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Factors influencing infants' ability to update object representations in memory

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ABSTRACT

Remembering persisting objects over occlusion is critical to representing a stable environment. Infants remember hidden objects at multiple locations and can update their representation of a hidden array when an object is added or subtracted. However, the factors influencing these updating abilities have received little systematic exploration. Here we examined the flexibility of infants' ability to update object representations. We tested 11-month-olds in a looking-time task in which objects were added to or subtracted from two hidden arrays. Across five experiments, infants successfully updated their representations of hidden arrays when the updating occurred successively at one array before beginning at the other. But when updating required alternating between two arrays, infants failed. However, simply connecting the two arrays with a thin strip of foam-core led infants to succeed. Our results suggest that infants' construal of an event strongly affects their ability to update memory representations of hidden objects. When construing an event as containing multiple updates to the same array, infants succeed, but when construing the event as requiring the revisiting and updating of previously attended arrays, infants fail.

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Our visual input contains dozens of interruptions each minute, including eye blinks, shifts in head or eye position, and surfaces occluding other surfaces. Yet we experience the world in terms of continuously persisting objects (Baillargeon, 2008; Hood & Santos, 2009; Scholl, 2001). Experiencing persisting objects is a feat not only because of changes to visual input, but also because of changes in the environment itself. Objects change their spatial locations, become obscured by other objects, and sometimes acquire new properties. Even bombarded by these challenges, representing persisting objects usually feels effortless.

Much research suggests that the abilities underlying object representation are in place from early in development. Even with interruptions in perceptual contact, infants perceive objects as persisting in time and space (Baillargeon, 2008; Baillargeon, Spelke, & Wasserman, 1985; Hood & Willatts, 1986). In addition to maintaining object representations in memory (i.e., in the absence of current perceptual input), infants can mentally manipulate representations of hidden objects to reflect dynamic changes to a scene. For example, 5-month-olds can update a representation of a hidden array to reflect addition or subtraction of an object. When infants saw an object hidden by a screen and then saw a second object added behind the same screen, they expected to see two objects when the screen was lifted, as demonstrated by their increased looking at the unexpected outcomes of one or three objects relative to the expected outcome of two objects (Feigenson, Carey, & Spelke, 2002b; Koechlin, Dehaene, & Mehler, 1997; Simon, Hespos, & Rochat, 1995; Wynn, 1992). Similarly, infants can accurately update their representation of a hidden two-object array when one object is subtracted from it (Feigenson et al., 2002b; Koechlin et al., 1997; Simon, Hespos, & Rochat, 1995; Wynn, 1992). Although it is clear that a variety of factors influence infants' success or failure at such occluded-object tasks, including which dependent measure is chosen (Fischer & Bidell, 1991), extant studies support the view that at least under some circumstances, infants maintain and update representations of hidden objects.

Infants' updating abilities also extend to more complex scenes containing multiple occluded arrays. For example, infants of 8 months and older remembered objects hidden behind two spatially separated screens when one object was hidden behind one screen and then a second object was hidden behind the other (Huntley-Fenner, Carey, & Solimando, 2002; Káldy & Leslie, 2003; Uller, Carey, Huntley-Fenner, & Klatt, 1999). And 10- to 12-month-old infants who saw a cracker hidden in one bucket and two crackers sequentially hidden in another bucket spontaneously chose to approach the bucket containing the larger quantity. Doing so required updating representations of the contents of each bucket as the hiding events occurred, maintaining the resulting object representations in memory, and comparing them to determine which array had more (Cheries, Mitroff, Wynn, & Scholl, 2008; Feigenson & Carey, 2003, 2005; Feigenson, Carey, & Hauser, 2002a; vanMarle, 2013).

This research shows that infants can mentally update representations of hidden arrays across multiple spatial locations. This ability undoubtedly serves infants well as they interact with and learn about their dynamic surroundings. However, less well understood are the limits of early abilities to maintain and update object representations. Infants in the cracker choice experiments saw all objects placed sequentially into one hiding location before seeing any objects in the other location. For example, two crackers were hidden in a bucket on the right, followed by a cracker hidden in a bucket on the left. Infants could mentally update their representation of the entire contents of the right-hand bucket before forming any representations of objects on the left. The same "orderliness" applies to the looking-time studies described earlier. Either infants saw all of the objects placed in the first spatial location before seeing any objects at the second location (Huntley-Fenner, Carey, & Solimando, 2002; Káldy & Leslie, 2003; Uller, Carey, Huntley-Fenner, & Klatt, 1999), or infants updated object representations at just a single location (Feigenson et al., 2002b; Koechlin et al., 1997; Simon et al., 1995; Wynn, 1992). These findings leave open the question of whether infants also can represent events that are less orderly, in which objects appear unpredictably and representations of hidden arrays must be revisited and re-updated as events unfold.

Changes in task complexity can shift up or down the age at which a particular cognitive ability is observed (Bidell & Fischer, 1992). However, to our knowledge, just one previous study has examined the effect of increasing a particular type of task complexity – the predictability of dynamic updates – on infants' representational abilities. In that investigation, infants saw events in which objects were added to hidden arrays in an unpredictable order, and their memory for the hidden objects was probed using the cracker choice method (Feigenson & Yamaguchi, 2009). For example, instead of seeing crackers