

## Chapter 1

### Development of Knowledge about Vision

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A developmental psychologist shows a 5-year-old girl a candy box with a picture of candy on it and asks her what is in it. "Candy," the girl replies. She then gets to look inside the box and, to her surprise, sees that it actually contains, not candy, but a little doll. She is then asked what another child who had not yet opened the box would think was in it. "Candy!" says the child, amused at the deception. The experimenter then presents a 3-year-old boy with this same false-belief task. His answer to the first question is the expected "Candy," but his response to the second is a confident and unamused "Doll." Even more incredible, the boy also maintains that he himself had first thought that the candy box would contain a doll. Unlike the 5-year-old, the 3-year-old shows no evidence of understanding that either he or other people could hold a belief that is false.

Results such as this are found in currently flourishing research on the development of our knowledge and beliefs about the mental world—our folk psychology or naive theory of mind. To a greater extent than earlier metacognitive and social-cognitive approaches to the same domain, the theory of mind approach probes children's conceptions of the most fundamental components of the mind, such as beliefs and desires. In less than twenty years, this fast-growing area of research has spawned hundreds of articles and scores of books and monographs. Indeed, the spate of papers and posters on this topic at recent meetings of the Society for Research in Child Development reminded older participants of the way Piagetian research dominated the program in years past. To illustrate, a recent meta-analysis of false-belief studies alone—just one topic in this area—included 178 studies (Wellman, Cross, and Watson, 2001). Developmental findings in this area have also become of interest to philosophers of mind, who believe that these findings may help clarify philosophical disputes about the nature of folk psychology. (For reviews of work on this topic, see, for example, Baron-Cohen, Tager-Flusberg, and Cohen, 2000; Bartsch and Wellman, 1995; Flavell and Miller, 1998; Hughes, 2001; Mitchell and Riggs, 2000; Moore, 1996; and Wellman and Gelman, 1998.)

Why this intense research interest in the development of knowledge about the mental world? Numerous motives, ranging from self-preservation to simple curiosity, impel people the world over to try to make sense of themselves and other people, and doing that requires a folk psychology. Human social and

cognitive life bereft of knowledge or beliefs about the mind seems virtually unimaginable, and the development of something that important and ubiquitous is surely worth learning about. In her lectures on this topic, Alison Gopnik likes to make this point in the following way. Imagine what it would be like for you to give a lecture to an audience if you had no conception of mental states. The audience might appear to you as bags of meat with two small holes at the top. You would see these bags and the shiny things in their holes shift around unpredictably in a way that perplexed and terrified you, although of course you would not realize that you were perplexed and terrified. Gopnik's scenario may not be as imaginary as it seems. Autistic individuals, known to be deficient in knowledge about the mind, sometimes act as if they viewed other people as unpredictable and scary.

Several types of theories have been offered as explanations for the development of children's mentalistic understanding. One is the so-called theory theory (Gopnik and Meltzoff, 1997; Gopnik and Wellman, 1994; Perner, 1991; Wellman and Gelman, 1998). Theory theorists argue that our knowledge about the mind constitutes not a formal scientific theory but an informal, everyday "framework" or "foundational" theory. An important insight of this approach is that we acquire knowledge or beliefs, not just about each type of mental state considered in isolation, but also about how each one relates to other mental states, to sensory inputs, and to observable behaviors. This insight is particularly compelling in the case of knowledge about vision. On the one hand, there are some things we could learn about vision construed narrowly—about what might loosely be called "visual sensing" or "basic seeing." On the other hand, there are some very important things we could learn about what can happen in people's minds and behaviors once the visual stimulus has been detected, that is, about the myriad possible connections between basic seeing and other mental and behavioral phenomena. This chapter summarizes much of what infants and children have been found to learn in this area, both about basic seeing and about its mental and behavioral correlates.

### *Development during Infancy*

There is research evidence that children have acquired some basic knowledge about vision by the age of 18–24 months. Most of this evidence concerns their developing understanding of the referential nature or "aboutness" of vision. That is, as they grow older, infants become increasingly aware that another person's gaze at an object is an action by that person directed at that object. In addition, they discover some of the implications of another person's gaze, for example, that the person's talk, expressed emotions, and other behaviors when interacting with them are likely to relate to the object of the person's gaze. There is also reason to think that by the end of infancy children are becoming increasingly aware that things happen inside people when they see: they receive information about the

world and have visual and other subjective experiences. (For reviews of research on infants' knowledge about vision, see Butler, Caron, and Brooks, 2000; Carpenter, Nagell, and Tomasello, 1998; Corkum and Moore, 1998; Flavell and Miller, 1998; Moore and Corkum, 1994; Winer, 1991; and Woodward, 2003, in press.)

*Looking as a Relation between Looker and Object*

To have any chance of understanding the meaning of other people's visual acts, infants must obviously first pay attention to the people's eyes and then be able to follow the direction of their gaze. Early in the first year, babies prefer to look at eyes over other facial features (Maurer, 1985). They also show sensitivity to changes in gaze direction and may sometimes look in the general direction another person looks (Hood, Willen, and Driver, 1998). This critical ability—to follow the other person's gaze successfully—improves considerably between 6 and 18 months of age.

Can we conclude from infants' gaze following that they are aware that the gazer is related to—or at least looking at—the object? Although this seems reasonable, Moore and Corkum (1994) have cogently argued that we cannot draw such a conclusion. They argue that infants may have simply learned from experience that, when they follow a person's gaze, they will see something interesting. Their representation of the event may not include the person or the person-object relation at all—only the object (see also Butterworth and Jarrett, 1991). As Woodward (in press) puts it, in such a construal, the other person's gaze merely “spotlights” the looked-at object. Although Corkum and Moore (1998, p. 38) accept that understanding of vision as person-object connectedness is in place by the end of infancy or somewhat earlier, they doubt that younger infants grasp the referential nature of looking, despite some ability to follow gazes.

Two recent investigations provide some support for Corkum and Moore's claim. Butler, Caron, and Brooks, 2000, studied the gaze-following behavior of 14- and 18-month-olds under three conditions. In each condition, infants faced an experimenter who would conspicuously turn head and eyes to look in the direction of stationary targets placed a few feet away, one on the right and one on the left. In the no-screen condition, there were no visual obstacles to prevent the experimenter from seeing the targets. In the screen condition, opaque screens were interposed between the experimenter and the two targets such that, whereas the infant subjects could still see the targets, the experimenter clearly could not. In the window condition, each screen contained a large transparent window that allowed the experimenter full visual access to the targets, as in the no-screen condition. The window was at an angle that allowed the infants to see through it to the back wall; in addition, the experimenter waved at the infants through it to demonstrate its transparency.

The authors reasoned that infants who do not understand the referential nature of looking and its line of sight requirements would turn equally in all three conditions; if the experimenter looks, they look. In contrast, infants who better

understand the link between looker and object would look toward the targets maximally when the experimenter would be able to see them (no-screen and window conditions) and minimally when not. Eighteen-month-olds showed the latter response pattern: They turned much more in both the no-screen and the window condition than in the screen condition. In contrast, 14-month-olds showed a mixed pattern. On the one hand, they turned less in the screen condition than in the no-screen condition. On the other hand, they turned at well above chance levels in the screen condition. More strikingly, they turned less often in the window condition than in the screen condition. In addition, whereas, among the 18-month-olds, 7 of 20 leaned forward to gaze at the inside of the screen in the screen condition, presumably to see what the experimenter might be finding to look at there, among the 14-month-olds, only 1 of 22 did. Brooks and Meltzoff (2003) showed that, during the second year of life, infants are likelier to follow an adult's head turn to look at a target if the adult's eyes are open or uncovered rather than closed or covered with a blindfold. Woodward (2003 and in press) also found that infants follow eye gaze before they understand that gaze expresses a relation between gazer and target object, although Woodward's method suggests an earlier age of transition than that indicated in Butler, Caron, and Brooks, 2000. Infants 7, 9, and 12 months of age were tested in a habituation paradigm in which they watched an experimenter look at one of two toys on a table. On each trial an experimenter made eye contact with the infant, said, "Hi," and then, "Look," as the experimenter turned to stare at one of the toys, and then stopped staring at it as soon as the infant looked away for 2 seconds. Infants saw the same event on subsequent trials until habituation. Then the positions of the two toys were reversed and two new kinds of test events were presented. On new toy trials, the experimenter continued to turn to the same side as during habituation, and thus looked at a new toy. On new side trials, the experimenter turned to the opposite side, thereby looking at the same toy as during the habituation trials. Woodward (in press) reasoned that if infants are representing the relation between the experimenter and the object the experimenter is looking at, then they should look longer on new toy trials, which present a new looker-object relation. If they attend only to a change in the experimenter's physical movements, then they might look longer when the experimenter turns to a different side (new side trials).

Woodward (2003, in press) found that infants of all three ages usually followed the experimenter's gaze to the looked-at object. However, the 7- and 9-month-olds looked equally on new toy and new side test trials, and also did not show a reliable increase in looking from habituation to test trials on either type of trial. "It was as if 7- and 9-month-olds identified the visible objects (the bear, the ball, and the actor) as being the same as during habituation, without considering the relations between them" (Woodward, 2003, pp. 303–304). In contrast, the 12-month-olds looked reliably longer on the new toy trials than on the new side trials and also recovered from habituation when presented with the new toy trials but not the new side ones.

How do infants learn that looking is a relation between looker and object? Woodward (2003) suggests two possibilities, both of which may be true. One possibility, elaborated in detail by Moore and Corkum (1994), is that repeated experience of joint attention on objects with adults serves as a vital crucible. According to this account, infants begin by associating their own visual experience of an object in these interactions with the adult's head and eye orientation toward the same object. In this way, they gradually come to realize that when they and other people gaze at objects, they are related to these objects via an inner experience of seeing them. The second possibility, proposed by Woodward herself (2003), is that infants gradually notice behavioral regularities associated with gaze. For example, having once learned that grasping involves a relation between people and objects, and noticing that people usually look at what they grasp, infants could eventually infer that looking also involves such a relation. Presumably, noticing the regular co-occurrence of people's looking with their touching, pointing, and object labeling could similarly contribute to this insight.

Finally, infants also show their burgeoning understanding of the referential nature of people's gaze, not merely by following it, but also by directing and checking it:

Franco and Butterworth (1989); Butterworth, (1991) found that at around 12 to 16 months children not only point but also check the gaze of the adult whose attention they are trying to direct. They do that in two different ways. Before pointing, they check whether the adult is looking at them; and as they point, they check whether the adult is looking at the indicated object. The fact that infants do not just try to manipulate the other's gaze but also check on it indicate that they are aware of its importance. (Perner, 1991, p. 129)

(See also Carpenter, Nagell, and Tomasello, 1998; Moore and D'Entremont, 2001; for a different approach to the study of infant gaze following and attribution of intentionality, see Johnson, 2000; Johnson, Slaughter, and Carey, 1998.)

### *Implications of Looking*

One important implication of looking that children discover by the end of infancy is that where people look is a clue to what object they are labeling. That is, babies learn the names for things by noting what object adults appear to be attending to when they say the label. Some clever studies of this kind of aboutness reading have been done during the past decade (see Baldwin and Moses, 1994; Moore, Angelopoulos, and Bennett, 1999; Tomasello, 1995; Woodward and Markman, 1998). Baldwin (1991, 1993; Baldwin and Moses, 1994) showed that infants 19–20 months of age sense that the verbal label an adult utters refers to the object the adult shows clear signs of visually attending to at that moment. These infants recognize that it does not refer to other perceptually salient objects the adult is not focused on: for example, an object that they, rather than the adult, are currently

looking at, or an object that the adult calls to their attention but in such a way as to not appear to be labeling it. In short, infants of this age seem to recognize that it is an adult's visual focus rather than their own that gives clues as to the adult's referential intent. Moore, Angelopoulos, and Bennett (1999) confirmed these results and also showed that this referential understanding is more robust in 24-month-olds than in 18-month-olds.

These word-learning studies show that infants develop the ability to learn what an object is *called* by reading an adult's visual focus when the adult labels it. There is also evidence that they develop the ability to learn what an object is *like* by reading an adult's visual focus when the adult is expressing a positive or negative emotional reaction to it. That is, they can recognize that an adult's emotional display refers to a particular object just as they can recognize that an adult's spoken label refers to a particular object. Seeking or using information about objects' positive or negative qualities conveyed by adults' perceptible emotional reactions to these objects has been called "social referencing"; the developmental literature on social referencing has recently been reviewed by Moses and colleagues (2001), Mumme and Fernald (2001), and Repacholi (1998). Parents often present young children with this kind of evaluative information, as when they try to interest them in a new toy by acting as if it were the greatest thing ever ("Wow, look at *this!*" "See what *this* does!" etc.).

One question that has arisen in the social referencing literature is whether babies actually realize that an adult's expressions of emotion are about the object. An alternative possibility is that these expressions just alter the babies' mood, which in turn alters the babies' reactions to all objects, for example, dampening them when the mood thus induced is negative. However, the evidence now strongly suggest that, although such mood modification effects also can occur, by 12 months or so, infants do have some understanding that an adult's behavior is about the specific object the adult is looking at when expressing the positive or negative affect (Moses et al., 2001; Mumme and Fernald, 2003; Repacholi, 1998). For example, Moses and colleagues (2001) showed that, on hearing a female experimenter's emotional outburst of pleasure ("Nice!") or disgust ("Yecch!"), 12-month-olds immediately checked her face, followed her gaze to the object she was emoting about, and acted appropriately—for example, spending less time with and responding less positively to objects that she had "yecched." Repacholi (1998) has also presented impressive evidence for object-specific social referencing in 14-month-olds.

The research on social referencing shows that infants can recognize the implications for their behavior of other people's visual and emotional regard. Four experiments by Phillips, Wellman, and Spelke (2002) give evidence that infants can also recognize the implications of these actions for an adult's own behavior. In one of their experiments, 8- and 12-month-olds first saw an adult look at one (A) of two almost identical stuffed animals (A and B) with facial and vocal expression of interest and delight. Then a screen was closed briefly, and when it

reopened, the infants saw the adult holding A. After habituating to this sequence, the infants were then shown two types of test trials in alternation. As in the habituation trials, one type of test trial was consistent with the principle that people will probably approach what they act as if they like. On these consistent trials, the adult first acted positively toward the second animal, B, and after the screen closed and reopened, was shown holding B, in accord with the principle. On the other, inconsistent trials, the adult began by acting positively toward A, but then grasped B instead, in violation of the principle. The 12-month-olds looked longer at the inconsistent event than at the consistent one, as if recognizing that looking at things with positive regard predicts approaching them. In contrast, the 8-month-olds looked equally at the two types of events. Wellman, Phillips, and Rodriguez (2000) found evidence for a more advanced understanding in 2½-year-olds: if an adult looks with positive affect at an object the child cannot see, that object is likely to be one the child regards as desirable rather than undesirable, whereas the opposite is true if the adult's affect is negative. Montgomery, Bach, and Moran (1998) found that 6-year-olds, but not 4-year-olds, showed a yet more advanced insight: that an object that is looked at for a long time is more likely to be a protagonist's goal than one that is only glanced at. Clearly, there are a number of developmental levels of social referencing.

#### *Seeing as an Internal Psychological Event*

A distinction within this category can be made between seeing as the receipt and use of information about the world and seeing as an action accompanied by a phenomenological experience. In the former, the emphasis is on the specific thing seen and the effects of seeing it on other mental states and behaviors. Seeing something results in obtaining information about it, and that information may then engender various beliefs, desires, intentions, and other mental and behavioral events. In the latter, the emphasis is on the act and subjective experience of seeing rather than on the specific object seen. There is at least suggestive evidence that some understanding of both the informational and the act-experiential aspects of seeing is present during late infancy or very early childhood.

Regarding the informational aspect, casual observation suggests that older infants, at least, often show their caretakers an interesting new object only once, even though their indulgent caretakers would probably be willing to reinforce additional showings with appropriate effusions of interest and approval. They may repeat other interchanges endlessly, to the point of adult tedium, but usually seem to feel the need to show things just once. Why? It seems possible that they somehow sense that the adult has received the new information on the first showing, and thereafter continues to "know it." They seem not merely to want the other person to look at or see the object—that would be as effectively accomplished on the nth showing as on the first—but in some sense to "know" what it is and that it is there. Such observations suggest that infants may at times be attributing to other people something inner and unobservable, even though we

are presently at a loss to imagine what that attribution experience might be like for creatures so unknowledgeable and nonverbal.

O'Neill (1996) obtained experimental evidence consistent with this possibility. Young 2-year-olds had to ask a parent for help in retrieving a sticker dropped into one of two identical containers that were placed out of reach. With the child watching, the parent had either seen which container the sticker was dropped into or had not seen it because the parent's eyes were conspicuously closed. In their requests for help, the children gestured significantly more often when the parent had not seen which container held the sticker than when the parent had. As will be seen, there is more compelling evidence for the understanding that seeing leads to knowing in studies with preschool children. Nevertheless, casual observation and the findings in O'Neill, 1996, suggest that at least the rudiments are present by the close of infancy. Finally, the evidence presented in the previous section on the implications of looking is also suggestive. Older infants seem aware that people's looking is a clue to their referential and other intentions.

As to the act and experience of seeing, there is also evidence that may indicate some early understanding (Flavell and Miller, 1998; Winer, 1991). Many children correctly understand and use the words *look* and *see* by their second birthday (Bretherton and Beeghly, 1982). Older infants' mastery of Piagetian object permanence tasks shows that they understand that objects can be now visible, now not, all the while continuing to exist. Infants and young children sometimes deliberately manipulate their own and other people's visual experience, as when playing peekaboo games and when rapidly opening and closing their eyes just for the experience of it. The following interchange between the developmental psychologist Elizabeth Spelke and her then 25-month-old daughter Mae, who had just dropped a cereal spoon and was touching her belly, seems to reflect good awareness of the act and experience of seeing:

*Liz:* Mae, do I have a belly?

*Mae:* Yes.

*Liz:* Can you see it?

*Mae:* (looks at [Liz's clothed] stomach, then looks up) No. Can't see it.

*Liz:* Do you have a bowl of cereal?

*Mae:* Yes (looking at [Liz]—she does not look down).

*Liz:* Can you see it?

*Mae:* (giggles, doesn't look down) No can see it!

*Liz:* You can't?

*Mae:* (looking down) Yes. See it. (Spelke, personal communication)

There is other evidence as well. If asked to show a picture to an adult, a woman, say, who has covered her eyes with her hands, 18-month-olds will move the adult's hands or try to put the picture between the adult's hands and eyes. They tend to show pictures to another person in such a way that they can also continue



to see them while the other person does, rather than turning them away from the self and facing them toward the other, as 24-month-olds tend to do (Lempers, Flavell, and Flavell, 1977). Accordingly, when asked to show a small picture glued to the inside bottom of an opaque cup, 18-month-olds tend to hold the cup low and tilt its opening back and forth so that both they and the other person can get alternating glimpses of it. Although not inclined to credit younger infants with knowledge that people's looking behaviors are accompanied by inner visual experiences, Perner (1991) regards the foregoing showing strategy as evidence that 18-month-olds probably do have this knowledge:

But why do they show the picture in such a way that they themselves can see it at the same time? An interesting possibility is that they understand from their own experience when being shown something that showing must lead to an *inner experience* of seeing. Since they cannot have the other person's experience, the only way of ensuring that this critical part is not missing is to produce the experience in themselves. This, of course, can only be achieved by looking at the picture simultaneously with the other. (Perner, 1991, p. 140)

Other findings suggest that older infants have a rudimentary sense of self and some capacity to attribute emotional experiences to self and others (Flavell and Miller, 1998; Wellman, Phillips, and Rodriguez, 2000). They show evidence of a rudimentary sense of self, which would seem to be a prerequisite for attributing inner experiences. They sometimes appear to be trying to manipulate other people's emotional responses rather than, as in social referencing, just reading these responses for the information about reacted-to objects that they may provide. Even toddlers occasionally seem to try to change other people's feelings, or at least change their affective behavior. In the second year of life, they begin to comfort younger siblings in distress by patting, hugging, or kissing them, and may even bring a security blanket to an adult in pain (Zahn-Waxler et al., 1992). An awareness of self and of inner experiences may develop together: Bischof-Köhler (1991) found a high correlation in 16- to 24-month-olds between a test of early self-concept (mirror self-recognition) and empathic responses to a person in distress, even after partialing out chronological age. Although evidence that older infants have a sense of self and attribute emotional experiences to people obviously does not prove that they also attribute visual experiences, it does lend plausibility to the claim.

Some of the infant competencies discussed in this chapter have also been investigated in other primates, most notably chimpanzees. The evidence suggest that chimps are skilled at following the gaze of other chimps and humans. Whether or to what extent they make adaptive use of gaze information is currently the subject of controversy (Hare et al., 2000; Karin-D'Arcy and Povinelli, 2001; Theall and Povinelli, 1999), however, and even those who think they do (Hare et al., 2000) doubt that they conceive of seeing as an internal psychological event.

In focusing attention on the development of knowledge about vision during infancy, it is easy to forget the broader stream of social and theory-of-mind development of which it is a part. This stream can be characterized in a number of ways. According to Barrett, Richert, and Driesenga (2001), children begin by distinguishing between the movements of people and those of inanimate objects. As they learn that, unlike inanimate objects, people are self-propelled, they gradually learn that people are also purposive—not just self-propelled, but self-propelled toward goals. Later, children start to attribute internal, mental states to people, at first in a not fully representational way (“He feels hungry. He will act”) and later representationally (“She thinks it is in the box, but it isn’t”). Knowledge about vision informs and is informed by these larger developments, not only during, but also after infancy, and as we will now see.

### *Later Developments*

#### *Level-1 and Level-2 Understanding*

Assuming that, at some quite early age, children begin to realize that people have inner visual experience or percepts, what do they know about these percepts? There is evidence for two roughly distinguishable developmental levels of early understanding about vision (Flavell, 1978, 1992; Flavell, Everett et al., 1981; Hughes and Donaldson, 1979; Masangkay et al., 1974). At the higher one, called “level 2,” children clearly understand the idea of people having different perspectives or views of the same visual display. Level-2 children can represent the fact that, although both they and another person see the very same thing from different station points, the other person nonetheless sees it a bit differently, or has a somewhat different visual experience of it, than they do. For example, they realize that a cat they see right side up in a picture book will look upside down to someone who views the book wrong side up. At earlier-developing “level 1,” children understand that the other person need not presently see something just because they do and vice versa. For example, they recognize that, whereas they see what is on their side of a vertically held card, another person, seated opposite, does not. However, they do not yet conceptualize and consciously represent the fact of perspective-derived differences between their and the other person’s visual experience of something that *both* people currently see. Level-1 children know that others also see things and that they and others need not see the same things at any given moment. They may also be able to infer exactly what things others do and do not see, given adequate cues. Thus it is clear they are not profoundly and pervasively egocentric in the Piagetian sense: they definitely do have some knowledge about visual perception. Level-2 children also possess this same knowledge and ability, of course, but in addition are aware that the same things may look different to another viewing them from a different position. They may also be able to infer approximately how these things appear from that different position, again given adequate cues.

Flavell and colleagues have made direct tests of this hypothesized developmental sequence by comparing the same children's performance on level-1 and level-2 tasks, and have also explored the nature and development of various sorts of level-1 and level-2 knowledge and skills. The first tests were made by Masangkay and colleagues (1974), on whose tasks the child and the experimenter faced each other across a small table. To assess level-1 knowledge, a card with a picture of a cat on one side and a picture of a dog on the other was held vertically between the child and the experimenter, and the child was asked to indicate which animal the experimenter sees. Their 3-year-old participants had no difficulty whatever in looking at the cat, say, but nonegocentrically reporting that the experimenter sees the dog. To assess level-2 knowledge, a picture of a turtle was placed horizontally such that the turtle appeared upside down from one side of the table and right side up from the other. Although the 3-year-olds always correctly reported how the turtle appeared to them (thereby demonstrating they understood the meaning of "right side up" and "upside down"), only about a third of them consistently attributed the opposite orientation to the experimenter. In contrast, a group of 4-year-olds performed virtually without error on both tasks.

Further experiments by Flavell, Everett, and colleagues (1981) provided additional evidence that there is a real and robust difference between level-1 and level-2 knowledge. Furthermore, relevant experience appears not to readily induce level-2 thinking in level-1 children, even when that experience consists of literally supplying them with the correct answer to level-2 questions. (For a summary of other studies of level-2 knowledge, see Flavell, 1992.)

As to level-1 knowledge, the research evidence shows that children have acquired a surprisingly rich fund of it by 2½–3 years of age (Cox, 1980; Esterly, 1999; Flavell, 1978; Flavell, Everett et al., 1981; Flavell, Shipstead, and Croft, 1978, 1980; Gopnik, Slaughter, and Meltzoff, 1994; Hughes and Donaldson, 1979; Lempers, Flavell, and Flavell, 1977; McGuigan and Doherty, 1999). By the age of 2½–3 years, children act as if they know implicitly that the following four conditions must hold if another person is to see a visual target (Flavell, 1978; Lempers, Flavell, and Flavell, 1977): (1) at least one of the person's eyes must be open; (2) the person's eyes must be aimed in the general direction of the target; (3) there must be no vision-blocking object on the line of sight between person and target; (4) what the children see has no bearing on what the person sees; that is, the young child's knowledge about vision is fundamentally nonegocentric when dealing with level-1, "what is seen"-type problems.

Tacit knowledge of these four conditions permits children 2½–3 years of age to engender, prevent, and diagnose object seeing by another person. They can engender the other person's seeing of the target by pointing to it or verbally designating it, by getting the person, a man, say, to open his eyes and face toward the target, by moving or reorienting it so that it is in the person's line of sight, and by repositioning either the target or a visual occluder so that the occluder no longer

blocks the person's view of the target. They can prevent the other person's seeing of the target by moving the target behind the occluder, or the occluder in front of the target, and by getting the person, a woman, say, to close her eyes or turn away from the target. Finally, they can diagnose or assess whether or not the person currently sees the target by noting whether or not the four seeing conditions obtain. Thus the research evidence indicates that children of this age have enough knowledge about vision to be nonegocentric show-ers (e.g., they will orient a picture so that the other person, but not they, can see it), nonegocentric hid-ers (e.g., they will place an object where they, but not the other person, can still see it), and nonegocentric percept assessors (e.g., as Flavell, Shipstead, and Croft, 1980, have shown, children 2½–3 years of age know that their bodies are still visible to a person when their own eyes, but not the person's, are closed).

Although, as we have seen, infants have some ability to follow another person's gaze, this ability improves considerably during the early preschool period (Doherty and Anderson, 1999). In addition, McGuigan and Doherty (1999) found that 2-year-olds' ability to judge where another person is looking from eye direction alone was significantly correlated with their ability to prevent the person from seeing an object by interposing a screen between the person and the object—both level-1 abilities.

Flavell and colleagues (1991) observed a developmental increase from 3 to 5 years of age in a more advanced type of level-1 understanding: that an observer not only normally, but always and necessarily, sees targets via straight-line looking paths. For example, they found that 3-year-olds showed no understanding that another person cannot see objects through C-shaped or J-shaped looking tubes, even right after they themselves had the experience of not being able to see through tubes of lesser curvature than those. Examining more exotic forms of level 1-related cognition, Winer and colleagues (see Winer and Cottrell, chapter 5, this volume) found a decrease with age in participants' belief in something akin to the extramission theory of visual perception held by Plato, Euclid, and other ancient thinkers: namely, that there are emissions from the eye during the act of vision. For example, many children and a number of adults responded affirmatively to the question: "When people look at something or someone, do you think that rays or energy or something else go out from their eyes?" Similarly, Cottrell, Winer, and Smith (1996) report that many adults as well as children believe that one can sometimes feel the stares of an unseen other person. (Is "My ears are burning" the auditory counterpart?) Finally, there is evidence that blind children show an understandable delay in their grasp of basic level-1 conditions of seeing (Bigelow, 1991; Warren, 1994).

There have also been additional studies of level-2 understanding. In Flavell, Flavell, and colleagues, 1981, children 4½, 5, and 5½ years of age were tested for their knowledge of three spatial perspective-taking rules: (1) any object will appear the same to the self and to another person if both view it from the same position; (2) a heterogeneous-sided object (in this study, a tangle of wire) will

appear different to the two observers if they view it from different sides, and (3) a homogeneous-sided object (a cylinder) will appear the same to the two if they view it from different sides. The data suggested that knowledge of at least rules 1 and 2 undergoes development during this age period and that 5½-year-olds have a good grasp of all three rules. In Flavell, Flavell et al., 1980, children 3, 3½, and 4½ years of age were tested for a different form of level-2 knowledge about visual perception, namely, knowledge that one observer stationed closer to a small object will be able to see it better than a second observer stationed farther away on roughly the same line of sight, whereas the two observers will be able to see it equally well if stationed side by side at the same distance from it. The data suggested that this knowledge also undergoes considerable development during the preschool period, with many 4½-year-olds seemingly possessing it in the form of a general rule. Finally, Pillow and Flavell (1986) showed that 4-year-olds are more aware than 3-year-olds of how the apparent size and shape of an object changes with changes in its distance and orientation with respect to the observer (see also Granrud, chapter 3, this volume). This is further evidence for a developing attentiveness during the preschool years to the way things appear perceptually.

### *Attention*

In the sense that they come to understand that people show by their gaze direction and other actions that they are psychologically directed toward various objects and events in the world, infants clearly could be said to possess at least a rudimentary understanding of attention. Indeed, some developmentalists are inclined to credit infants with a quite rich understanding of attention (e.g., Baron-Cohen, 1993). We have also just seen that children begin with a more connections-like, whether-perceived-or-not, level-1 conception of perception and subsequently go on to develop a more representation-centered, how-it-is-perceived, level-2 conception.

There is evidence that children also go on to acquire other important insights about attention (Fabricius and Schwanenflugel, 1994; Flavell, Green, and Flavell, 1995; Miller, 1985; Parault and Schwanenflugel, 2000; Pillow, 1988, 1989a, 1995). First, attention is selective. We do not see or hear everything that is in our field of vision or in earshot; perceptibility does not guarantee perception. Even the things we perceive we may not devote much attention to, and therefore may not comprehend, reflect on, or remember. Second, attention entails constructive processing of what has been attended to. It involves a level 2–like interpretation and elaboration of the sensory input, rather than just a level 1–like internal registering or copying of it; as a consequence, one person’s cognitive representation of what has been perceived may differ from another person’s. Third, attentional capacity is limited. If we try to pay full attention to one thing we will not normally be very aware of other things in the perceptual field—unless the other things are very attention capturing (e.g., visually salient or loud), in which case attention to the first thing will suffer correspondingly.

To illustrate some of these developmental acquisitions, let us consider the following sample studies. When Miller and Bigi (1977) asked children to select objects to surround the target in a visual search task in order to make the search for the target, a red triangle, harder, they found that younger children simply add a lot of objects, regardless of their color or shape. By age 8 or 9, however, children begin to realize, in addition, that surrounding the target with objects identical to the target in shape and color (other red triangles of various sizes) makes the target blend into its background and not be seen immediately even though it is "right in front of his eyes." In a related investigation, Fabricius and colleagues (1997) asked third graders, fifth graders, and adults, "Can somebody look at something, but not see it?" The modal answers and answer justifications at the three age levels were: no, with no justification given (third graders); yes, because of a vision or lighting problem (fifth graders); yes, because attention was elsewhere (adults).

Flavell, Green, and Flavell (1995) tested children 4, 6, and 8 years of age for their understanding that a person who is mentally focused on one thing will devote little or no simultaneous attention or thought to another, totally irrelevant thing. For example, a person busy trying to recognize the people in a group photograph will not at the same time pay much attention to the frame around the photograph. Whereas most of the 6- and 8-year-olds demonstrated an understanding that task-oriented thought and attention are selectively focused in this way, most of the 4-year-olds showed no such understanding. These results are consistent with evidence obtained by Miller and Bigi (1979) and Pillow (1989a) with regard to auditory attention (see also Montgomery, Bach, and Moran, 1998). Flavell, Green, and Flavell (1995) speculated that 4-year-olds may implicitly conceive of the mind as more like a lamp than a flashlight, that is, as a device that can radiate attention and thought in all directions at once rather than in only one direction at a time.

Finally, experiments by Fabricius, Schwanenflugel, and colleagues (see Parault and Schwanenflugel, 2000) have shown some intriguing further developments in children's understanding of attention and other mental phenomena after the age of 8. As examples, older children seem to acquire a clearer distinction between attention and comprehension, a more abstract, supramodal conception of selective attention, and a more process-oriented, constructivist conception of the mind (cf. Pillow, 1995).

### *Knowledge*

Among studies testing young children's understanding of the importance of perceptual access in acquiring knowledge, some have found that even 3-year-olds tend to attribute knowledge of a box's contents to a person who looks inside the box rather than to one who just touches the box (Pillow, 1989b; Pratt and Bryant, 1990). Others, however, have found that young children have considerable difficulty in isolating perceptual access as a critical condition for knowledge (Perner

and Ogden, 1988; Ruffman and Olson, 1989; Wimmer, Hogrefe, and Perner, 1988). For example, Lyon (1993) found that 3-year-olds tend to attribute knowledge of a box's contents to a doll that does not look inside the box but moves toward it, in preference to one that looks inside but moves away from it. In both this and another study by Lyon (1993), 3-year-olds tend to attribute knowledge on the basis of something like desire or engagement rather than perceptual access, whereas 4-year-olds tend to do so on the basis of perceptual access alone. Similarly, Montgomery and Miller (1997) found that, unlike 5-year-olds, 3-year-olds believe that listeners will not know information they have clearly heard if the speaker did not want them hear it (see also Koerber and Flavell, 1998). It seems, then, that children of this age will sometimes wrongly deny knowledge to a person with perceptual access as well as wrongly attribute knowledge to a person without access. Such results support Taylor's conclusion (1996, p. 296; see also Montgomery, 1992, p. 423) that "the bulk of the evidence suggest 3-year-olds often do not know much about the relation between perceiving and knowing."

There is also considerable development during the preschool period in children's understanding of the conditions that provide a person with knowledge (O'Neill and Chong, 2001). To illustrate, in Gopnik and Graf, 1988, 3-, 4-, and 5-year-olds learned about the contents of a drawer in three different ways: by seeing them, by being told about them, or by inferring them from a clue. Later they were asked how they knew about the drawer's contents. The oldest subjects had little difficulty identifying the specific source of their knowledge, but the youngest were quite poor at this task. Consistent with this evidence, Aksu-Koc (1988, chap. 8) found that, among Turkish children, 4-year-olds are more aware than 3-year-olds of verb endings in Turkish that tell the listener how the speaker knows about an event, namely, by actually witnessing it (one verb ending) versus being told about it or inferring it (a different verb ending). This also suggests a developing sensitivity during the preschool period to sources of knowledge. O'Neill and Chong (2001, p. 803) have summed up the research findings on this issue as follows: "3-year-olds are somewhat able to identify the source of their beliefs, but in many cases their performance is substantially poorer than that of 4- or 5-year-olds." Taylor, Esbenson, and Bennett, 1994, found that young preschoolers are also often unclear about when as well as how they acquired a piece of knowledge. For instance, they tend to say that they have known for a long time both familiar, long-known information and new information that the experimenter just taught them.

In addition to learning about access and sources, children also need to learn about aspectuality—what senses yield what type of knowledge. A number of investigations have documented substantial developmental changes during the preschool and early elementary school years in children's understanding of the modality-specific nature of knowledge (O'Neill, Astington, and Flavell, 1992; O'Neill and Chong, 2001; Perner and Ruffman, 1995; Pillow, 1993; Rummel, 1999; Robinson et al., 1997; Weinberger and Bushnell, 1994). For example, O'Neill and

Chong (2001) presented 3- and 4-year-olds with five scenarios, each requiring a different sensory action to be performed in order to identify an object's property: in the case of a visual property, the action of looking inside a paper bag to determine whether a ball inside was red or green. The experimenter modeled a sensory action (e.g., looking) and then the children did it. The children were then asked (1) to tell how they found out the ball was red or green, (2) to show how they found out, and (3) to indicate which body part a doll would need to use to find out. The results were striking. Even though the 3-year-olds were asked about their own knowledge and very recent experiences, and could respond nonverbally, they were only correct about half the time, performing considerably worse than the 4-year-olds. Although 4-year-olds are better than 3-year-olds at identifying the correct modality on such tasks, they frequently overestimate the knowledge that can be obtained from seeing (Robinson et al., 1997).

As children develop, they gradually come to construe the mind as a selective, representational, and interpretive device rather than as one that just copies the objects and events presented to the senses. This allows them to recognize that visual and other perceptual information needs to be adequate as well as merely present. Children's understanding of the modality-specific nature of perceptual input (aspectuality), just discussed, is an early step in this direction. They also come to appreciate other ways in which the input may fail to engender a clear and correct interpretation in the perceiver (Carpendale and Chandler, 1996; Flavell and Miller, 1998; Miller, 2000; Montgomery, 1992; Robinson et al., 1997). One way is that the input may not contain enough information to allow a correct interpretation or, in some cases, any interpretation at all. For example, preschoolers are apt to think that a naive other person can tell that a picture contains a giraffe even if only a small, nondescript part of the giraffe is visible to the person. In contrast, older children are more likely to realize that, although a naive other person does indeed see the giraffe (there is visual access), the person simply does not see enough of it to be able to identify it as a giraffe (Chandler and Helm, 1984; Taylor, 1988; but see Gopnik and Rosati, 2001, Perner and Davies, 1991, and Ruffman, Olson, and Astington, 1991, for evidence that older preschoolers can manage some tasks of this type). There is a similar age trend with respect to understanding something like the opposite: a person may sometimes be able to infer information to which the person does not have direct visual access (Sodian and Wimmer, 1987). In addition, research by Lagattuta and colleagues (Lagattuta and Wellman, 2001; Lagattuta, Wellman, and Flavell, 1997) shows that even preschoolers may recognize that seeing something that was previously associated with a sad event can trigger memories and feelings associated with that event—but only in a person who has had that sad experience.

Children also learn that visual information can be not just insufficient but downright misleading. Hundreds of studies have shown that older children have a more secure and articulate understanding than younger ones of false belief, deception, and appearance-reality discrepancies (see the references cited in the



second paragraph of this chapter). Development in this area can be quite extended. For instance, Flavell, Green, and Flavell (1986) found that although 6- to 7-year-olds could easily manage the simple appearance-reality tasks that 3-year-olds fail (e.g., they could recognize that the experimenter's fake rock simultaneously looks like a rock and is really a sponge), their ability to reflect on and talk about visual appearances, realities, and appearance-reality relations remained very limited. In contrast, the appearance-reality knowledge of 11- to 12-year-olds and especially college students was richly structured and highly accessible. For instance, adult participants could identify and differentiate among realistic-looking nonfake objects, realistic-looking fake objects ("good fakes"), nonrealistic-looking fakes ("poor fakes"), and even fake-looking nonfakes. Doing this reflects the development of quite sophisticated knowledge about relations between visual input and cognitive response.

There is also a growing understanding of the cognitive effects of visual input that is inadequate by dint of being ambiguous rather than impoverished or misleading (Miller, 2000). Chandler and colleagues (see Carpendale and Chandler, 1996) found that not until they were 7 or 8 did children clearly understand that an ambiguous visual stimulus (a reversible figure) could be construed differently by different people (cf. Gopnik and Rosati, 2001). The same was true for lexical ambiguities (e.g., homophones) and ambiguous messages. A higher form of this understanding is needed to evaluate the evidence—often subtly ambiguous—for scientific and other knowledge claims. This kind of metacognition is useful when trying to judge how confident one should be that a given conclusion is warranted by a given complex body of evidence (Kuhn, 2001; Moshman, 1998).

Older children also discover that what gets known or believed depends on the perceiver as well as the quality of the available information. For example, they learn that people's preexisting biases or expectations may influence their interpretation of the perceptual evidence. In experiments by Pillow (1991) and Pillow and Weed (1995), child participants heard scenarios in which character A likes character C, but character B does not. C does something damaging, but with ambiguous intent—perhaps accidentally, perhaps on purpose. The participants' task was to predict A's and B's interpretation of C's action. Kindergarten and second-grade children were able to attribute the appropriate biased interpretations to A and B, whereas preschool children responded at chance. On the other hand, research by Ross and other social psychologists (e.g., Ross, Pronin, and Puccio, 2001; Ross and Ward, 1996) reminds us that the ability to attribute bias correctly both to others and, especially, to oneself is far from completely developed even in adults.

Eisbach (2001) tested 5-year-olds, 9-year-olds, and adults for their understanding that the same visual input can engender different trains of thought in different people, and even in the same person on different occasions. In one of her studies, two protagonists, A and B, saw the same depicted object (e.g., a strange-looking animal) and then had a succession of three thoughts, represented by

empty thought bubbles. The participants were asked: “Do you think that A and B are having exactly the same thoughts, or do you think that some of their thoughts are different?” Most 5-year-olds thought they would be the same because both A and B saw the same object, whereas most 9-year-olds and adults thought they would be different because A and B were different people, had different past experiences, and so on (or, as one 9-year-old put it, “because their brains aren’t the same, so they don’t think exactly alike”). Similar age differences in judgments and explanations were found when the same protagonist viewed the same object on different occasions, each time experiencing a succession of three thoughts. Somewhat similarly, Winer (1989) found that third graders and sixth graders were more aware than kindergartners of perceptual adaptation effects, for example, that the sun will seem brighter to the same person coming out of a movie theater than coming out of a house.

### *Conclusion*

It is obvious that there are many facts about vision that children and most adults do not acquire. Uncovering such facts is the task of the vision researcher. Moreover, some of the visual metacognition adults have acquired is inaccurate. For example, Levin, Scholl, and colleagues (see Scholl, Simons, and Levin, chapter 7, this volume) have shown that adults overestimate their ability to detect large between-view changes in scenes—a metacognitive shortcoming called “change blindness blindness.” Recall also Winer and colleagues’ data on extramission and unseen stares (see Winer and Cottrell, chapter 5, this volume; on adult shortcomings in other areas of metacognition, see also Diana and Reder, chapter 8; Keil, Rozenblit, and Mills, chapter 11; Rachlinski, chapter 12, all this volume; Gilovich and Savitsky, 1999; Ross, Pronin, and Puccio, 2001).

Nevertheless, this chapter documents a number of important truths about vision that children do acquire. One way to characterize development in this area is to say that children seem to acquire a succession of general rules plus a set of specific qualifications or restrictions on those rules. For example, they learn that people see things when their eyes are open (rule), but then need to learn that people do so only if their eyes are pointed in the right direction, if there is no intervening visual barrier, and if the things are not too small, too far away, too dimly lit, or too camouflaged (qualifications). Children learn that things look a certain way when they see them, but also that the things may present a different appearance to someone who sees them from a different vantage point. They learn that perceivers frequently acquire knowledge by looking at things, but also that for one reason or another perceiver A may not acquire knowledge of type B when looking at object C. They learn that seeing things triggers thoughts, but also that seeing them is apt to trigger different thoughts in different people. The usual case seems to be that, when they err, children err by overestimating the cognitive yield of a visual encounter. Thus they are apt to assume that, if one looks, one will

automatically see all, and if one sees, one will automatically know all. This seems to be a sensible, adaptive way for development to proceed: first learn the prototypical patterns, the ones that often or usually hold, and then tease out the exceptions. Cognitive and linguistic development often seems to proceed in this first-overshoot-then-correct fashion (cf. Jusczyk, 2002; Markman, 1992).

If one could further the development of visual metacognition beyond the usual, what dispositions or skills might one target? Here are my candidates:

1. Improve people's attentional strategies. Teach them when to skim and when to search thoroughly and reflect in depth on what they unearth.
2. Help them remember that appearances are often different from and better than the realities they conceal (think of advertising and packaging). A healthy skepticism can be very helpful in navigating through the world's visual enticements.
3. Encourage them, nevertheless, to cherish many visual appearances, in particular, to savor the beauty they see in art museums, theaters, and the world outside.
4. Make them aware of the important metacognitive shortcomings currently being identified by psychological research. Where feasible, also provide them with ways of reducing these shortcomings, or at least their negative effects. People not only need to develop metacognition; they also need to acquire accurate and useful knowledge about their metacognition.

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