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The relation between crawling and 9-month-old infants' visual prediction abilities in spatial object processing

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ABSTRACT

We examined whether 9-month-old infants' visual prediction abilities in the context of spatial object processing are related to their crawling ability. A total of 33 9-month-olds were tested; half of them crawled for 7.6 weeks on average. A new visual prediction paradigm was developed during which a three-dimensional three-object array was presented in a live setting. During familiarization, the object array rotated back and forth along the vertical axis. While the array was moving, two target objects of it were briefly occluded from view and uncovered again as the array changed its direction of motion. During the test phase, the entire array was rotated around 90° and then rotated back and forth along the horizontal axis. The targets remained at the same position or were moved to a modified placement. We recorded infants' eye movements directed at the dynamically covered and uncovered target locations and analyzed infants' prediction rates. All infants showed higher prediction rates at test and when the targets' placement was modified. Most importantly, the results demonstrated that crawlers had higher prediction rates during test trials as compared with non-crawlers. Our study supports the assumption that crawling experience might enhance 9-month-old infants' ability to correctly predict complex object movement.

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Introduction

From birth, infants are fascinated by seeing objects. However, if objects move in space in a cluttered environment, such as when a ball rolls behind the sofa, or if infants' point of view changes, the objects or object parts are repeatedly occluded. To overcome this period of nonvisibility, infants need to visually predict how these temporarily occluded objects could behave in their spatial environment. It is already known that visual predictive abilities that are related to the prediction of linear object motion emerge in infants as young as 4 months (Bremner, Slater, & Johnson, 2015; Gredebäck & von Hofsten, 2007). However, little is known about infants' ability to predict the motion of more complex partly occluded objects, for example, when an array of objects moves in space. In addition, it is unclear whether developmental factors such as infants' motor skills enhance these visual prediction abilities. Therefore, the current experiment aimed at investigating whether infants are able to predict the motion of a complex object array and whether this ability is related to their crawling experience.

Infants' visual prediction within spatial object processing

From early in life, infants encounter objects in their surrounding environment and continuously learn about different object characteristics. Infants' perception of object unity has been found in 4-month-olds (Johnson & Aslin, 1995; Kellman & Spelke, 1983). At the same age, infants perceive two neighboring objects as being separate from each other (Kaufman & Needham, 2010; Needham, 1998, 2000) and have been found to be sensitive to objects' solidity in three-dimensional space (Shuwairi, Albert, & Johnson, 2007). Moreover, infants, especially boys, from 3 to 5 months of age are also able to mentally rotate two- or three-dimensional objects (Moore & Johnson, 2008, 2011; Quinn & Liben, 2008).

Infants' ability to find and predict object locations involves acquiring an allocentric space concept. Infants, thus, need to structure the space before them by themselves in order to mentally represent, manipulate, and recall certain object locations in space. One classical task used to study infants' ability to find the location of an object is the A-not-B task, during which an investigator hides a small attractive toy in one location (Location A). After a number of hidings and recoveries at A, the investigator hides the toy in a second location (Location B). It has been found that 7- to 10-month-olds typically show the A-not-B error; they generally reach back to the original location A (e.g., Bjork & Cummings, 1984). The A-not-B error has been attributed to a developmental deficit in infants' object representation (e.g., Piaget, 1954), object array segmentation (e.g., Lange-Küttner, 2008), and deficits in their memory or motor control (e.g., Diamond, 1985). Exactly for the reason to control the motor aspect, the object concept as tested in the A-not-B task was later investigated by the use of eye-tracking tasks that lacked the reaching component and, therefore, relied on infants' gaze behavior (e.g., Diamond & Lee, 2000). Here, 5-month-olds succeeded in retrieving objects when demands in reaching skills were reduced.

To gain more insights into infants' ability to visually predict the location of objects, later studies used the so-called occluder paradigm. Here, infants are presented with an object (e.g., a ball) that moves behind an occluder (e.g., a box) and subsequently reemerges. Eye-tracking technology allows the measurement of visual prediction by analyzing the extent to which infants produce anticipatory eye movements toward the location of reappearance during the occlusion interval relative to reactive gazes to the visible object *after* occlusion. Studies using this method demonstrated that infants' ability to track occluded objects and to make predictions about where an object will become visible next emerges by 4 months of age (Johnson & Shuwairi, 2009; Johnson et al., 2012; Rosander & von Hofsten, 2004; von Hofsten, Kochukhova, & Rosander, 2007). By 6 months of age, infants' visual predictive performances increase dramatically as they begin to deal effectively with nonlinear trajectories (Gredebäck & von Hofsten, 2004; Kochukhova & Gredebäck, 2007), and they predict the final orientation of an object rotating during the occlusion interval (Hespos & Rochat, 1997). The above-described abilities in visual prediction continue to improve until 12 months of age (Gredebäck & von Hofsten, 2004).

Predictive performance in infants can be enhanced by recent experience. Correspondingly, infants' prior experience with the respective object trajectories before occlusion facilitates visual prediction