study of these questions will enhance our understanding of the mechanisms for form and motion coupling at different stages of visual analysis that underlie our perception, decisions and actions.

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Can infants' object concepts be trained?

Brian J. Scholl

Department of Psychology, Yale University, Box 208205, New Haven, CT 06520-8205, USA

Decades of research and debate on the origins of object permanence in infancy have contrasted various types of learning with possible innate contributions. A recent paper by Johnson *et al.* adds a new perspective to this debate by reporting that even very brief training periods can dramatically influence infants' persisting object representations. Such training studies have the potential to constrain 'nature versus nurture' debates in novel ways, although important challenges remain.

Coherent visual experience requires that we represent objects as individual entities that persist through visual disruptions such as occlusion. Accordingly, research into the underlying nature of this ability has long been a central focus in many areas of cognitive science [1]. Decades of research and debate on the origins of this ability in infants have contrasted learning with possible innate contributions from 'core knowledge'. Indeed, this issue can be seen as one of the defining controversies of the field, with lively debates appearing every few years in the literature (e.g. [2] vs. [3], [4] vs. [5], [6] vs. [7]). A recent paper by Johnson *et al.* [8] adds a new perspective to this debate by reporting that even very brief training periods can dramatically influence infants' persisting object representations, as revealed by eye movement recording. Such training studies have the potential to reveal *how* object representations develop, in addition to *when* they develop. This method also has the potential to constrain nature–nurture debates in novel ways, if several important challenges can be overcome.

Looking at the infant's object concept (with eyetracking)

Whereas looking-time methods have dominated much recent research in infancy (e.g. [9,10]), Johnson *et al.* have returned to older visual tracking methods (e.g. [11]) – now aided by adaptations of recent corneal-reflection eye-tracking technology for use with infants – to argue for constructivism. In Johnson's study, 4- and 6-month-old infants viewed simple animated displays in which a ball oscillated back and forth on a computer monitor, passing behind a central occluder. Previous looking-time experiments with this display suggested that 4-month-olds were

Corresponding author: Brian J. Scholl (Brian.Scholl@yale.edu).

on the cusp of being able to represent the ball as persisting while occluded [12]. An eyetracker monitored the infants' eye movements during viewing, and their saccadic responses to the occlusion events were coded as 'anticipations' (moving to the far side of the occluder before the emergence of the ball) and 'reactions' (moving to the far side of the occluder more than 200 ms after the ball's re-emergence). Both 4- and 6-month-olds anticipated on many events, but the 6-month-olds did so with greater frequency. Anticipations declined over time for both groups, however, suggesting that the infants were not just gradually picking up on a repetitive pattern.

In the crucial and novel manipulation, infants were then 'trained' to expect the balls to persist throughout their trajectories, by first viewing the ball oscillate for two minutes without an occluder. This training resulted in significantly more (and faster) anticipations in the 4-month-olds, but did not affect the 6-month-olds. These results are interpreted in terms of the on-line development of a persisting object concept: 4-month-olds initially lack such a concept, but develop one in response to the training. Six-month-olds, by contrast, already possess object permanence, and so are not aided by the training. As evidence that the 4-month-olds' improvements reflect an abstract skill rather than the entrainment of an arbitrary specific motor habit [13], the authors report that 4-month-olds anticipated more often even when trained on vertical unoccluded motions, and then tested on horizontal trajectories.

Competence or performance?

The authors conclude that persisting object representations are acquired via an associative learning mechanism, from even a surprisingly sparse amount of visual experience. This is taken to weigh heavily against a nativist perspective, which holds that 'in the absence of evidence to the contrary, functional object representations are rooted in processes that operate *independent of experience*' ([8], p. 10568, emphasis added). This represents a new and particularly direct way of demonstrating the role of experience in revealing object concepts, during the course of a single experiment.

Even so, this demonstration is unlikely to compel many nativist theorists, who embrace a view in which innate core knowledge can be triggered and tuned via experience with the environment [14–16]. In this more nuanced view of nativism, innate structure is designed precisely to learn certain adaptively important abilities from experience – for example by orienting attention to only certain kinds of regularities, or by uncovering how a core ability might apply to new situations and event categories. In addition, models developed in the context of adult visual perception reveal how the very same mental processes can both be innately specified and yet develop richly in response to experience [16]. A stronger constructivist case thus requires evidence that training creates the object concept itself – the underlying competence.

One of the most salient trends in the history of infancy research has been the repeated demonstration that null effects at early ages represent performance limitations, which can be sidestepped by using more sensitive methods to reveal an underlying competence. Johnson *et al.*, though, do not consider this possibility, and assume that their training effects represent a developing competence. In fact, however, their own looking-time experiments with the same types of displays provide evidence that 4-month-olds *can* already represent object persistence through occlusion with shorter occlusion durations [12]. Moreover, this is consistent with the many other looking-time studies that have demonstrated object permanence in infants as young as 2.5 months [10,17]. Even using eyetracking, other researchers have demonstrated successful oculomotor anticipations in 4-month-olds using real objects (rather than abstract computer displays) with different spatio-temporal parameters (Kochukhova, O. and Rosander, K., pers. commun.). Thus Johnson *et al.*'s training results might be most important, not because they are inconsistent with nativist theories, but rather because (a) they caution against strict claims of when abilities emerge in infancy, and (b) they constitute a powerful new tool for determining precisely how experience influences object representations.

Is it sensible to ask when infants acquire an ability?

A core project in developmental psychology is to pin down the precise ages at which key abilities are acquired. The results of Johnson *et al.* [8] and other recent training studies [18] question whether this project is always sensible, however, because infants' success will be determined by their immediate past experience. Moreover, a demonstrated competence in one experimental context may not transfer easily to others – or even to the very same context a few moments later. In another important recent training study, for example, Rosander and von Hofsten observed enormous improvements in oculomotor tracking through occluders over the course of individual trials, but this learning from experience did not carry over into later trials [18]. Thus, although Johnson *et al.* stress how quickly training effects can arise, they might also fade away just as rapidly. Such transient learning effects – coupled with the fact that unusually large individual differences are often observed in infants' oculomotor abilities [18] – make it difficult to derive precise age milestones at which infants can represent persisting objects.

From *when* to *how*: can anomalous competencies be trained?

Ultimately, training studies in infant cognition might have their greatest influence in their potential to determine *how* experience affects underlying representations – beyond the question of *when* such representations come on-line. Hence, future training studies could examine in detail precisely which types of abilities and concepts can be trained, and by which types of experience. This research program will be of incredible value to infancy research, by delineating the underlying flexibility and potential of infants' minds. This project would also be of great use in evaluating theories that appeal to specific mechanisms – for example, those that identify infants' object-cognition

abilities with mechanisms of object-based attention in adults [19,20].

Reneé Baillargeon has recently begun such a project in studies that attempt to train young infants' concepts of support and containment [10,17]. 11-month-olds, for example, will typically fail to appreciate the importance of proportional distribution in evaluating support relationships (i.e. whether a block would fall off another block), but this ability can be trained with as few as six familiarization trials with other objects [10]. Experiments of this sort could even address constructivist theories in other ways, by exploring whether 'anomalous' concepts can be trained just as easily. In Johnson's object-persistence displays, for example, could another kind of training lead infants just as easily to think that objects will *not* persist when occluded? If such anomalous concepts could be trained just as easily as veridical concepts, this would lend support to constructivist proposals. This is therefore a particularly important question for further research.

Preliminary findings, however, hint that some such results might be consistent with nativist theories: Baillargeon reports that 11-month-olds can be readily trained to appreciate true support relationships, but cannot be trained in this way to appreciate anomalous support relationships [10]. This is reminiscent of earlier and more extreme training studies with animals, which also supported nativist theories. For example, the visual systems of many animals (including humans) assume an overhead light source, and this bias persists even in animals that are raised from birth in an environment lit from below [21].

These future directions illustrate the importance and potential of training studies. The innovative methods and results of Johnson *et al.*, along with those of other researchers [10,18], are not the last word on the nature of cognitive development – but they have the strongest potential to advance our understanding of how experience shapes and tunes the minds of young infants.

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Something in the way she moves

Kevin G. Munhall and Julie N. Buchan

Department of Psychology, Queen's University, Kingston, Ontario, K7L 3N6, Canada

A recent study using a crossmodal matching task showed that the identity of a talker could be recognized even when the auditory and visual stimuli that were being matched were different sentences spoken by the talker. This finding implies that general temporal features of a person's speech are shared across the auditory and visual modalities.

When old friends call on the telephone, it is easy to imagine their faces speaking the words. The visual image of our friends and the sounds of their voices are somehow linked in a rich multimodal representation. A recent paper by

Corresponding author: Kevin G. Munhall (munhallk@psyc.queensu.ca).