Journal of Experimental Child Psychology **78**, 55–60 (2001)
doi:10.1006/jecp.2000.2603, available online at http://www.idealibrary.com on IDEAL®

The Role of Object Recognition in Young Infants' Object Segregation

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Needham's (2001, this issue) new results confirm that young infants draw on experientially derived representations in resolving individuation ambiguities due to shared boundaries between adjacent objects. They extend previous findings in a surprising way: The memory representations that infants draw upon have bound together information about shape, color, and pattern. Our commentary on these important results draws a distinction between two senses of "recognition" and asks in which sense object recognition contributes to object individuation in these experiments.

Key Words: infant cognition; object recognition; object segregation.

Sensory input is continuous. The array of light on the retina, even processed up to the level of Marr's 21/2D sketch (Marr, 1982), is not segregated into individual objects. Yet distinct individuals are provided by visual cognition as input into many other perceptual and cognitive processes. It is individuals we categorize into kinds; it is individuals we reach for; it is individuals we enumerate; it is individuals among which we represent spatial relations such as "behind" and "inside"; and it is individuals that enter into causal interactions and events. Because of the psychological importance of object representations, the twin problems of how the visual system establishes representations of individuals from the continuous input it receives and the development of these processes in infancy have engaged psychologists for almost a century.

Needham's elegant research program addresses this problem through an examination of early perceptual development. Many researchers have shown that young infants, like adults, draw upon spatiotemporal information—information about the spatial arrangements and motions of visible surfaces—to establish representations of discrete individuals. Two objects separated in space (on the frontal plane or in depth), or moving on spatiotemporally discontinuous trajectories, are resolved into distinct individuals (e.g., Baillargeon, 1991, 1995; Spelke, 1991; Spelke, von Hofsten, & Kestenbaum, 1989; von Hofsten & Spelke, 1985; Xu & Carey, 1996). In her previous work, Needham has shown that by 4.5 months of age, infants also draw upon featural information to resolve ambiguous displays

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0022-0965/01 $35.00

into distinct individuals (Needham, 1998; Needham & Baillargeon, 1997). That is, shown adjacent objects sharing a boundary, such as the box/hose displays in the target article, infants as young as 4.5 months can use dissimilarity of shape, color, and texture to resolve this display into two distinct objects. These results are somewhat fragile at younger ages, as young infants' performance appears to be highly dependent on the properties of the test objects: Four-and-a-half-month-olds fail when the object features are too complex. However, if infants are first exposed to either component of the test array alone for a few seconds, 4.5- to 5-month-old infants can succeed more reliably at this task, looking longer when the objects move in a unitary manner than when they separate into two discrete individual objects (Needham & Baillargeon, 1998; Needham & Modi, 1999). The effects of experientially derived knowledge extend to brief exposures to one of the objects in the infant's home 24 h earlier.

Needham's article in the present issue examines the process through which infants use experiential knowledge for the object individuation task, attempting to understand what sort of memory representation is provided by prior experience with the test object and how this representation enters into the object segregation process. She finds that it is only upon experience with the same object (i.e., a blue box with white squares), or a highly similar one (i.e., a blue box with white circles; a blue box with white squares but on its side), that the infants succeed. If familiarized to a less similar object (i.e., a purple box or a blue box with red or yellow squares), infants are agnostic as to whether the test display is one or two objects. These are very important results. They confirm Needham's previous findings that infants draw on experientially derived knowledge in resolving individuation problems where there is spatiotemporal ambiguity. They also extend the previous findings in a surprising way: the memory representations that infants draw upon have already bound together information about object shape, color, and pattern, and only a full match, or a close match, between this representation and the observed object will do. Thus, infants are not only capable of processing information about object color, shape, and pattern in brief encounters with new stimuli; they are also able to combine and store this information and later draw upon it in order to parse the perceived world into individual objects.

Needham argues, quite reasonably, that these results show object recognition plays a role in object segregation by 5 months of age. Indeed, it must be that successful object segregation in these studies involves establishing a match between a current perceptual representation and a stored representation, which is what one may mean by "recognition." However, the term "recognition" is often taken to refer to richer, more specific, processes. In our commentary, we characterize two richer senses of the term and ask whether it is likely that recognition in these senses is likely to be implicated in these tasks.

Consider the process of recognizing a particular object, such as a cup, or a particular person, such as Bill Clinton. First, when we recognize an object as a cup or as Clinton we not only establish a match to a stored object representation, but we also access a semantically meaningful kind category or a rich representation of a particular individual. We then have access to a wealth of information about that object based on its kind membership: we know that the cup is the right size to fit in our hands, that the part on the side is a handle, and that it often contains coffee; we know that Clinton is man, that he eats and sleeps, and so on. Second, recognition also involves a conscious experience of familiarity: when we recognize a person such as Bill Clinton, we know that it is Bill Clinton in particular and are immediately aware that we have seen him before. These are stronger, richer senses of the term "recognition," and Needham implicitly draws on them in her article. When she provides the thought experiment in which the infant's pacifier jumps out at him from the undifferentiated mess of drawer contents, she is using recognition in this richer sense.

But this is not necessarily the kind of recognition process that underlies Needham's experimental findings. Recognition in the strong sense (placement with respect to stored representations of kinds or individuals or a conscious feeling of familiarity) is empirically dissociable from recognition in the weaker sense (establishing a match between a current stimulus and a stored representation). Experiments on implicit memory routinely show the effects of recognition in the weaker sense in the absence of recognition in the stronger sense (e.g., Schacter, 1987; Tulving, Schacter, & Stark, 1982). Patients with agnosia, a condition characterized by the inability to recognize familiar objects, or prosapagnosia, a condition characterized by the inability to recognize familiar faces, have lost both the capacity to place the stimuli in the relevant category and the feeling of familiarity. Agnosias, by definition, involve loss of recognition in the stronger sense. Yet patients with agnosia and prosapagnosia sometimes reveal implicit memory for the presented item: the items can serve as effective primes, for example (e.g., de Haan, Bauer, & Greve, 1992; Ellis, Young, & Keonken, 1993; Humphreys & Riddoch, 1987; Young, 1994). Recognition in the weaker sense is therefore intact in these patients.

Mary Peterson and her colleagues have provided a salient demonstration of the dissociation of recognition in the stronger sense, on the one hand, from the processes of recognition that subserve object segregation, on the other. Peterson's work concerns the processes that establish figure–ground representations. Establishing a representation of figure is a paradigmatic individuation problem, for a single figure is seen as an individual with a defined shape in front of an undifferentiated background. As is well known, both featural information (gestalt properties of arrays, such as similarity, symmetry and boundedness) and spatiotemporal information (e.g., binocular depth cues that specify one surface as in front of another) enter into the computations that resolve figure–ground ambiguity at the earliest stages of processing. What Peterson has shown is that experiential knowledge also enters into the computations and does so early in visual processing. In a series of studies, she has compared figure–ground displays in which one of the surfaces is bounded by a meaningful shape (e.g., a face profile or a sea horse) and in which its complement is not. She often manipulates other cues to figure–ground segregation as well (e.g., symmetry and binocular depth cues).

Peterson finds that meaningfulness of shape—which can only have been derived from experience—enters, in parallel, with other factors at the very earliest stages of figure determination (within the first 14 ms) That is, the meaningful shape is more often seen as figure than its complement, and this factor sometimes overrides other cues to figure such as symmetry or depth cues (Peterson & Gibson, 1993, 1994a, 1994b).

Most relevant to us here, Peterson et al. (in press) presented neuropsychological evidence that the experientially derived shape representations that enter into this process are not the meaningful kind representations that mediate conscious object recognition. They presented a double dissociation between a visual agnosic patient with bilateral temporal–occipital lobe lesions and a patient with bilateral occipital lesions who was impaired on a variety of sensory and perceptual capacities. Agnosic patients cannot recognize familiar objects; they cannot name them, say what they are for, describe them, or show any other evidence of having placed them with respect to a familiar kind. The agnosic patient nonetheless showed the effects of experientially derived shape-on-figure determination to an equal extent as normal participants in these studies. That is, she was more likely to see a sea horse as figure than an upside-down sea horse (inversion controls for all other cues to figure–ground segregation), even though she could not recognize the sea horse. The occipital-lesioned patient showed no effect of experientially derived shape representations in figure–ground decisions, but when he did see the meaningful shape as figure, he could recognize it as well as did normal participants in this experiment.

In sum, Peterson's research provides a robust demonstration that kind representations—those involved in placing a stimulus in a meaningful conceptual category—are not the only experientially derived shape representations that play a role in processes of individuation and that the recognition processes that do contribute to object segmentation need not be recognition in the stronger, richer sense. Thus it is still a very open question whether it is recognition in the weak or strong sense that is involved in infants' performance in Needham's studies.

We cannot know, of course, whether the infant experiences a conscious feeling of familiarity. We do know that these experiments do not involve kind representations, for there is no stable, long-term, functionally relevant entry for the kind "blue box with white squares." But what of pacifiers, or key rings, or other functionally relevant objects? When recognition of such objects supports individuation, as in Needham and Lockhead's (1999) individuation task presenting 5.5- and 7.5-month-old infants with a key ring, is it recognition in the weaker sense, as in Peterson's agnosic patient, or recognition in the stronger sense? Elsewhere, we have argued that it is unlikely that full kind representations are drawn upon in these tasks (Van de Walle, Carey, & Prevor, 2000; Xu & Carey, 1996; Xu, Carey, & Welch, 1999) until the end of the 1st year of life. One experiment in particular is worth flagging. In a paradigm quite similar to that of the target article, we habituated 10- and 12-month-olds to stationary ambiguous displays (a duck on a car; a cup on a shoe) (Xu et al., 1999). After habituation, a hand grasped the top of the top object and lifted. Test trials alternated; either the duck/car (cup/shoe) was raised as a single object or just the duck (or cup) was raised. Ten-month-olds did not look longer at the Move-together outcome, whereas 12-month-olds did. (Convergent evidence from two other paradigms for a change between 10- and 12-month-olds in the ability to draw upon kind representations in object individuation is provided in the papers cited above.) Providing infants with 30 s experience with the duck alone and the car alone did not facilitate the performance of the 10-month-olds. Clearly, in this study, 10-month-olds did not succeed in drawing on stored kind representations to resolve an ambiguous object segregation problem.

Xu and Carey (2000) address the apparent discrepancies between our results and those of Needham and her colleagues. Why do 10-month-olds fail to draw on experientially derived representations, or feature differences, in our tasks in the face of success at much younger ages in Needham's studies? We argue that many factors make our tasks more difficult than those of Needham and her colleagues, making it necessary that even adults draw on kind representations to support individuation in these cases, and we review evidence from many sources suggesting that robust kind representations are not available until the end of the 1st year of life. Space prevents the rehearsal of these arguments; here we wish only to introduce a note of caution against conflating the weaker and the stronger senses of recognition when interpreting the elegant studies of the target article.

Although it is extremely difficult to settle what kind of recognition plays a role in object individuation in young infancy, the work reported in the target article is the first step in what we hope will be an extended series of studies on the nature of the representations derived from visual experience that are drawn upon in resolving ambiguities about object number. As indicated above, Needham has already shown that shape, color, and pattern are bound in them, and ongoing work in Needham's laboratory explores abstraction processes. It may be possible to bridge the gap between Needham's studies and those from our laboratory by systematically studying the role of object complexity. What kind of object features are responsible for making the array too "complex" for young infants to parse it successfully? Will infants be able to succeed, for example, if the objects entering into the ambiguous display each have multiple parts? We look forward to future results provided by Needham's fascinating research program.

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Received February 3, 2000