enhanced performance on object individuation tasks when the objects are labeled (regardless of whether the labels are "real" words or nonsense words) than when the objects are associated with other types of sounds, such as "ooh" or "ahhh." Labels provide a simple, yet conceptually meaningful way to tag and track individual entities.

Recent advances in the application of optical imaging technology into the experimental setting have allowed investigators to begin to explore the neural basis for object processing and individuation in the infant. Functional neuroimaging studies using near-infrared spectroscopy have revealed specific areas in the cortex important to the individuation process. For example, the temporal cortex is activated in response to tasks that require analysis of object features, whereas the parietal cortex is activated in response to tasks that require analysis of the spatiotemporal properties of objects. Further research is needed to explore the functional development of neural areas important to the individuation process.

Developmental changes in infants' capacity to individuate objects depends on a number of factors, including maturation of the visual system, experience with objects in the physical world, language, and conceptual development.

Object Identification

Object identification requires the binding of features to individual entities. Although infants as young as 4.5 months use featural information to individuate objects, at least under some conditions, they do not necessary bind those features to objects. That is, infants may individuate-by-feature but not identify-by-feature. For example, if a green ball disappears behind one edge of an occluder and a red box emerges at the other edge, infants may use the featural differences between the ball and the box to infer that two objects are involved in the event and expect to see two objects when the screen is lowered (as indicated by the fact that they show prolonged looking when only one object is revealed). At the same time, young infants may not hold expectations for what those two objects look like (when the screen is lowered they look equally at a display containing a green ball and a red box or one containing two green balls). There is evidence that infants first start to identify-by-feature during the middle or latter part of the first year. This is consistent with the idea that the representations of young infants are more basic, and less detailed, than those of older infants. Finally, there is some evidence that the developmental progression in infants' capacity to bind features to objects is similar to that of object individuation. For example, older infants are more likely to identify objects on the basis of shape differences than color differences. However, this has not been as well researched as infants' changing capacity to individuate objects, so conclusions remain more speculative.

Object Permanence and Identity in Other Perceptual Domains

Although the majority of research investigating object permanence and object identity in infants has been in the visual domain, these processes are not unique to the visual system. Infants represent the presence of objects experienced through other modalities (e.g., tactile, auditory) and individuate objects on the basis of sound differences. In addition, there appears to be a developmental hierarchy in the type of auditory information infants use to individuate objects. Infants are more likely to use property-rich sounds than property-poor sounds in an individuation task. Property-rich sounds are sounds that are intimately tied to the physical properties of an object and the nature of the physical event in which it is engaged (e.g., the sound of a wooden ball hitting a solid surface); and property-poor sounds are sounds that are more contrived and ambiguously linked to objects (e.g., the ringing of a telephone or doorbell). One possible explanation for this finding is that infants have more experience with property-rich than property-poor sounds. Another possible explanation is that property-rich sounds are more intimately tied to objects (e.g., are dependent on the structure and material composition of an object) than property-poor sounds, and hence are a better predictor of an object's identity.

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See also Attention: Object Based; Binding Problem; Object Persistence; Perceptual Development: Color and Contrast; Perceptual Development: Object Perception

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Perceptual Developmental Disorders

See Vision: Developmental Disorders

Perceptual Expertise

The study of *perceptual expertise* addresses the acquisition of perceptual skills that generalize across objects in a domain, such as the ability to recognize birds, to match handwriting samples, or to interpret x-rays or weather maps. Although perceptual expertise in many domains is rare (e.g., few people can match fingerprints), most people