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Research Focus

Fast tracking: infants learn rapidly about object trajectories

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Research on early object concept formation has the potential to provide a unique contribution to the debate between constructivism and nativism but has, thus far, generated only controversy. New research by Kochukhova and Gredebäck that examined infants' predictions of the reappearance of an occluded object offers new insight into not only when but how such concepts are acquired.

Introduction

Perhaps no issue is more central to cognitive science than how and when humans are capable of forming mental representations of objects in the world. The ontogenetic origins of this knowledge, in particular, have been at the core of a trenchant debate that began with the Greek philosophers more than 2000 years ago and continues unabated today among developmental scientists. Following the pioneering empirical work of Jean Piaget, it was generally assumed that representations for objects emerged during the first year of life as a result of infants' manual exploration of the environment [1]. However, with the emergence of more sensitive methodologies, such as habituation, researchers found that infants who are not yet accomplished in manual search nonetheless possess object representations [2,3]. These findings led several theorists to propose that object concepts emerge early in life as the result of innate constraints or principles. Finally, a third, more recent perspective is that object representations, and constraints on learning about objects, emerge as the result of visual experience in the first months of life [4]. A recent article by Kochukhova and Gredebäck [5] provides fascinating evidence regarding which of these three views best describes the ontogeny of object knowledge in infancy.

Prior expectations or rapid learning?

Kochukhova and Gredebäck [5] used a corneal-reflection eye-tracking technique to examine six-month-old infants' ability to predict the future trajectory of a temporarily occluded object. There are at least two ways by which an infant (or adult) can anticipate where an object will reappear from behind an occluder: predictions can be based on prior assumptions about how objects move (e.g. things move along linear trajectories) or they can be based on recent experiences with similar or identical objects (e.g. these things move nonlinearly). The experiments reported by Kochukhova and Gredebäck were cleverly designed to disentangle these predictive mechanisms.

Separate groups of six-month-olds were presented either with a linear occlusion event, in which a ball was occluded as it moved back and forth along a straight line (each presentation was of a different randomly sampled linear trajectory), or with a repetitive nonlinear occlusion event, in which a ball was occluded but then reappeared at a 90° angle from its original trajectory (Figure 1). Consistent with the findings of previous research that used a similar procedure [4], infants' predictive saccades for the linear occlusion events were at asymptote, or near ceiling, from the first presentation – although it is worth noting that all analyses were based only on the first saccades. This implies that infants used an expectation formed before the experiment that objects continue along the same motion trajectory when hidden by an occluder as that observed before disappearing behind it. By contrast, infants initially made no correct predictive saccades for the nonlinear occlusion events but reached asymptote within three occlusion passages, which suggests that by six months of age infants rapidly can learn a novel, nonlinear motion trajectory even when the change in direction is hidden from view.

The robustness of infants' representations formed during the laboratory session was examined in a second experiment in which six-month-olds were tested three times using the nonlinear occlusion event, with the first two presentations separated by 15 min and the last presentation occurring 24 h later. The results revealed the same basic effect in the first two presentations, such that infants' initial saccadic predictions were poor but quickly reached asymptote; however, infants performed at asymptote from the first trial when re-tested 24 h later.

The origins of expectations about physical movement

These findings are noteworthy because they show that six-month-olds can learn quickly about the novel motion trajectory of an object and retain this information for at least 24 h. However, a key question remains concerning the ontogeny of the pre-existing assumption about linear trajectories that infants brought with them to the laboratory. According to a nativist perspective, this prior assumption is based on an innate principle of inertia that constrains expectations about the way that occluded objects move (e.g. linearly) [6]. Such principles are thought to arise because humans have been exposed consistently to environmental regularities over evolutionary time [7]. Nevertheless, there are several reasons to be cautious before accepting this nativist stance in interpreting infants' trajectory tracking.

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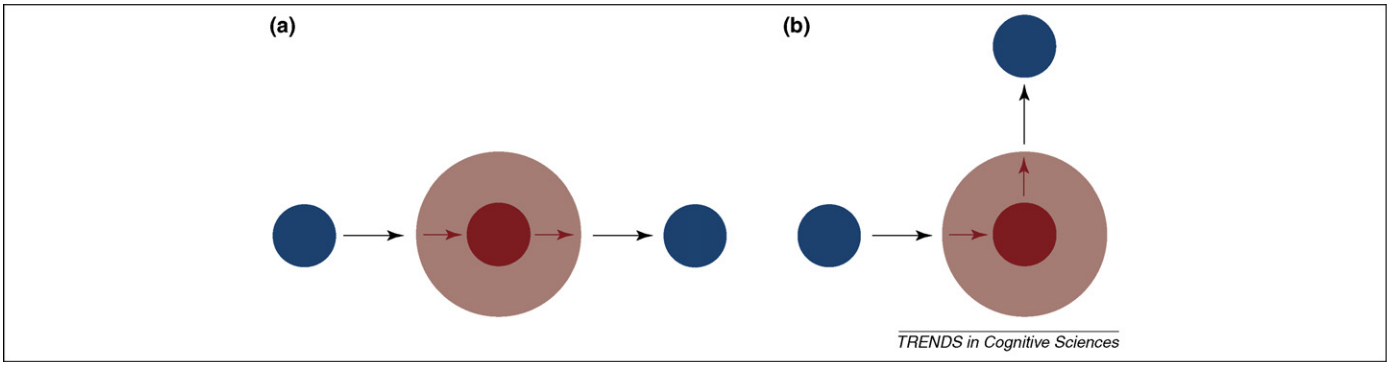

Figure 1. Typical and novel occluded trajectory displays used with young infants. **(a)** In a prototypical display, infants observe an object move along a linear trajectory until it disappears behind an occluder and then reappears on the other side. In Experiment 1 of Kochukhova and Gredebäck [5], infants observed a different linear trajectory on each trial. **(b)** In the adaptation of this procedure, developed by Kochukhova and Gredebäck [5], infants observed an object move linearly behind an occluder but then reappear at a 90° angle from its original trajectory. There were eight possible nonlinear trajectories, but each infant was presented with just one throughout the experiments. This figure shows the object trajectory as it passes behind the occluder; however, this was concealed from the infants' view in the experiments. Note also that the object could have followed a curvilinear trajectory behind the occluder if its speed decreased temporarily. With this in mind, future research could manipulate the duration of occlusion to investigate whether infants expect the object behind the occluder to move along a rectilinear or curvilinear trajectory.

First, a nativist position is incompatible with findings that occlusion emerges in a piecemeal fashion over developmental time during the first four months of life; for example, newborns do not perceive occlusion [8] and four-month-olds are sensitive to it only under certain conditions [9]. Second, the long-term presence of regularities in the environment could be taken to mean that general mechanisms, such as statistical learning, and not innate principles are sufficient for them to be represented. Finally, despite the often-made claim that concept formation at six or three months of age is evidence of innate knowledge, during the first months of life infants are provided with ample experience to learn at least some of the regularities around them [4].

Can the findings of Kochukhova and Gredebäck [5] be taken, then, as support for a constructivist account? Scholl [10] recently suggested that the case against nativism 'requires evidence that training creates the object concept itself – the underlying competence' (p. 50). This is precisely what Kochukhova and Gredebäck's data demonstrate. The rapid learning and long-term retention shown by six-month-olds suggests that the pre-existing assumption that objects move linearly could easily be derived from frequent exposure to such trajectories in the environment. Such an interpretation is consistent with Piagetian constructivism as well as the more neo-constructivist view of Johnson and others [4,11] that general mechanisms, such as associative learning, underpin concept formation.

Why is infant memory improved after a day?

That six-month-old infants can form long-term memories for object trajectories is significant because the representation must incorporate not only the object itself but also its spatiotemporal continuity. At the same time, long-term memory retention over 24 h has been previously demonstrated using the operant conditioning leg-kicking paradigm with two-month-olds [12]. Perhaps more intriguing is that Kochukhova and Gredebäck [5] found that six-month-olds' long-term memory was improved after 24 h but not after 15 min. The authors do not provide an account for this finding but two potential explanations stand out. First, it is plausible that a second training session was necessary to stop representations for the trajectory from degrading over time; that is, the test after a 15-min delay might have served to provide additional training or a re-activation of what was learned during the first session. Second, it has recently been shown that napping aids abstract learning in 15-month-olds [13], and it might be the case that the same effect occurred in the six-month-olds in Kochukhova and Gredebäck's experiment. Future training studies could address this issue by examining whether infants generalize the learned novel trajectory to different objects after a nap but not after a similar time delay without a nap.

Not what and how but why

The innovative methods and subsequent findings of training studies by Kochukhova and Gredebäck and others [4] can help developmental scientists to make giant steps in understanding the fundamental nature of when and how concept development begins. Although Kochukhova and Gredebäck do not adopt a developmental approach by studying multiple age groups, other researchers have started to make headway in this endeavor [9]. However, as yet, few have asked why such rapid learning occurs with regard to object trajectories when the perceptuo-cognitive system is relatively slow in acquiring other kinds of object concepts. For example, it is not until the second year of life that infants develop representations that incorporate the motion trajectories of different object kinds [14]. Future research that combines methodologies from cognitive development and cognitive neuroscience with human and non-human animals should shed light on this issue. Only then will developmentalists begin to understand the how, when and why of concept development.

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