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Inside the Minds of Infants

Looking into the eyes of a newborn can be a profound experience of awe and wonder. Infants are so small; they can not talk, or walk, or complete the simplest task for their own survival. Yet infants also look at us knowingly, as though they must be thinking something profound about their new world of, "blooming, buzzing, confusion (James, 1890, p. 462)." Are we attributing something greater to infants than is really there, just as we might believe a malfunctioning computer is angry?

We will examine how the science of Developmental Psychology informs us about what is going on inside the minds of infants. We will examine thoughts and feelings from birth – and occasionally beforehand – through the stage of infancy (from zero to about two years of age), and into toddlerhood, the third year of life. We begin by examining the basic cognitive processes of attention, memory, and learning. Through these basic processes we will see some of the techniques developmental psychologists have devised for studying infants' thinking. Next we consider infants' experience of sensations and their perceptions. Third, we explore infants' expression of emotion, understanding the emotions of others, and the beginnings of their own self-concepts. Finally, we examine how infants understand abstractions like language and mathematics.

Attention

The first step to learning anything, or doing anything, is paying attention. After all, paying attention in class, or as you read this chapter, is how you learn. In contrast, merely dialing or answering a cell phone while driving makes you four times more likely to have an accident; the lack of attention while texting makes your risks 10 times greater (Simmons et al., 2016). If infants are to grow into children, they must attend well.

As early as two months of age, infants share ***joint attention*** with others; they will follow the gaze of other people to potentially interesting objects. As infants get older, parents and older children respond to infants' joint attention by naming the object (Callanan & Sabbagh, 2004). Vocabulary is only part of what 12 month olds learn. At this age, infants also engage in ***social referencing***, they interpret others' feelings about those objects. For example, when parents looked at a toy with happiness, their 12-month-old infants approached it. But when parents looked at the same toy with fear, infants avoided it (Repacholi, 1998). Similarly, when parents looked at one of two toys with disgust, 12-months-olds chose to play with the other toy (Moses et al., 2001).

In a revolutionary study that set the stage for the modern scientific research of infancy, Robert Fantz (1961) watched precisely when infants attended to get inside their minds. Babies would lie comfortably on their backs at the bottom of a "box" while looking up at a ball-shaped light fixture. An experimenter stood upon a stool so that he or she could look down at the infant through a peephole and observe how long the infant looked at the light. Sometimes two- to three-month-old infants were only shown the light fixture, or the light fixture painted a particular color. Infants attended to the light, but not for very long. Sometimes infants were shown a pattern, like concentric circles or words. Infants attended twice as long to these, suggesting that complexity interests them. Finally, when they were shown a painted face on the light fixture, they looked at it four times as long as the simple, blank light fixture. Very young infants prefer to look at faces, not only because people are complex, but also because older people have so much to teach.

Fantz's method of measuring how long infants look has been substantially refined over the decades. Now, infants typically sit in a car seat. Rather than using a peephole, a video camera is often placed behind the stimuli so an experimenter in another room can press buttons indicating when infants look. Perhaps the biggest advance is that the stimuli may be presented on a large computer screen. This allows different stimuli to be presented on the left and right. Experimenters do not only note how long infants look, but which side they prefer. This is called ***forced preferential looking***, and in forthcoming sections we will see how much we can learn about infants using this simple method, our knowledge of infants' memory, and some scientific creativity.

Memory

Think about your earliest memory. The vast majority of people cannot remember anything that occurred before they were three years of age, and practically no adult has a memory from before two years of age. You might think this ***infantile amnesia*** means we do not form memories as infants. We do. But brain development and how we start thinking in words around two years of age, means we lose the ability to retrieve those early memories (Madsen & Kim, 2016). But if infants cannot tell us what they remember with words, how can we observe their memories?

Carolyn Rovee-Collier and colleagues (1985) designed an ingenious experiment to observe infants' ***long-term memory***. A mobile hangs overhead as an infant lies in a crib. A string is attached from one of the infant's legs to the mobile. As time goes by, infants fidget and if only by accident discover that they can shake their leg to move the mobile. As early as one to two months of age, infants express delight when they discover that they can cause events to happen (Lewis, Alessandri, & Sullivan, 1990). Now that infants have learned that they can cause the mobile to move, we can see what happens when they return to the laboratory at a later date. If they take as long as before to discover their ability to move the mobile, we have no evidence of a memory. But if the infant immediately starts shaking their leg, we infer that they have a memory of this. Eight-month-old infants can remember the mobile up to two weeks after their first visit if everything is set up in precisely the same way (i.e., same mobile, crib, leg attached to string) (Rovee-Collier et al., 1985). Infants from one to two months of age can remember the mobile one to two months later. Infant memory continues to improve in both how much time can pass and how different or elaborate the situation can be. For example, 18-month-olds who learn that they can push a lever to move a train remember this relationship more than a year later (Rovee-Collier, 1999).

In addition to memory over the long-term, infants need to work with information in the short-term, and this ***short-term memory*** (or ***working memory***) develops gradually over infancy just like long-term memory (Grobman, 2004). For example, if an infant watches a toy "hidden" in one of several wells (little holes within reach), can they immediately search for the toy in that location? Seven-month-olds can retrieve a toy from one of two wells if allowed to search within two seconds of hiding the toy. By 24 months of age, infants can find the toy in one of four wells with a delay of 10 seconds (Diamond, 1995). Another design elicits imitation from infants. For example, an infant might watch an experimenter put clay in an extruder and squeeze out "spaghetti." Presented with the same materials, can infants imitate all the steps in the same order? As early as nine months of age, infants can imitate a single step, 11- to 16-month-olds can imitate two steps, and 20-month-olds can imitate four steps correctly (e.g., Meltzoff, 1988; Bauer et al., 1999). Since faces attract infants' attention, they are the first things infants can imitate. At only two to three weeks of age, infants will imitate an adult who keeps doing the same thing with his or her face (e.g., tongue protrusions, moving mouth like a fish) (Meltzoff &

Moore, 1977). When newborns imitate others, they illustrate that they can make an association between someone else's face and their own.

Learning Associations

Infants are born with an ability to make associations and find patterns. This is not surprising within Psychology because it is well established that many animals can learn with associations. Among the most famous examples is Pavlov's dogs, who repeatedly heard a bell ring just before receiving food. Food naturally makes animals salivate, and after several repetitions of bells with food, the dogs would salivate to the bell, without any food (Pavlov, 1927). The process by which Pavlov's dogs reacted to an association between two things in the environment is called ***classical conditioning***. We might also learn by ***operant conditioning***, seeing how what we do causes something to happen in the environment. Infants might notice that when they smile, their parents have a big reaction. Another example is Rovee-Collier's aforementioned experiment where infants learned to shake their leg to cause a mobile to move.

Operant conditions can be a surprisingly powerful method for helping us understand the minds of infants. For example, we might wonder whether infants already know their mother's voice when they are born because they heard it in utero. To find out, DeCasper & Fifer (1980) recorded mothers reading Dr. Seuss's first children's book, "And to Think I Saw it on Mulberry Street." Newborn infants were given a specially designed pacifier to suck on that measured their rate of sucking. Once they established an infant's base-rate for sucking, they connected the pacifier to audio recordings of their mother and another women reading the book. If they sucked faster, they heard one reader and if they sucked slower they heard the other reader. Whether they heard their mom with faster or slower sucking, they adjusted their sucking rate to hear their mom more. Amazingly, using operant conditioning, we now know that infants have a preference for their mother's voice at birth.

Habituation

Combining attention, memory, and learning together provides Developmental Psychology with an especially powerful method for studying infants – ***habituation***. Suppose infants lie in cribs and you shake a blue rattle above their heads. It draws their attention and they look. Shake it again and they look again. But each time you shake the rattle, infants pay less and less attention, because they now have a memory of it; they habituated. Now you shake an identical rattle that is red instead. Suddenly they perk up and look longer; they ***dishabituated***. We now know infants can see the difference between red and blue. After all, if they did not see colors, the rattle color change would not be an unexpected event and they would have stayed habituated. We can ask even more complex questions with the habituation method.

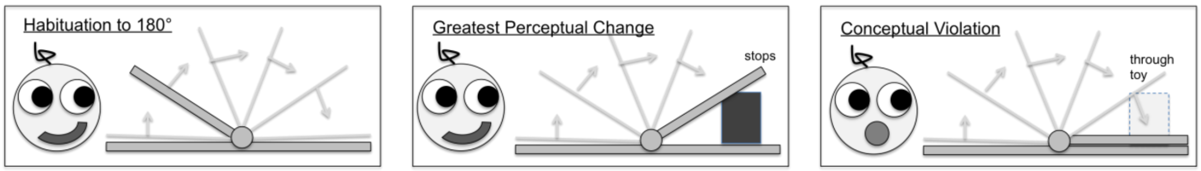
We see colors categorically, like the bands of a rainbow, even though colors are wavelengths of light along a continuum. For example, we see wavelengths of 475 *nm* as blue, and we see wavelength of 525 *nm* (50 *nm* larger) as green, but we see wavelengths of 425 *nm* (50 *nm* smaller) as still blue. In a study of four-month-old babies, infants saw color patches of 475 nm (blue) over and over again for several trials (Bornstein, Kessen, & Weiskopf, 1976). Then they alternately saw color patches of 425 *nm* and 525 *nm*. The infants dishabituated to 525 *nm* (green) but stayed habituated for 425 *nm* (blue). Now we know that four-month-olds see colors in the same categorical way as we do.

Perhaps the most revolutionary example of habituation involves a challenge to Jean Piaget's (1954) meticulous account of development through infancy. He suggested that young infants only know about objects they're seeing, and the moment an object is not visible, it seemingly no longer exists. He designed an ***object permanence*** task where infants would play with a toy and then an experimenter would put the toy under a cloth right in front of them. All an infant would need to do is lift the cloth to continue playing with the toy, but seven-month-olds would not. Only infants a month or two older would retrieve their toy. Baillargeon (1987) thought younger infants might have object permanence, but that Piaget expected too much of them; he asked infants to keep in mind a goal (i.e., the toy), and to use of a strategy to retrieve the toy (i.e., lifting the cloth). She designed an ingenious use of habituation to tap the conceptual understanding of infants.

Four-month-old infants watched a drawbridge move through a 180° arc over and over again. They habituated. Next, a toy was placed in the path of the drawbridge on the far end from the baby. Now the drawbridge came up and either completed the full 180° arc or stopped sooner (Figure 1). Which would be more surprising to see? Probably you would wonder how the drawbridge continued through 180° arc with a toy in the way; that is because you have object permanence. By four and a half months of age, infants are just as surprised as us, suggesting that they share our understanding that objects we cannot see continue to exist (Baillargeon, 1987). By the way, there was a trap door in the table, so while you could not see the toy, it was surreptitiously removed.

We have explored the basic cognitive processes during infancy. Developmental psychology has invented several methods to study infancy scientifically that use these basic processes. We now examine some of many psychological topics studied in infants.

Figure 1. Baillargeon (1987) Object Permanence Study



Sensation

All five basic senses are present from birth. Taste, smell, and touch, are quite well developed, while hearing and vision develop into toddlerhood. It was once widely believed that young infants could not experience pain, which may seem odd as infants show signs of distress following injections or circumcision, and they may have disturbances to their sleep for several days afterward (Emde et al. 1976). Newborns clearly experience pain (Buchholz et al., 1998). Indeed, their sense of touch is so well developed that even tiny puffs of air to various parts of their bodies is enough to increase their heart rates (Bell & Costello, 1964; Rose et al., 1976). Similarly, even newborns notice the difference between salty, sour, bitter, and sweet tastes (Rosenstein & Oster, 1997). They prefer sweet tastes (Steiner et al., 2001), and if their mothers consume vanilla, they will nurse more afterward (Mennella & Beuachamp, 1996).

Newborns like many of the smells adults find pleasing (e.g., honey, chocolate), and they recoil from smells we find unpleasant (e.g., rotten eggs) (Mennella & Beauchamp, 1997). Newborns do have their own preferences; they especially like the smell of breast milk (Marlier & Schall, 2005), and prefer their own mothers' scent to that of other new mothers (MacFarlane, 1975; Porter, Makin, Davis, & Christensen, 1992). Some infant smell preferences precede birth, and mothers can make choices that shape their babies' preferences. In one study, pregnant women were randomly assigned to a Mediterranean diet, where flavoring with the herb anise is common. Compared with infants whose mothers had different diets, these newborns preferred the smell of anise right after birth, and again four days later (Schaal et al., 2000).

Though infants are not born with a fully developed ability to hear, they begin hearing a month or two before birth. They recognize their mother's voice at birth (Lecanuet et al., 1995). Two-day-old babies prefer their mother's voice to another woman's, even if they only hear her speak a single syllable (Fifer, 1987). Like adults, newborns and young infants hear the sound frequencies typical of human speech (250 *Hz* to 6000 *Hz*) most clearly. However, their ***auditory threshold***, the softest volume of sound they can hear, is louder than adults'. One-month-old infants can hear sounds at 40 *dB* to 55 *dB*, like a babbling brook or light traffic. Their hearing rapidly improves so that by six to twelve months of age they can hear sounds at 10 *dB* to 30 *dB,* like a pin dropping, leaves rustling, or people whispering (Olsho et al., 1988; Trehub et al., 1980).[1] Their auditory threshold continues to improve so that by two years of age their auditory sense is fully developed (Moore & Linthicum, 2007).

The building blocks of vision are present at birth, but take years to fully develop. Within minutes of birth, infants start scanning the room, and whenever their eyes land upon an object (including a person), they stop to focus (Haith, 1980). Newborns see only a small amount of color, but by three- to four-months of age, infants perceive color the same way as adults (Kellman & Banks, 1998). ***Visual acuity***, the ability to see details, takes longer to fully develop. Visual acuity is what your doctor is measuring when you read letters on a chart from across the

[1] By definition the typical healthy young adult has an auditory threshold of 0 *dB*. Examples of decibel levels are from a public database of common environmental sounds provided by the Australian government's National Acoustic Laboratory: https://noisedb.nal.gov.au/

room. Of course, we can not ask babies to read letters, nor can we use the “small child” version, in which we ask children to show the orientation of a figure with their hands. Instead, an experimenter holds up a gray rectangular card in front of a baby. There is a small peephole in the center and the experimenter looks through it to see which way the baby looks. Then the experimenter looks at the card to see whether the infant looked at the all-gray side or the side with black-and-white stripes (Figure 2). Recall from Fantz’s box that babies will be more interested in the striped side than the plain gray side, because the stripes are more complex. The first Teller (1979) Visual Acuity card has very thick stripes, but the stripes on subsequent cards get thinner and thinner, so much so that even adults have trouble seeing them. Try it for yourself. Prop this book up and look at Figure 2 from further and further away. At some point you will not be able to see the gray side as different from the striped side. When infants cannot see this detail, they look aimlessly or blankly straight ahead. Using this forced preferential looking procedure, we can estimate that newborn infants have 20/800 vision. That is, they see from 20 *feet* away what the typical healthy adult can see from 800 *feet* away. Their vision is quite blurry! Infants’ vision rapidly improves to 20/200 by three-months of age and then to 20/100 by six-months of age. It gradually improves to typical healthy adult vision (20/20) by about three years of age (Kellman & Arterberry, 1998).

Figure 2. Visual Acuity Cards

Perception

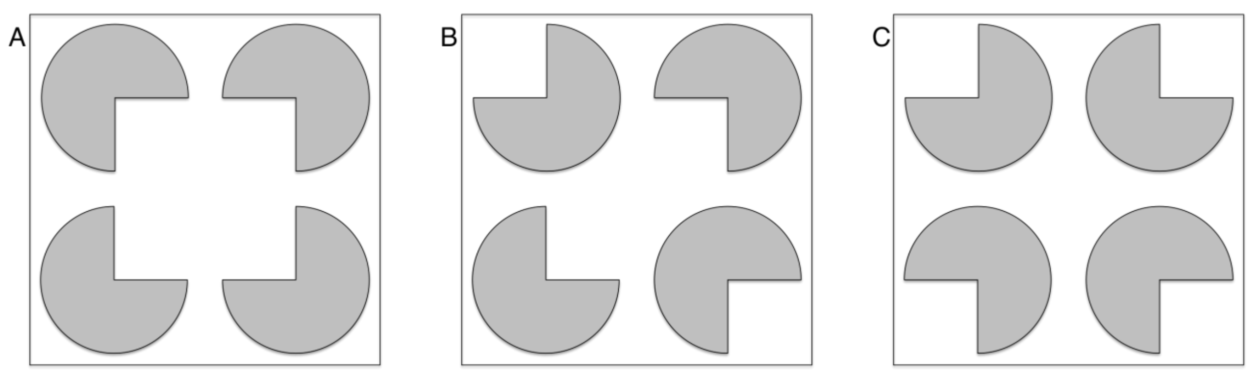
Sensation, the basic information from our senses, is not the same as our ***perception***, how we interpret what we sense. To illustrate, what do you see in image A of Figure 3? Almost everyone sees a square in this famous Kanizsa square illusion. But there is not really a square there. You are interpreting the picture with the Gestalt principle of closure: when disconnected shapes line up, we can't help but close the line. In contrast, you probably do not see a shape in the middle of image B or C of Figure 3. Do infants share our interpretation? When 7-month-olds are habituated to (become bored with) seeing image A, they dishabituate (are very surprised) to see image C, even though it's the very same four ¾ circles in nearly the same configuration. In contrast, when 7-month-olds are habituated to image B, they are not nearly as surprised when presented with image C (Bertenthal et al., 1980). The same study with five-month-olds shows no recognition of Gestalt patterns.

Recognizing motion is a fundamental aspect of perception. By three months of age, an infant can recognize a figure moving about in a pitch-black room with only tiny lights attached to their joints, as a person. By five-months of age, they can recognize the lights as a person with hardly any movement (Bertenthal et al., 1984). Infants have much more difficulty recognizing ***optic flow***, the change of their visual field as they move (e.g., the way everything zooms in as you move forward when playing a first-person video game, or how you see your direction changing when looking out the window of moving car). Whereas adults can detect a fraction of a degree change in their own direction, three-month-olds need the change to be almost 90° (e.g., going straight ahead to a sharp turn), and five-months olds only notice changes of about 22° (Gilmore et al., 2004). Really understanding changes in direction seems to begin just as infants begin self-produced locomotion (e.g., crawling) (Shirai & Imura, 2014).

One of the best-known studies in developmental psychology tied together infants' self-produced locomotion and depth perception. Eleanor Gibson and Richard Walk (1960) put newly crawling infants on the edge of a three foot drop, while their parent coaxed them to crawl over the cliff to join them three feet away. The drop was made obvious with a checkerboard pattern. In case you worried, the cliff was actually only a ***visual cliff*** because the whole path was covered with glass. Infants who had just begun crawling would readily crawl over the cliff, whereas those with a month or two of crawling experience would refuse, showing fear. This suggests that perceiving depth requires experience with moving oneself around.

Thus far we have seen basic processes like attention, memory, and perception inside the minds of infants. To study these topics, infancy researchers implicitly rely on infants' likes (e.g., novel or complex things to look at) and dislikes (e.g., fear of going over a cliff). But emotions are a fascinating part of infant development in their own right.

Figure 3. Gestalt & Non-Gestalt images like stimuli in Bertenthal et al. (1980)



Expression of Emotion

Emotions are present from birth. Among the great joys of new parents is seeing their infant smile. By three- to eight weeks of age, infants smile in reaction to all sorts of stimuli, from gentle touching, to faces and high-pitched voices (Sroufe & Waters, 1976). By six to seven weeks some infants direct their smiles at particular people (White, 1985), especially those familiar to them (Weinberg & Tronick, 1994), and most infants show such social smiles by 10 to 12 weeks of age (Haviland & Lelwica, 1987). Infants also have negative emotions from birth, though it is unclear if newborns differentiate sadness, anger, and fear. Anger is first clearly apparent around four to six months of age, when angry expressions appear on the faces of infants who have a favorite food taken away (Sternberg & Campos, 1990). About a month or so later, infant facial expressions match the events around them, such as smiles to mom and frowns from rough handling (Izard et al, 1995; Weinberg & Tronick, 1994).

Among the biggest challenges people of all ages face with self-expression is ***emotion regulation***. Sometimes you might be very angry because of an unfair teacher, but showing that anger would not be in your best interest. Sometimes you might be scared to try something new, but know it's best to hold down your fear and do it anyway. When do these abilities to regulate our emotions begin? In one study, 6-, 12-, and 18-month-olds were left with a stranger. The most basic kinds of emotion regulation, such as looking away or rubbing their clothes to self-soother appear at six-months of age. By 18 months of age, some infants attempted to engage with the stranger (Mangelsdorf et al., 1995). As infants transition to toddlerhood, they can handle even more stressful circumstances. Imagine you just turned two years old and you meet an experimenter with a plateful of raisins and crackers. She eats some while saying, "Mmm, that tastes good. These are for later. I need to do something outside. I'm going to put them away for a little while and when I get back, you can have them." She puts them well out of reach on a shelf and leaves you alone. What would you do? At this age, children use multiple emotion regulation strategies like distracting themselves with toys in the room or physical self-soothing such as hair-twisting (Grolnick et al.,1996).

Emerging emotion regulation abilities will help young children with ***delay-of-gratification*** as they get older. These tasks are essentially the same as the raisins and crackers just described; instead of placing them on a shelf, put them right in front of the child and ask them to wait in order to get a prize. The better children have developed emotion regulation strategies, the longer they can delay eating. By four years of age, individual differences in children's ability to regulate emotions become stable. This ability began years earlier as 18-month-olds who regulated their emotions better when left alone in a room become five-year-olds who are better at delay-of-gratification tasks (Sethi et al., 2000). This individual difference predicts success for years to come. It predicts social skills with peers, self-esteem, and even SAT scores (Mischel et al., 1989).

Cultures have different expectations about appropriate emotional expression, and children internalize these norms. For example, consistent with adult ideas about how, "boys don't cry," by two years of age we see boys attempt to conceal their fear and pain more than girls do (Lewis & Michalson, 1985). Though Americans have some rules about who can display emotion when (e.g., boys should not show fear, girls should not show anger), generally, individualistic cultures like America encourage emotion expression. In contrast, more communal-oriented cultures, like China, encourage emotional restraint. As such, by 11 months of age, we already find American infants crying and smiling more than Chinese infants (Camras et al., 1998).

Understanding Emotion

Expressing emotions is only half of emotional development, the other half is how infants understand emotion. These processes are related as families who are more emotionally expressive have infants who more quickly come to understand emotions (McClure, 2000). During the early weeks of infancy, children develop the ability to recognize emotions. When mothers show dramatic happiness on their faces and speak with a very happy tone toward their 10-week-old infants, the infants respond positively. On the other hand, when the mothers use dramatically sad or angry faces with matching vocal tones, the infants respond negatively (Haviland & Lelwica, 1987). By four to six months of age, infants distinguish facial expressions of emotion even without movement or vocalization. For example, in one study infants were habituated to a series of full color photographs of many different women expressing the same emotion (e.g., surprise); they dishabituated when a women's face showed a different emotion (e.g., fear) (Serrano, Iglesias, & Loaches, 1992). Around seven months of age, infants start matching facial expressions to tone of voice. In a study using forced-preferential looking, infants heard a voice speaking with a distinctly happy, bubbly tone, and saw two faces on a screen in front of them. When hearing the bubbly voice, they looked at the happy face; when hearing a sad, somber voice, they looked at the sad face (Walker-Andrews & Dickson, 1997).

In contrast with the near full development of recognizing emotions during infancy, the ability to predict emotions does not even begin until the end of infancy, and is much more an achievement of preschoolers. For example, Borke (1971) gave three- to eight-year-old children drawings of four faces: happy, sad, afraid, and angry. She read them simple stories and asked them to point to the emotion a child character was feeling. If a character was eating a favorite snack, even three year olds correctly chose the happy face. But if a character was lost alone in the woods, it took closer to four years of age to choose the scared face.

A fun experimental design shows that 18-month-olds can make some limited predictions based on emotion. Imagine you are a small child sitting in front an experimenter who has two plates of food. One plate has goldfish crackers. The experimenter picks one up and eats it, having a big reaction of disgust, "Eww, crackers!" Then the experimenter eats some raw broccoli from the other plate showing great joy, "Mmm, broccoli!" The experimenter asks you to, "give me some." Which plate do you give the experimenter? By 18 months of age, infants give broccoli, but 14 month olds do not (Repacholi & Gopnik, 1997). In fact, in a similar experiment using habituation, 14 month olds were no more surprised to see a person take food from a cup they expressed disgust about, than one from which they expressed happiness about (Vaish & Woodward, 2010). By 18-months of age, infants are recognizing that others might be made happy by things that disappoint them. Similarly, self-conscious emotions like pride, guilt, and embarrassment emerge around 18- to 24-months of age (Lewis, 2000). The confluence of self versus other distinctions, and self-conscious emotions suggests this may be about the age infants develop their own self-concepts.

Self-Concept

Who are you? Understanding who we are is a complex process that takes decades for us to develop. For example, even teenagers give distinctly different answers to the, "who are you?" question than adults. Young children give distinctly different answers from teenagers. For example, based on many interviews with children across many ages, Susan Harter (1999, p. 37) provided the following prototypical answer of a three-year-old:

> I'm almost 3 years old and I live in a big house with my mother and father and brother and sister. I have blue eyes and a kitty that is orange and a television in my own room. I know all my ABC's, listen: A, B, C, D, E, F, G, H, J, L, K, O, P, Q, R, X, Y, Z. I like pizza ... I can climb to the top of the jungle gym. I'm not scared! I'm never scared! I'm always happy. I have brown hair and I go to preschool. I'm really strong. I can lift this chair, watch me!

Since infants only begin to speak toward the end of infancy, we need a more creative method than simply asking, "who are you?" to explore the origins of self-concept at this age. Among the most famous and creative experimental designs for studying infancy is the ***rouge task***. In a typical study, a parent sneaks some rouge (i.e., blush) onto their child's nose while hugging their child or cleaning their face, creating a red splotch. The child is then shown a mirror. Young infants touch the baby in the mirror, seemingly trying to touch the red splotch; between 18- and 20-months of age, infants touch their own noses to touch the splotch (Lewis & Brooks-Gunn, 1979). We find this milestone even in cultures like those in the desolate deserts of Israel, where infants have never seen mirrors and have rarely seen reflective surfaces (Priel & deSchonen, 1986).

Soon after showing self-recognition in a mirror, between 20- to 25-months of age, about 63% of children can pick out photographs of themselves from photographs of other children of the same age and gender (Bullock & Lutkenhaus, 1990). The same pattern can be found with entirely different tasks. For example, 16-month-olds were given a toy cart to play with. Naturally they would like to push it, but it would not budge. Why? The cart had a mat attached that infants naturally stepped upon as they tried to push. By about 21-months of age, infants were self-aware enough to avoid standing on the mat so that they could push the cart (Moore et al., 2007). During the second year of life, still well before giving full answers to the "who are you" question, children increasingly use their own names and refer to themselves with pronouns like, "I," "me," and "us" (Bates, 1990).

Understanding Language

It may seem like an almost impossible task to enter the world without any language and somehow be speaking by two years of age. Despite how startling the achievement seems, it's the routine trajectory of infants into toddlerhood. What do adults do to make learning language easier for infants, and how are infants able to make sense of the words they hear? Imagine you were speaking to a baby; how would you speak differently than to an adult? You would probably make your voice a higher pitch, speak more slowly, make shorter statements, emphasize vowels, and exaggerate your ***prosody*** (rhythm) to create a singsong style. When developmental psychologist began studying this style of talking, we called it, "motherese" (Newport et al., 1977). But since fathers (Niwano & Sugai, 2003) and even preschoolers (Weppelman et al., 2003) use it when talking to babies, we now call it, "***infant-directed speech***." Western cultures tend to use infant-directed speech more, with Americans being on the high end (Fernald, 1989), though non-Western Lebanese culture uses even more infant-directed speech than American culture (Farran et al., 2016).

Cultures vary widely in which elements of infant-directed speech they use (Ervin-Tripp & Strage, 1985), but even in cultures that use almost no infant-directed speech, adults can clearly differentiate foreign speech intended for adults versus children (Bryant et al., 2012). This cross-cultural universality suggests that infant-directed speech may be innate. It clearly helps infants learn language (Spinelli et al., 2017). Infant-directed speech draws infants' attention (Kaplan et al., 1995), helps them hear vowel sounds more clearly (Kuhl et al., 1997), and parse out new words in sentences (Golinkoff et al., 1996). Infant-directed speech is so natural, your foreign language teacher may start speaking this way to you. Though it may seem silly to treat you like a baby, it actually helps adults acquire a new language in much the same way it helps babies (Golinkoff & Alioto, 1995). In addition to cross-cultural differences, we see individual differences within language communities; the infants of mothers who speak especially clearly are better at learning the basic sounds of their language (Liu et al., 2003).

The most basic building blocks of language are ***phonemes***, the sounds that make the meaningful differences in words. In the first month of life, infants distinguish some vowel phonemes like hearing the /e/ in "bed" (Aslin et al., 1998a). Within the first few months of life, infants hear the distinctions between phonemes like /pa/ in "pad," /ba/ in "bad," and /da/ in "dad" even though technical sound analysis shows they vary along continua (Eimas et al., 1971). Those are amazingly subtle distinctions young infants can make. Even more incredible, across all human languages there are several hundred different phonemes, and young infants can distinguish them all. But you can't! Each language only uses a small portion; for example, English has about 40 phonemes.[2] By the time you reached about 12-months of age, you honed in

[2] Counting phonemes is difficult because of different precise definitions of phonemes and different variations in the same language. Estimates provided are from the PHOIBLE cross-linguistic phonological inventory database sponsored by the Max Planck Institute for Evolutionary Anthropology, available at: http://phoible.org

on the phonemes used in your native language, and lost the ability to discriminate those used in other languages (Werker & Tess, 1984).

Have you ever listened to people speak a language you do not know? It sounds like one continuous stream of sounds without any clear pauses for words. In fact, you speak the same way in your native language; you are just too familiar with the words in your language to realize that technical sound analysis shows that we can not use the pauses in speech to distinguish words. Amazingly, 7 ½ month olds can distinguish familiar words (Jusczyk & Aslin, 1995), and this ability to segment speech rapidly improves from 15- to 24-months of age (Swingley & Aslin, 2000). Infants' remarkable ability to segment speech into words is a consequence of three converging influences: the seemingly innate ability to recognize phonemes; adults' contribution, because infant-directed speech helps (Trainor & Desjardins, 2002); and the implicit ability to learn associations discussed earlier.

The implicit ability to find statistical patterns by infants is remarkable, and they use this ability to learn words. Making the statistical patterns explicit is complex, but let's try. Infants hear many familiar words over and over in simple sentences: "Mom loves you. Dad loves you. Mom and dad love you. You are mom's and dad's love." Of course, infants do not hear it like you see it here. They hear:

momlovesyoudadlovesyoumomanddadloveyouyouaremomsanddadslove

Notice that certain patterns of phonemes happen over and over, for example /mo/ often precedes /m/. That suggests "mo + m" makes a meaningful unit (like "mom" is). But notice that /m/ precedes /l/ just once, and that suggests it's a break between meaningful units (like the space in "mom loves" is). Could infants actually be using these statistical patterns? Developmental psychology researchers made up a language with "words" of 3 phonemes that were repeatedly presented to infants in different orders as "sentences." After just 3 minutes of listening to this made-up language, eight-month olds treated the made-up "words" as words (Aslin et al., 1998b; Saffran et al., 1996)!

Producing Language

It is much more obvious to observe how infants produce language than understand it, though it is no less dramatic a change to watch. By two-months of age infants begin ***cooing*** long continuous vowel sounds like, "oooooo" and "ahhhhhhh." By six-months of age, infants start combining a single consonant sound with the vowel coo to create single-syllable utterances like, "gah." Over the next several months infants combine more consonant and vowel sounds into more complex patterns that we call ***babbling*** (Hoff, 2005). Though babbling is not the same as producing words, infants' babbles are not random. Babies' babbling resembles their language, suggesting that they are imitating those around them. They tend to produce phonemes from their language (Locke, 1983). Moreover, the prosody (rhythms and intonations) of the babble of 8- to 11-month-olds matches the way their language is spoken (Davis et al, 2000; Levitt & Utman, 1992). For example, in English, pitch rises at the beginning of a sentence and falls as the sentence ends. The prosody is so distinct it does not require specialized equipment to detect. In one study, French parents could sort French and Cantonese babies from only audio recordings of eight-month-old babbling (Boysson-Bardies, Sagart, & Durant, 1984).

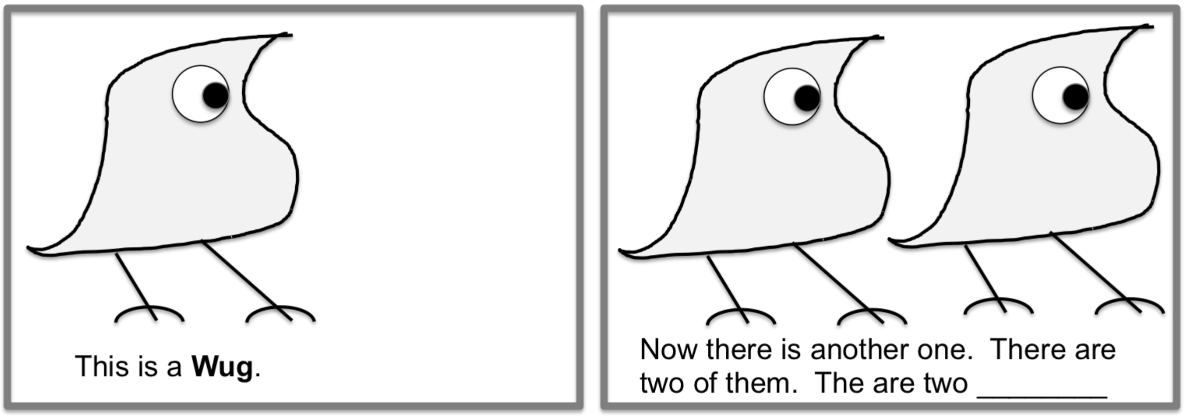
Among the milestones new parents look forward to is their baby's first word. Though the first word is usually spoken between 10 to 12 months of age, anywhere from 8 to 18 months is considered typical (Bates et al., 1992). In a cross-cultural comparison, infants' first words were usually common concrete nouns or persons; the two most common words are for “mom” and “dad” (Tardif et al., 2008). Infants’ first words are often those said frequently by their parents (Hart, 1991). As a consequence, when cultures differ in how they speak to their infants, the infants’ first words differ. Compared with Americans, Germans have a much more directive parenting style. Germans have infants who learn to say “no” younger (Shatz, 1991). On a lighter note, Italian infants’ early words include many kinds of pasta (Tomasello & Mervis, 1994).

Just after infants speak their first word, language development continues slowly and then speeds up. Infants take about three to four months to learn their first 10 to 30 words (de Villiers & de Villiers, 1999). By 18 months of age, infants can typically produce 50 words and understand 100. Then something dramatic happens – the ***language explosion***. By two years of age infants can produce 200 words and understand 900 words (Benedict, 1979). Starting around 18 months of age, infants add 10 or more words to their vocabulary each week (Fenson et al., 1994). Parents who talk more with their infants and toddlers have children who build their vocabularies more quickly (Huttenlocher et al., 1991).

To fully understand infants’ language development we need to go beyond considering words in isolation. How are infants’ words connected to the ideas they would like to communicate, and how are words connected to each other? Children’s very first sentences are ***telegraphic speech***, where every word is essential to conveying meaning. At first, infants’ telegraphic speech is limited to single word utterances during the ***holophrastic period***. For example, “milk,” might mean, “would you please give me a bottle of milk (Hoff, 2005)?” Gradually infants combine words in a simple grammar to convey meaning such as, “give cookie (Brown, 1973).” Telegraphic speech development is a cross-cultural universal (Brown & Fraser, 1963; Tager-Flusberg, 1993), but once infants combine multiple words we see the role of culture. Specifically, different languages have different grammars and children's telegraphic speech matches their language. English-speaking children say things like "give cookie" but Japanese and Turkish children say, "cookie give" (Bloom, 1970).

Though infants begin to appreciate grammar, it will not be until toddlerhood that they readily apply it. If an experimenter uses a simple sentence like, "this is a zav," a two-year-old will map this made-up word "zav" onto a novel object the experimenter presented (Katz et al., 1974). More complex mappings take until three to four years of age. If two similar objects are presented that differ in features like color or texture, two year olds will not realize that, "this is zavish," maps onto one of those qualities, but three to four year-olds will (Hall et al., 1993). Similarly, it's only between three to four years of age when children understand that "this is sibbing" is referring to an action that a character is doing (Brown, 1957). One of the most famous early studies of grammar presented two- to four-year-old children with the ***Wug Test*** (Figure 4). Shown the images, children are asked to complete the sentence with a grammatical change for a made-up word. They might be told, "This is a Wug. Now there is another one. There are two of them. There are two _____." By four years of age, children say "wugs" illustrating they know a grammatical rule to put "s" on the end to make a noun plural. They similarly apply their language's rules to other grammar structures like past tense and possessive (Berko, 1958).

Figure 4. Adaptation of the Wug Test by Berko (1958)



Mathematics

Mathematics is among the most fundamental abstractions people use in everyday life. Like language, we find the roots of mathematical abilities in early infancy, and their gradual development into a genuine abstract ability during toddlerhood. Let's examine how infants come to understand numbers as real things, how some numbers are bigger than others, and ultimately see how toddlers learn to count.

You might have two apples, two rattles, and two books. Though apples, rattles, and books are totally distinct things, your possessions share in common "two-ness." Do infants recognize this numerical equality? A habituation study might show infants two apples, two rattles, two books and so forth until the infant is bored with pairs. We could then show three objects. If the infants dishabituate, we infer that they abstracted the idea of "two-ness." Around five months of age, infants show that they understand numerical equality for one, two, or three objects, but not more (Starkey et al, 1990; Van Loosbroek & Smitsman, 1990). By six months of age they recognize numerical equality with larger quantities if the change is large. For example, they notice that 8 dots are a different amount than 16 dots, but they do not see 12 dots as different from 8 (Brannon, 2002; Lipton & Spelke, 2003).

Noticing quantities is a stepping-stone to understanding the relationships between quantities. Infants as young as four months of age, who are habituated to an increasing sequence, dishabituate when the pattern changes. This understanding of relationships between quantities is limited; four month olds do not show the same pattern for decreasing sequences (Cassia et al, 2012). By 10 months of age infants appreciate the greater than and less than relationships for small quantities. If an experimenter put two crackers in one container and three in another, 10 month olds typically reach for the container with more crackers (Feigenson et al., 2002)

One of the most startling habituation studies suggests that 5 months olds may even implicitly perform simple addition (Wynn, 1992). Imagine that you see an empty stage before you (Figure 5). A hand comes in from stage right and places a toy all the way to stage left. The hand leaves. Now a screen comes up blocking your view of the toy and half the stage. The hand comes in again from stage right, again carrying an identical toy. The hand goes behind the screen and when it leaves, it is no longer holding the toy. The screen comes down. What do you expect to see? You expect to see two toys because 1 + 1 = 2, and you would probably be surprised to see only one toy. This is how five-month-olds behave as well! They dishabituate more, by staring longer, at the arithmetic error. Finding such young infants do addition is so astounding, developmental psychologists debate intensively exactly what is happening in the minds of infants during this experiment (e.g., Moore & Cocas, 2006). Nevertheless, the basic finding has been found repeatedly (Christodoulou et al., 2017).

By about three years of age, most children can correctly count up to 10 objects (Gelman & Gallistel, 1978). Given the amazing ability of young infants to add, it may be surprising that counting is much more difficult. If we step back and consider counting, we may realize it is more complicated than it appears from our adult perspective. Counting is more than memorizing the sequence of numerals (e.g., 1, 2, 3,…). Counting builds on understanding numerical equality (e.g., "two-ness"), and understanding the relationships between quantities. Of greatest complexity is that it requires us to make a one-to-one correspondence between the objects and the numerals; you may not skip over 'counting' any of the objects and you may not 'double-count' any objects. Despite all this complexity, it's clear that three- to five-year-old preschoolers genuinely understand the one-to-one correspondence of counting based on what kinds of errors they make counting 11 to 20 objects (Gelman & Meck, 1983). The youngest we find evidence for one-to-one correspondence is about 2 ½ years old. In one clever study using the imitation method discussed previously, children watched a puppet with 10 food tokens put some into slots. On each trial the puppet put a precise number of food tokens into slots, from 1 to 6. The child was asked to imitate. About a quarter of the children put all their food tokens into slots regardless of the puppet's behavior; they were just seeing the action and not thinking about counting. But three-quarters of the children did imitate the counting aspect. When the puppet counted 1, 2, or 3 food tokens, the majority of these children correctly counted food tokens. When the puppet counted 5 tokens, about half of the "counting" children put 4 to 6 tokens into their slots (Sella et al., 2016). Though infants have many remarkable mathematical abilities, it still takes years to develop a basic understanding of arithmetic.

Conclusion

Exploring inside the minds of infants is a fascinating part of developmental psychology. Research taps a central question of nature versus nurture. As we have seen, the foundations of abilities from perception, memory, learning, and aspects of emotion and language are present early in infancy. At the same time, these aspects of ourselves take many, many, years to fully develop. The more abstract aspects of infant thought such as self-concept, mathematics, language, and some aspects of emotions only begin to emerge around the end of infancy (two years of age). At the same time, elements of these thoughts build gradually from even more simple building blocks.

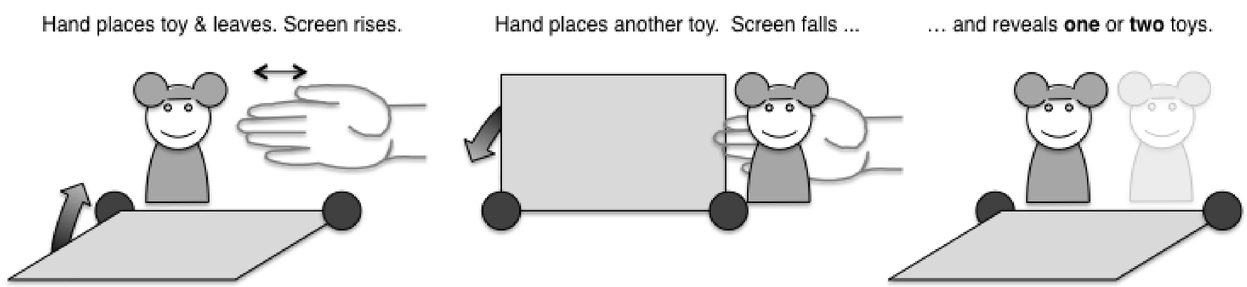
Though we discussed what happens inside the minds of infants in sections, reality is much more intricate and inter-connected. Every aspect of infants' development happens at the same time. For example, when infants refuse to cross the visual cliff when called by their mothers, this tells us something about depth perception. It also tells us about the limits of social referencing and how infants understand the emotional expressions of others. A variation of the visual cliff method has even been used for this purpose. While about 74% of 12-month-olds crossed the cliff when mothers used a positive tone to encourage it, not a single infant would cross the cliff if mom looked fearful (Sorce et al., 1985).

We have focused on what goes on *inside* the minds of infants. But what about what happens *outside* the infant? The social context outside the infant matters for infants' socio-emotional and cognitive development. We saw some examples, such as parents' use of infant-directed speech. However, there are many more examples. Two-year-olds with more attentional difficulties, and difficulties with emotion regulation are watching more television and videos

(Radesky et al., 2014). The next chapter will explore the role of the social context in greater depth.

One of the greatest struggles for the scientific study of infancy is that we only become flexible users of language at the end of infancy. Yet this challenge is being overcome as developmental psychology has invented some of the field's most creative methods to explore inside the mind's of infants, such as forced preferential looking an habituation.

Figure 5. Adaptation of Wynn (1992)



Further Reading

The current chapter provides a broad introduction to some of the many ways developmental psychology explores inside the minds of infancy. Readers who would like to deepen their understanding with a more detailed descriptions of each aspect of infancy, as well as discussion of the many theories that attempt to bring coherence to these findings, might be enjoy reading:

Rochart, P. (2001). *The Infant's World.* Cambridge, MA: Harvard University Press.

The current chapter provides short descriptions of some of the most famous and creative studies in developmental psychology. Readers who would like to know more about these studies and others, as well as the social contexts in which they were designed, might enjoy reading:

Dixon, W. E. (2003). *Twenty studies that revolutionized child psychology*. Upper Saddle River, NJ: Prentice Hall.

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Citation and Abstract

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Abstract

The current chapter provides a broad introduction to some of the many ways developmental psychology explores inside the minds of infancy. We will examine how the science of Developmental Psychology informs us about what is going on inside the minds of infants. We will examine thoughts and feelings from birth – and occasionally beforehand – through the stage of infancy (from zero to about two years of age), and into toddlerhood, the third year of life. We begin by examining the basic cognitive processes of attention, memory, and learning. Through these basic processes we will see some of the techniques developmental psychologists have devised for studying infants' thinking. Next, we consider infants' experience of sensations and their perceptions. Third, we explore infants' expression of emotion, understanding the emotions of others, and the beginnings of their own self-concepts. Finally, we examine how infants understand abstractions like language and mathematics.

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