Lee, C. D., Meltzoff, A. N., & Kuhl, P. K. (2020). The braid of human learning and development: Neurophysiological processes and participation in cultural practices. In N. S. Nasir, C. D. Lee, R. Pea, & M. McKinney de Royston (Eds.), *Handbook of the cultural foundations of learning* (pp. 24-43). Routledge.

# 2

# THE BRAID OF HUMAN LEARNING AND DEVELOPMENT

## Neuro-Physiological Processes and Participation in Cultural Practices

*Carol D. Lee, Andrew N. Meltzoff, and Patricia K. Kuhl*

We offer a framework for understanding human learning and psychological development as situated within a system that entails dynamic interplay between neurobiological processes and people's participation in cultural practices. We draw from multiple disciplines, including evolutionary biology, neuroscience, human development, anthropology, cognitive science, cultural and social psychology, and the learning sciences.

Human development is a complex interchange that includes neurobiological processes, evolved over many millennia (Quartz & Sejnowski, 2002; Tomasello, 2019) that now get taken up and adapted as people engage in cultural practices, which themselves vary over communities and historical time (Rogoff, 2003; Saxe & Esmonde, 2012). We highlight *intersections* between neurobiological processes and people's participation in cultural practices. These intersections shape human sense-making, which in turn influences people's goals, effort, and persistence—what people do and why. We also consider "time" as a key factor (Bronfenbrenner & Morris, 1998). A comprehensive theory of human development and learning must account for when in the life course we have experiences (age matters), when in cultural-historical time learner experiences occur (e.g. The Great Depression), as well as how micro-level interactions unfold in moment-to-moment activity.

We underscore the historical context of our proposals. We fully recognize that some readers may question elevating the relevance of neurobiology and evolution in human development and learning. For this reason, we wish to differentiate ourselves from certain ill-conceived theorizing in this vein. Hypothesizing about how biology and evolution influence psychology and sociology has been misused going back to Herbert Spencer's use of "social Darwinism" to argue for hierarchies of human communities, positioning those of European ancestry, constructed as "white," as superior to other human communities (Gould, 1981; Jackson & Weidman, 2004). In the nineteenth century, craniology—the study of brain size and shape—was also used to argue for natural human hierarchies. These views were used to advance the eugenics movement, which argued for inherited deficits within certain human communities; eugenics itself was taken up to support social policies and practices such as forced sterilizations to minimize the presence and impacts of those believed inferior. These accounts were used not only to distinguish Europeans from others (e.g. Africans, Asians, indigenous populations in the Americas, Australia, New Zealand), but also, at points, to distinguish northern European "Nordics" from southern European "Mediterraneans." These deficit orientations came to include not only biological accounts but cultural accounts of "deficits" in terms of presumed hierarchies (from superior to inferior) of cultural practices across communities associated with race/ethnicity, class, and religion. More recently, arguments for a presumed "culture of poverty" have arisen.

We reject these views, and want to articulate a new way of integrating evolution, neuro-biology, and human development. The modern study of brain science is not focused on "fixed traits" that are hardwired into the brain and immutable (and certainly not hardwired in ways correlated with the constructs of "race" or ethnicity). Modern brain science instead emphasizes the human brain's flexibility and adaptiveness. It celebrates "neuroplasticity" (studies of how experiences change the brain itself) in all humans. Modern neurobiologists focus on understanding how the brain learns socially in cultural contexts. It is this new convergence we wish to codify and amplify. We explore these ideas to see what we can learn from emerging findings in the neurosciences and the convergence of these ideas in other areas of study, including human development, studies of cognition-in-context, and studies of the socio-emotional consequences of participation in cultural practices.

## Theory: Six Overarching Propositions Linking Biology, Psychology, and Culture

We offer six overarching propositions emerging across diverse fields that converge on a new conceptualization of the relations among brain science, psychology, and culture.

*Proposition 1: Biology does not determine the endpoint of human ontogeny*. Renewed attention to biological processes is important because such processes are largely driven by our evolution as a species and are compelling drivers of human behavior. Yet understanding how such processes influence behavior in modern humans is complex. Among the important takeaways of our current understanding is that biological processes are *not* deterministic, and that the ways such processes unfold within an individual is intertwined with people's participation in cultural practices (Cole, 1996). A central tenet of modern neuroscience is that the brain is not fixed nor finished developing at birth—the brain itself changes postnatally due to experience. One of the most rapidly growing aspects of brain science is the neuroscience of learning. Biology is therefore not personal destiny: In seeking to understand complex human behavior, it is not genetics but *epigenetics* that holds the most promise. Waddington (1942) initially coined the term epigenetics, which heavily influenced Piaget's (1971) views on human development and constructivist psychology. Epigenetic studies document how experience shapes the expression of genetic factors. Meaney's (2001) work on epigenetics continues to influence neuroscientific studies.

*Proposition 2: The primacy of learning from, with, and through others.* There are foundational aspects of psychological functioning shared among all human beings, but these are displayed in myriad ways because of our participation in different cultural practices. These foundational elements include, but are not limited to: (a) a focus on understanding the internal states of other people (Flavell & Miller, 1998); (b) taking in and adapting to experiences—not simply reacting to perceptions given via physical senses, but responding to our *interpretations* of events based on our life histories (Bruner, 1990; Spencer, 2006); (c) the importance of emotions in human functioning (Adam, 2012; Damasio, 1995); (d) our need to satisfy a sense of "belonging" to social groups; (e) how we interpret ongoing social interactions in terms of safety/threat and relevance to our goals (Maslow, 1943); and (f) the salience we attribute to our sense of agency and efficacy and how experiences relate to our ego-focused goals (Bandura, 1993). Moreover, our social brain has evolved in part because of our interactions with others, and human adults and children experience a basic motivation to interact socially, including the powerful activation of our "neural reward system" by social signals such as faces (Stavropoulous & Carver, 2014). A comprehensive theory of human development must take into account basic motivations for learning from, through, and in relationships with social others.

*Proposition 3*: *Diversity in developmental pathways is core to realistic accounts of human development*. A diversity in pathways of development is essential to the survival of our species. The human species occupies more diverse niches—from the poles to the equator—than most other species, which demands flexibility. Across cultural-historical time the tools we create are embedded in increasingly complex forms of social interaction and institutional configurations, requiring adaptability that is enhanced by diversity of pathways (Cole, 2007; Rogoff & Chavajay, 1995).

Indeed, humans also exhibit flexibility in the face of basic sensory losses, showing that our brain can creatively adapt to atypical input in its quest to make meaning. Many blind adults navigate the world through taps and clicks, using echolocation to sense obstacles and navigate the world. Scientists have built tools to translate light into tactile information projected onto the tongue's surface so that the blind can "see" with their tongue (Bach-y-Rita, Kaczmarek, Tyler, & Garcia-Lara, 1998). Deaf infants have advanced responses to *visual* communicative signals and exhibit enhanced gaze-following behavior compared to hearing infants—countering "deficit models" (Brooks et al., 2020). Humans can cope and even thrive with the loss of multiple sensory channels (viz. Hellen Keller), in part because we don't actually perceive with our eyes or ears alone, but rather with our brains, and our brains are flexible enough to interpret the patterns that typically come through one sense in new modalities in the quest to make meaning.

One of the most unique aspects of the human species is our cultural diversity. Here, we can refer to the film *Babies*, a documentary about babies born in San Francisco, Tokyo, Namibia, and Mongolia. What one sees in this film is each child actively seeking to develop the competencies of the first year of life, but diversely. Children are socialized through different cultural practices, deploy normative competencies toward different social goals, and learn to use different cultural tools.

*Proposition 4*: *Individuals belong to multiple, not single, cultural groups—"intersectionality."* People belong to many cultural communities, and are not limited or wholly defined by any single one. One common meta-narrative and conceptualization about "culture" suffers from what Gutiérrez and Rogoff (2003) call "the box problem": Assuming people belong to a *single* cultural community associated with race and ethnicity, especially as pan-ethnic groups (e.g., African American, Latinx, Asian American, and "White").

In this chapter, we recognize that people belong to multiple cultural communities, known as "intersectionality" (Carbado et al., 2013). Some communities—such as those associated with ethnic and in some cases with pan-ethnic communities—have inter-generational longevity that persists even when national borders change. But even with such longstanding communities, we find both stability and change. Irish communities in the USA may celebrate St Patrick's Day, but the USA celebrations look quite different from Ireland's celebrations. In African-descent communities across the diaspora, one will find commonalities concerning reverence of ancestors, respect for elders, and the centrality of the drum and rhythm. Yet, these practices also differ by time and place (Asante & Asante, 1990). In addition, people also belong to communities bound by cultural-historical periods: Video game aficionados, readers of Harry Potter novels, lovers and practitioners of particular sports, etc. Through participation in diverse cultural communities ("communities of practice"), people develop different repertoires (skills, habits, ways of using language, use of particular tools) and different identities or self-representations (e.g., ego-related goals, sense of belonging, sense of efficacy). In our efforts to understand and influence human learning and education, an essential question is what we make of such repertoires in relation to some targeted learning goals.

*Proposition 5*: *The social brain "expects" and is modified by social interactions.* Humans have evolved to be a hyper-social species. We interact with other human beings, using tools (physical and conceptual) created by humans to interrogate our experiences. Crucially, even if we are engaging in an activity without another person present, we often are still engaging with tools developed by others. We are never truly alone, devoid of all perceptions, thoughts, memories, or tools made by others.

Research has shown that young babies pay more attention to other human beings than to physical objects, but this is simply the kickoff of our path of social interaction with others. Social cognition researchers examine how the capacities for interrogating the internal states of self and others shift over the life course, and illuminate the complexities that arise in such efforts. Modern studies of the brain have widened their lens from sensory processes to investigating social understanding and social interaction. This new field is called *developmental social neuroscience* (Ward, 2012). The goal is not to usurp or replace the field of human development, but rather to provide an additional, complementary "level of analysis." The tools of modern neuroscience now allow us to begin, for the first time in history, to examine what's going on in children's brains as they learn, and how this changes with experience, development, context, and life history (Meltzoff et al., 2009).

*Proposition 6: The power and pervasiveness of implicit and observational learning*. We learn through explicit verbal instruction and intentional guidance from others, but we also learn more implicitly through simply observing the practices of other people (Bransford et al., 2006; Meltzoff et al., 2009). We form long-lasting representations of the behaviors we witness. These internalized representations are then used to organize our subsequent actions and color our world views. People become role models for us, and role models influence us even when they are absent or dead, or para-social as in media characters. Some of the most powerful influences of role models derive from information implicitly picked up, despite the role mentor's lack of intention to convey it.

Observational learning and implicit learning are especially powerful channels for learning prior to formal schooling. Children learn about the social world both through interactions with others and also from third-party "eavesdropping" on the interactions they observe between others. Children abstract skills, customs, norms, from such everyday implicit social learning. Many of life's most important lessons and practices are learned through merely observing others' behaviors , not through explicit, intentional instruction.

*Summary of 6 propositions and organization of the chapter*: What we internalize from our participation in diverse, social communities of practice is an outgrowth of the complex relations between (a) biological processes inherited as a species for taking in physical inputs from the environment (e.g., what we see, hear, taste, feel, smell), and (b) the translation of those inputs into psychological representations that embody meaning for us. The schemas and mental models we encode as filters for attributing significance and meaning to our perceptions of the world are inherently social, outgrowths of shared cultural practices among communities of humans. Because all humans, by evolutionary design, are born with an immature brain that is wired postnatally in a social context, we are socially attuned to others starting from our earliest years, months, and days of life (Kuhl, 2007; Meltzoff & Marshall, 2018). Being nurtured is part of our nature. The human brain is "prepared" to encounter and learn from others; those social interactions in turn wire and remodel the brain, starting at birth and throughout the lifespan.

We next describe new empirical work that illustrates and amplifies our six propositions. The empirical examples discussed will be drawn from educational research, and also draw heavily on our own research in early childhood. We use these examples to put empirical meat on the six skeletal propositions we have put forward. In the final section of the chapter we consider the broader implications of the six propositions and the empirical work for our understanding of how people learn in both formal and informal settings. In sum, we hope to sketch a broad arc that extends from evolution and neurobiology through developmental science to education.

## Childhood Social Learning and Imitation: Where Biology First Meets Culture

Humans are unique learners. It is not that we learn faster, learn earlier, or remember our learned experiences longer. We learn differently. Human beings have evolved a distinctive type of social learning—a generative capacity for imitation (Meltzoff & Marshall, 2018). We are imitative generalists (Meltzoff, 1988b) and seamlessly intermix imitation and innovation.

In this chapter, we are using the word "imitation" in a generic way to mean copying the acts of others. More technically, there can be a distinction between copying the *way* people do things (sometimes called "imitation") and copying the *ends or goals* they achieve (sometimes called "emulation"). Many animals are restricted almost entirely to emulation (Tomasello, 2019). Human infants have the capacity for *both* imitation and emulation—they are "imitative generalists." Thus, in this chapter we use the word imitation as a superordinate term, as in everyday language, to encompass both children's imitation and their emulation of others.

The capacity for generative imitation allows infants to imitate postures, actions, vocalizations, tool use, and novel goal-directed acts. Imitation is also a mechanism for the intergenerational transfer of cultural practices prior to language, and is an avenue for learning the diverse customs, rituals, and norms that sustain social cohesion among group members. Next, we examine the roots of human imitation using empirical work to flesh out propositions 2, 5, and 6. This empirical work serves to illustrate how strikingly early in development humans start to pick up the ways of their culture.

## *Transfer and Generalization of Imitative Learning Is Basic to Humans: Propositions 2 and 6*

For imitation to serve cultural learning, two cognitive competencies are required—deferred imitation (imitation from memory) and imitation after a change in context (generalization). Both of these capacities have been demonstrated in young children and infants. They allow children to learn from observation and to transfer their learning across time and space, and also support the early formation of "communities of practice" in the ways articulated below.

One warrant for these claims derives from a study of 14-month-old infants, who saw an adult perform an unusual act, one with no evolutionary significance and one not previously seen or performed by the child. The adult demonstrated using his head to activate a light by leaning forward and tapping a panel with his forehead. Infants simply observed the adult's odd behavior. When re-presented with the panel after a 1-week delay, infants imitated the novel head-touch act based on recall memory (Meltzoff, 1988a). The imitation of novel acts has been replicated and extended across several cultures, from infancy through the preschool period and beyond (Legare et al., 2015; Tomasello, 2019; Wang et al., 2015).

The demonstration of head-touch imitation speaks to several of our propositions. First, young children can learn new and unusual acts implicitly, based on the mere observation of other people (proposition 6). Second, imitation of novelty occurs without food inducement (imitation in non-human primates often revolves around food). For humans, imitation is its own reward—infants are intrinsically motivated to become "like others" in their group (proposition 2). Third, infants imitate using the same body part (or *means*) adopted by the adult, and do not simply duplicate the same result (or *ends*). Infants re-enact *what* the adult does and *how* he does it (a head-touch), rather than only doing the more practiced act of hand-touch to reach the goal. This is important, because it verifies that infants imitate novel acts used by members of the culture with high fidelity, which can be used for learning diverse cultural practices and customs.

Young children also demonstrate transfer of learning to new settings. In one study, infants were shown what to do with objects in a laboratory environment and later given the objects at home after a delay. We found that infants imitated across the context change (Klein & Meltzoff, 1999). Infants also rapidly learn from peers. Researchers taught an "expert infant" what to do with novel objects. The expert was then brought to daycare centers where he/she encountered "naïve infants" who watched them deftly handle the toys. Researchers subsequently visited the homes of the naïve infants, gave them the relevant objects. The naïve infants duplicated the behaviors they had seen the expert peer do two days earlier (Hanna & Meltzoff, 1993). This shows that infant learning is not place bound; they remember what they observe others do and productively use these actions across changes in space and time. This is fertile ground for young children learning the social practices they observe and becoming full-fledged members of the diverse cultures in which they are raised.

The convergence between these laboratory studies and the field studies done cross-culturally (e.g., Rogoff, 2003) lends confidence to these theoretical inferences. It helps us to understand the rapid nonverbal diffusion of skills among children, and shows that the capacities needed to form "communities of practice" is so deeply embedded in the human species as to be present in infancy, before children utter their first sentences.

### *Learning to Use Tools (Proposition 5)*

Observational learning and imitation play a significant role in humans' learning how to use tools. If you give a nonhuman primate an instrument, it can often use trial-and-error to work out how to use the instrument to achieve an end. An important characteristic of human children is that they learn to use tools through the imitation of social others (Meltzoff, 2007; Tomasello, 2019).

Vygotsky (1978) presciently argued that tools extend and augment human capacities. Modern research shows that this begins early. Infants covet their mother's lipstick and keys because they have seen her use them; they hold mobile phones to their ears because they witness adults so use the devices; and they learn to type on screens partly by imitating others. And preschool children are beginning to use computers, smartphones, and tablets as vehicles for learning and communication with parents and grandparents. The use of amplifying tools is not learned solely through independent invention, trial-and-error learning, or linguistic instruction. Young humans get a jump start on enculturation because of a fundamental pre-existing capacity for social imitation. Vygotsky (1978) noted the role for imitation in his concept of the zone of proximal development. We wish to move the starting point for Vygotskyian processes from preschool to infancy, because laboratory research shows that imitative processes begin even before Vygotsky had surmised.

### *Emotions and Selective Imitation: A Choice, Not an Echo (Propositions 2 and 5)*

Infants do not automatically imitate everything they see. Emotions play a major role in regulating imitation, as discovered in research where infants were shown what to do with an object by a "Demonstrator," but another adult ("Emoter") became angry at the Demonstrator for performing the act (Repacholi & Meltzoff, 2007). The Emoter then adopted a neutral face, and the infant was handed the object to see whether he/she would imitate. The study varied whether the Emoter did or did not watch the infant's behavior. Results showed that infants were more likely to imitate the Demonstrator's act when the (previously angry) Emoter did not watch the infants' imitation.

These results are not reducible to simple emotional contagion, because the same Emoter showed the same amount of anger across cases. The authors hypothesized that infants *keep track of the emotional history* of people. Infants then regulate their imitation depending on who is watching them, because they do not want to become a target of the Emoter's anger by duplicating the act that had made that person angry in the past (Repacholi, Meltzoff, Toub, & Ruba, 2016), (relevant to proposition 2's discussion of emotions and the role of threats to the self in learning).

These findings are important for three reasons. First, they suggest infants are capable of a primitive form of self-control prior to language (recalling Luria and Vygotsky's ideas about "executive function"). Second, they show infants do not need direct involvement but learn from "eavesdropping" on interactions between other people. Infants learned about the Emoter's tendencies from watching her interaction with someone else. Third, the work indicates that anger is a powerful emotion in the world of young children, and that they take action to avoid a personal threat.

Imitation is also modulated by other social factors. For example, young children preferentially duplicate intentional rather than accidental acts, ingroup versus outgroup members, models who seem more efficient and competent, and models who receive favored treatment by others (Meltzoff & Marshall, 2018; Skinner, Olson, & Meltzoff, 2019). In sum, imitation is not compulsory; it is a choice, not an echo. Young children flexibly choose what, when, and who to imitate. In a sense they choose their teachers and thus participate in their own learning and social development, starting from infancy.

## *Newborns: In the Beginning There Was Imitation (Proposition 6)*

A primitive form of human imitation exists at birth, particularly the matching of simple facial and manual acts such as tongue protrusion or moving the fingers (Meltzoff & Moore, 1977, 1983). This discovery came as a surprise, because Piagetian theory had considered it a landmark milestone achieved later in infancy. The existence of early imitation has now been replicated in more than two dozen experiments from independent labs (reviewed by Meltzoff & Moore, 1997, also see recent replications by Heimann & Tjus, 2019; Nagy, Pal, & Orvos, 2014). One simplistic idea was that it is an arousal effect activated by seeing moving faces or fingers; however, this has now been ruled out by experiments that used other dynamic movements as controls.

The leading model explaining early infant imitation is the "active intermodal mapping" (AIM) account (Meltzoff & Moore, 1997), which emphasizes the infant's own agency. The central notion of AIM is that imitation is a cross-modal matching process involving an *active comparison* between the acts of self and other. According to AIM, infants' movements yield proprioceptive feedback that is used to correct imitative efforts so that they correspond to the visual target.

Based on this and other work, Meltzoff (2007, 2013) offered the "Like-Me" social-developmental framework. It holds that newborns are not born social isolates, monads, devoid of all connections to social others. The baby is born into a social community and immediately recognizes similarities between their own bodily actions and those they see. This is the starting state for interpersonal engagement, not an end-state achieved after years of development. Of course, newborn social cognition is primitive. For example, they are limited to matching bodily actions and are too young to use tools or to assimilate cultural norms. But the initial state is a launchpad for the further social learning and development. It is a foundational launchpad because infants grasp a primordial, nonverbal connection between self and other. Infants are born learning socially. Through observations of others and social interactions, they construct more complex beliefs, desires, intentions, and values.

## *What's the Brain Got to Do With It? (Proposition 5)*

The neurobiology of social learning and imitation has been illuminated by using the modern tools of brain science with infants and young children.

### *Connecting Perception and Action*

One new line of studies on social learning used electroencephalography (EEG) techniques. These studies discovered significant changes in neural oscillations ("brain waves") that occur between 6–9 times a second (the "mu rhythm"), both when a baby performed an action (such as pushing a button), and also when they simply watched someone else do the same action (Marshall & Meltzoff, 2014).

In other EEG work, researchers tested infants' brain reactions to social games. Infants played a mutual imitation game with an adult while infants' brain waves were measured (Saby, Marshall, & Meltzoff, 2012). Results showed significant changes in mu rhythm when the adult imitated the infant compared to when the adult did not. There are special neural signatures associated with being "in synch" with another person and having them imitate your behavior. Mother-infant dyads commonly play mutual pat-a-cake and mutual rattle shaking games, often to peals of laughter. Babies—like marital partners and psychotherapy patients—like to be "matched," because it is a form of nonlinguistic communication and an embodiment of "being in synch" with one's interactive partner.

### *Infant Embodiment: What the Infant Body Tells the Infant Brain*

Further work has zeroed in on similarities between the bodies of self and other: My hand is like your hand; my lips are like your lips. The way these studies worked was to touch different parts of the infant's body and to measure brain responses. Scientists have been able to localize the infant's body in the infant's brain with enough precision to identify the "hand area," "foot area," and "lip area" in the infant brain (Meltzoff, Saby, & Marshall, 2019). The crucial findings involved having infants observe *another person's* body being touched without the infant being touched themselves. The results showed activity in the infant's *own hand* area when they saw *another person's* hand being touched (Meltzoff et al., 2018). The infant brain uses some of the same neural machinery to process both self and other, emphasizing a fundamental social connectivity from a young age.

### *Theoretical Synthesis: Brain, Body, and Roots of Social Understanding*

These brain studies inform theories about the neural underpinnings of imitation, perspective-taking, and empathy. To imitate, infants need to know what part of their body corresponds to yours. Empathy also depends on recognizing the other as "Like-Me"—at first at a bodily level (Meltzoff, 2013). Of course, young children do not construe self-other similarities in the sophisticated ways that adults do. This will come through social interactions with others. But by the same token, infants are not born blank slates. They are deeply connected to other people through their body and actions even before they can talk, and this launches them on the stormy path of navigating the similarities and differences between self and other.

We now turn to how infants' build on these foundational social capacities to acquire language, which in turn transforms their understanding of people, things, and events.

## Language, Brain, and Culture: Rethinking Language Through a Sociocultural Lens

Language acquisition presents a cardinal case of culture influencing the mind (Bruner, 1983; Vygotsky, 1962). Children's acquisition of a culture's unique coding of meaning, and its distinctive sound patterns and gestures, represents a powerful case in which infants rapidly and effortlessly construct a highly complex system that allows them to communicate effectively with other members of their social group—and the language(s) they learn influence cognition.

Theories of language acquisition have been transformed over the last half-century from being linked primarily to biology to theories in which biology and culture are inextricably intertwined. Chomsky's (1957) view of the child's innate universal grammar downplayed the role of learning. Culture's contribution was minimal in that the language a child heard simply served to "trigger" the appropriate innately specified parameters, which then generated a specific language. Fodor's (1983) *Modularity of Mind* characterized language as an innately specified "module" that was cognitively impenetrable and informationally encapsulated—an entity separate from other higher-order cognitive processes, and immune to sociocultural influences. The opposing view of language acquisition offered by Skinner (1957) was a learning account, but highly reductionist, suggesting that language acquisition required explicit reinforcement on the part of parents to "shape" specific verbal behaviors. These views deeply underestimated the role of social, cultural, and cognitive influences in the child's acquisition of language (Kuhl & Meltzoff, 1997), but they dominated the study of language for decades.

A newer view emerged from a variety of scholars who studied the earliest forms of language learning in flesh-and-blood contexts, in the crib. Breakthrough diary studies conducted by Brown (1973), Bloom (1973), and Bates (1976) chronicled children's words and grammatical utterances from the beginning, in actual settings, emphasizing the complexity of children's constructions of meaning and the role of prior cognitive and social development on the language learning process. Similarly, Tomasello (2003) argued that children learn language through social-cognitive processes that allow young children to read the intentions of others and find patterns in their social discourse interactions with others. It was shown that children's early language learning critically depends on social interactions with others during infancy (Kuhl et al., 2003).

Current views of language acquisition embrace the child's natural drive to learn from and with other members of a culture, and the way in which the construction of language occurs in the brain through social interaction within a particular cultural community. The details of how language is expressed in a particular culture—whether signed or spoken language and whether one or three languages are mastered—are viewed as diverse routes for children engaging through social interaction with members of their community and learning to communicate. On this emerging view, biology's contribution is the extraordinary adaptability and neuroplasticity of the child. Our six propositions help illuminate language acquisition in interesting ways.

## *Young Children Learn Language Implicitly (Proposition 6)*

It doesn't require a scientist to see that young infants absorb language by being bathed in the world of words and sounds (or signs) that characterize a particular culture. By ten months of age, the babbling of a baby raised in France will sound "French," a baby in Rome will babble in Italian, and a baby in Beijing will sound distinctly Chinese. The infants already are conforming to their cultural milieu through vocal learning and imitation (Kuhl & Meltzoff, 1996). By 12–15 months, these same infants will harness their language-specific babbling to create words in their mother tongue as they become more formal French, Italian, or Mandarin speakers.

Studies of young children show they are implicit learning masters. Learning occurs unconsciously as infants experience the patterns in auditory (speech) or visual (sign) input. A specific form of implicit learning, referred to as "statistical learning," helps explain how young children begin to master the sound structure and words of a language. This is easily illustrated by examining the earliest learning infants accomplish, learning which phonetic units (the consonants and vowels that make up words) are used in their mother tongue. Prior to six months of age, infants accomplish a feat that no adult can achieve. Under the age of six months, infants from all cultures can hear the sound differences used to differentiate words (like the 'r' vs. 'l' difference that distinguishes 'read' from 'lead') in *all languages of the world*, something adults cannot do. Each language employs a distinct set of these phonetic distinctions, and 6-month-olds discriminate between them all. Yet six months later, perception for all infants has narrowed. The universal differences 6-month-old infants once were able to hear in foreign languages can no longer be discerned by the 12-month-old, and only the sounds used in the language(s) spoken by their caretakers and surrounding community can be distinguished. Despite rapid and impressive advances in AI, no current computer in the world can glean the sound structure of a language from language input, yet all infants across the world do so with ease, whether reared in Western society or in a non-industrialized culture.

What kind of learning allows the child to construct a linguistic system that contains certain sounds, words, and grammatical constructions by listening to us speak? It turns out that unlike the learning theory held by Skinner, in which young children learn through structured reinforcement, children can learn simply by listening and detecting the stochastic patterns in language input (Kuhl et al., 1992; Saffran et al., 1996). This "observational" learning in language is not unrelated to the observational learning in actions described in the previous section (Meltzoff et al., 2009). During an early "sensitive period" between 6 and 12 months of age, infants are particularly sensitive to the distributional frequency of phonetic patterns in language they hear (Kuhl et al., 2006).

Children's early word learning similarly exploits the stochastic properties in language input. Experiments have shown that when 8-month-old infants are presented with a 2-minute long uninterrupted sequence of syllables with no discernable breaks (e.g., the string of syllables *pigudofadimepigulatu* spoken in a monotone voice) the transitional probability that one syllable will follow another affects children's detection of likely words even before they know words exist. In the example above, the sequence 'pigu' appears twice in the string. After two minutes of listening, young children treat sequences of syllables that always follow one another as units ('pigu' in the string), as "words" (Saffran et al., 1996). They remember these units and easily link them to a new object they have not seen before. These findings emphasize infant learning and show that infants learn in unsuspected ways from cultural experience, and in ways that allow them to structure and interpret the input they hear.

Two additional notes about implicit learning are important. The first is that the *timing* matters. The period between 6 and 12 months of age constitutes a sensitive period in human phonetic learning (Kuhl et al., 2006), and infants' statistical learning of likely "words" is particularly keen at the end of the first year when infants' cognitive and social capacities increase and word learning begins. The second is that statistical learning is a *cross-domain* skill, a cognitive skill on which language capitalizes mightily.

Cross-cultural studies designed to test across diverse cultures and languages have shown that children throughout the world exhibit this capacity to learn from language experience, regardless of the culture, language, or socio-economic status (SES) of their parents. The emerging model thus depends heavily on learning, but learning of a type that differs fundamentally from the classic Skinnerian learning, and also offers more details and mechanisms for language acquisition than described by Piaget (1962) and Vygotsky (1962, 1978).

## *Early Learning of Language is Driven by Social Interaction (Propositions 2 and 5)*

A key component of the transformation in language acquisition theory is the requirement that infants' early learning of language mandates a social context. The critical nature of social interaction in early second-language learning was demonstrated experimentally in studies in which language learning through social interaction was compared to learning from a disembodied source (a video) at nine months of age (Kuhl, 2007). Infants were given the exact same language material, in the same setting, with the same frequency; the only difference was whether infants experienced live speakers interacting with them or the identical input delivered via video (Kuhl et al., 2003). Results showed that the *live* social interaction resulted in rapid and robust learning of sounds and words from the new language. However, exposure via video yielded no language learning whatsoever. Additional studies revealed that infants in the live sessions used tutors' social (eye gaze) patterns to learn, and that infants' attention in the live, interactive social settings is significantly higher than when watching the same material via video (Conboy et al., 2015). The idea that infants' social motivation and their early abilities to detect intentionality in human actions is a key driver of language acquisition has also been discussed by Tomasello (2019) who theorizes that the origins of human language emerged from the drive to cooperate socially.

Parents in cultures around the world adapt the type of language used when speaking to their infants and young children—often termed "motherese" or "parentese." Parentese is inherently social and engages children, fostering turn-taking conversations (Kuhl & Ferjan Ramírez, 2019). Parentese was first discovered by anthropologists and linguists documenting languages in the 1960s and was later revealed to be nearly universal in the world's languages, although some cultures rely on it more than others (e.g., Ferguson, 1964). It has a simpler grammar and lexicon, a slower tempo, and it exaggerates the relevant acoustic differences in speech. Infants given a choice choose to listen to parentese over standard speech, and its use has been shown to be linked to advanced language development.

Parents' social reactions to children's vocalizations increase the complexity of children's vocalizations. It's as though having a social audience motivates young children to display their best and most complex linguistic abilities (Sundara et al., 2020). Once again, the social exchange is critical to this kind of developmental advance. Through back and forth exchanges, parents provide feedback that is constantly adjusted to their child's linguistic needs, and children, in turn, adjust their vocalizations in response to parental reactions. Communicative turn-taking between parents and infants is prevalent long before infants utter their first words and may have been essential for the evolution of language.

In short, historically, the role of the "social" brain and the sociocultural context has been underappreciated by language theorists. On the one hand, the profound impact of the social context was not predicted by nativists (Chomsky, Fodor) or learning theorists (Skinner). On the other hand, social-developmental theories duly discussed the importance of social interaction for language (Bruner, Vygotsky), and research amply demonstrated that language acquisition is assisted by children's grasp of communicative intentions, and their sensitivity to joint visual attention and goals (Brooks & Meltzoff, 2008; Kuhl, 2007; Tomasello, 2019). However, the new data demonstrating that babies need social contexts to learn even the earliest aspects of language, phonetic units—the essential building blocks of language—was not expected. It suggests that language, social evolution, and social learning contexts are entwined from the earliest phases.

### *Diversity of Pathways Toward Language (Propositions 3 and 4)*

Culture provides a social context and engaging speakers that stimulate the young brain. In children born unable to hear, language input comes from culturally-invented visual sign languages that differ across countries like oral languages do. Deaf infants exposed to natural sign language (such as ASL) acquire language through the visual-manual pathway following many of the same principles and same developmental timeline as infants acquiring oral language. There is evidence that experience with sign language in deaf speakers activates the same brain tissue as spoken language in hearing speakers (Petitto et al., 2001). Moreover, the "deficit model" of deafness has been overturned. Deaf children who experience visual sign language from birth show certain social-cognitive strengths. They show *accelerated* gaze following of others, illustrating the neuroplasticity of infants, and a strong capacity to become well-adapted to their particular sociocultural and linguistic ecologies (Brooks et al., 2020). In other words, there is no one pathway to language.

Multilingualism also provides an example of a pathway that differs from what is typical in the United States (though it is common worldwide). In the USA, some politicians and pundits speculated that hearing multiple languages could overwhelm the infant brain and lead to deficits in learning. This pernicious and inaccurate view of bilingual learning has been disproven, and indeed additional evidence indicates *benefits* of bilingualism in certain domains.

Taking a step back, the original claims were that bilingual children were slower to develop vocabulary when compared to their monolingual peers, but more recent studies by Hoff and colleagues (2012) showed that when young bilingual learners are given credit for each conceptual vocabulary item that they know (from either of their two languages) bilingual children's total vocabulary skills either equal or exceed those of their monolingual peers. Behavioral and brain-imaging studies comparing monolingual and bilingual infants confirm that bilingual infants are on the same timetable with regard to mastery of the sound systems of their two languages when compared to monolingual infants who master only one language (Ferjan Ramírez et al., 2017). In other words, bilingual infants and children do not lag behind their monolingual peers in either behavioral or brain measures of learning.

More strikingly, bilingual infants show cognitive advantages. Bilingual infants learn novel speech structures faster, and exhibit a more prolonged period of flexibility in their interpretation of potential words. Bilingual children also show advantages on cognitive "executive function" tasks that involve task switching or inhibitory control tasks; and there is evidence of a protective effect against cognitive decline with aging in bilingual adults (Bialystok, 2011). In translational science work taking place in Madrid, Spain, results show that a *Bilingual Baby* curriculum based on language learning principles uncovered in the laboratory can be used to ignite infant bilingual learning at rates about five times faster than ordinary community bilingual programs that are not evidence based (Kuhl & Ferjan Ramírez, 2019; Ferjan Ramírez & Kuhl, 2000).

Deafness and bilingualism provide evidence that all young brains are malleable—open to the right experience at the right time—rather than fixed at birth. They are not rigidly fixed either with regard to the modality thorough which they learn language, nor the number of languages that they learn. In a world in which communication, flexibility, and understanding of cultural differences and values are of vital importance, understanding the nature of human brain flexibility and the positive effects of diversity would appear to be a rich vein of scientific research with potential educational and policy implications. The fact that human brain plasticity and flexibility are fundamental characteristics of our species means that infants' brains expect and are prepared for cultural diversity—and all the advantages cultural diversity provides.

## *What's Biology Got to Do With It? (Proposition 1)*

The baby brain begins with all of the brain areas necessary for processing sights, sounds, touch, smells, and taste. At birth, sound activates the baby's auditory brain areas, the sight of an object or person activates the visual brain centers, and touch activates the somatosensory cortex. In short, the infant brain comes into the world remarkably well organized. However, the cultural information coded by neurons in those brain areas—the cells that will eventually allow us to detect individual faces, people's voices, human actions, and, importantly, the *neural pathways that connect* brain areas to one another to process a "whole" person or event—require experience. In other words, although the baby brain begins with all of the brain areas necessary for processing auditory, visual, somatosensory, and motor information, the development of neurons that code specific culturally-valued information, and the architecture of neuronal networks that connect brain areas, requires cultural experience. Brains begin life ready to learn, but experience is necessary to construct the infant brain with all its culturally-dependent processing networks. The baby brain comes ready to be mapped by cultural experience.

Multiple genes play a role in this developmental unfolding, but they are *not* deterministic. As Gottlieb (2007), Meaney (2001), and others have elegantly described, extragenetic factors modify the expression of genes during development (Waddington's "epigenetics"). The earlier orthodox view that our genes determine development no longer predominates, and the debates about nature *or* nurture have given way to nature *and* nurture and a more nuanced understanding about how culture and biology interact.

Recent neuroscience studies suggest that the infant brain "expects" experience, and that without it, the brain does not develop normally. Experience maps the neurons and networks as infants interact in the world, and the infant brain begins to construct internal representations of culturally valued information. As infants' brains develop internal representations of the world, and the brain's neural networks become tuned to the categories and constructs embodied in their cultural environments, children's brains begin to act as "filters" on new incoming information. It is as though a child's new experiences are processed through the lenses formed by cultural experience, amplifying a particular way of perceiving the world. In the field of language, these "filters" are the phonetic structure of the learned language, the words and concepts we understand, and the grammar of the language(s) we know. The child's construction of these filters, based on experience, is the primary reason why learning a second language later in life is so difficult. The second language does not fit the filters established by the first.

Studies of children's brains can now use sophisticated brain-imaging technologies such as magnetoencephalography (MEG), which provides a movie of brain activity as the infant listens to speech or sees a person. Another technology, magnetic resonance imaging (MRI), can be used to track the growth of individual brain areas and the connections linking them, and allows us to measure how experience alters the anatomy of the brain. Studies using these technologies are now beginning to reveal how closely the social areas of the brain are linked to the language networks (e.g., Kuhl et al., 2014). Eventually, we believe that studies of the child's brain in action may reveal neural mechanisms by which the child constructs not only a language, but behavioral patterns, values, and beliefs (Meltzoff & Marshall, 2018) that reflect a particular human environment. Of course, brain studies will need to be done in conjunction with psychological and sociological studies, both within and across cultures, and across developmental time periods, in order to construct a comprehensive theory of how culture affects biology and vice versa.

## Implications

In this chapter we have articulated several synthetic ideas about human learning and development starting from birth: (a) human functioning is an outgrowth of neurophysiological and psychologically linked capacities that have emerged over evolutionary history, but that are taken up and shaped by people's participation within and across a diverse array of cultural practices; (b) these neurophysiological-psychological relationships create representations in the brain subject to immense plasticity over the life course; (c) from a young age, humans seek to read the internal states of others, and in so doing to engage in social interactions with people and tools (physical, conceptual, ideological) embedded in the activities and settings in which they engage; in the earliest years, humans chiefly learn in informal settings, often through observation and imitation of others, and during the K-college years this is supplemented with explicit verbal instruction in formal learning institutions such as schools; (d) our social experiences (and even basic perceptions) are threaded through our emotional reactions, feelings of safety/threat, and weighed for relevance, in the human striving to feel efficacious, agentive, and a sense of belonging; (e) the diversity in pathways through which human learning and development unfold is essential to the human species; (f) all people participate in multiple cultural communities.

We have sought to illustrate these principles as they unfold in infancy and early childhood, as demonstrated by empirical studies. We have focused on infancy and early childhood because the evidence for the existence of these foundational principles during these early phases is so dramatic and often unexpected. These principles are operative even before children receive formal training, during the earliest years of brain and body development, and before the development of complex linguistic communication. This primacy supports the idea that these dispositions and competencies are an outgrowth of natural processes—where "natural" still means a combination of biology and culture.

In this section we want to draw out the implications of these foundational propositions for learning in later childhood and adolescence, and in particular the implications they have for the intentional design of robust learning environments that productively take up these foundational ideas (Lee, 2005, 2010, 2017). We can think about what it means to take seriously the importance of perceptions of safety, efficacy, and relevance, the importance of emotional salience, the kinds of knowledge we develop as we grow and experience the social and physical world, and the relevance of such prior knowledge for our choices to engage in tasks and challenges.

In many respects, parents and other early caregivers have an intuitive sense of the relevance of these ideas for how we interact with infants and young children. Yet we have greater challenges in translating these ideas with older children and adolescents. And even here, we are more efficacious in thinking about these ideas in non-formal settings, where youth elect to participate, than in formal schooling where children are forced to attend (Barron, 2006; Master & Meltzoff, 2020).

With this challenge in mind, we examine the implications and applications of our six theoretical propositions to older children and adolescents. We do so through examining the role of everyday knowledge for youth within and across diverse communities. We particularly focus on the work of learning in academic disciplines and on examining the design of robust learning environments that explicitly address relationship building, self-efficacy, and socio-emotional well-being.

### *Everyday Knowledge and the Academic Disciplines*

One fundamental idea from studies of human cognition is the importance of prior knowledge to new learning (Bransford, Brown, & Cocking, 1999; National Academies of Sciences, Engineering,

& Medicine, 2018; Piaget, 1952; see also our six propositions). For example, studies have documented how young children develop competencies about numeracy and narrative prior to explicit formal training, and supported by social interactions and observation of the physical world that are primed by our evolutionary roots. Infants are able to distinguish between what is more and what is less (Starkey & Gelman, 1982; Wynn, 1992). Bruner (1990), Pinker (2007) and others (Mandler, 1984, 1987) have argued that narrative is a form of sense-making endemic to humans. Research on what is called story grammar (Applebee, 1978; Stein & Glenn, 1979; Trabasso & van den Broek, 1985) documents that even young children intuitively understand that stories involve agents with internal states that inform their goals, who engage in actions chronologically and logically connected, toward some broader goal or coda. We have shown in earlier sections how intuitively children learn the nuances of the languages they routinely hear. There is also research on how children intuit naive concepts about biology and physics (Carey, 2009; diSessa, 1982), again from observations in the world and building upon prior knowledge they bring to those observations. These well-established findings open up questions about their implications for learning beyond early childhood. They raise questions about how academic disciplinary knowledge is connected to everyday practices, and how the diversity of related everyday practices may inform the design of formal teaching practices.

The field of ethno-mathematics (Ascher, 1991; Saxe, 1991) takes up this issue by documenting the range of ways that cultural communities now and historically have created mathematical representations and forms of reasoning. Saxe's (1988a, 1988b) research on the mathematical problem solving of child street vendors in Brazil, as well as his longitudinal studies of the changes in mathematical representations among the Oksapmin of Papua New Guinea (Saxe, 1981; Saxe & Esmonde, 2005), contribute to our understandings of relations between everyday and academic knowledge in mathematics. Nasir (2005) and colleagues have analyzed the mathematical reasoning of children who routinely learn to play dominoes, including the nature of the social supports that surround the practice, socializing a sense of self-efficacy. Similarly, she has analyzed statistical reasoning used in everyday life among adolescent basketball players (Nasir, 2000). Taylor (2009) has documented how young African American children living in poverty develop arithmetic problem solving through the social practices surrounding purchasing activities after school at the local liquor store.

Other research has examined how language repertoires from everyday experiences, especially of youth from minoritized communities, can scaffold disciplinary literacies. Lee's (1995, 2007, 2014) research in Cultural Modeling empirically documented the affordances of supporting students in making public and explicit tacit strategies they employ in examining everyday texts (music lyrics, oral figurative language use, visual media) as heuristics in interpreting literature. Orellana (2009; Orellana & Reynolds, 2008), Valdés (1996, 2003) and others have examined the meta-linguistic knowledge that children who act as translators for their families develop as bilinguals. Levine and Horton (2013) have examined how the basic dispositions to attend to the salience of emotions can serve as a resource for detecting interpretive problems in literature. Champion (1998, 2003) has documented the range of oral storytelling styles among children who are speakers of African American English, and Gee (1989) has examined relations between these storytelling styles and more complex literary narratives.

### *The Salience of the Social Organization of Learning Environments*

Among the big ideas we have attempted to convey is the importance of how learning environments are organized to optimize engagement, rooted in understanding the importance of social relationships, and of emotional attributions in signaling opportunities for self-efficacy and a sense of belonging. These principles are well demonstrated in the infant studies, which shows how fundamental they are to human beings. At the same time, studies of robust learning in everyday settings exemplify how learning across the life-span is also an outgrowth of distributed sources of support. Scribner's (1984, 1985) studies of dairy factory workers document how reasoning is socially distributed across people, objects, and tools, and that the knowledge being deployed embodies rich mathematical problem solving. Rose's (2001) examination of the social organization of learning in waitressing illustrates the distribution of supports, but equally the multi-dimensional nature of the knowledge being deployed and the ways the efficiencies (e.g., on deploying limited working memory) are distributed.

Other studies integrate cognitive, social, and phenomenological goals in designed learning environments. Gutiérrez's (Gutiérrez et al., 2009) longitudinal Migrant Student Project worked with high school students from migrant families in California during summer months across years on the UCLA campus, supporting students in seeing the campus as accessible to them, and that they belong. Students examined sociological texts interrogating political, ideological, and economic conundrums that impacted their lives through community cultural practices such as teatro (writing and enacting testimonials based on their work together and their readings). A striking outcome was that the students were overwhelmingly accepted into UC system colleges.

Cole and colleagues, across multiple sites of the 5th Dimension Project (Cole & Consortium, 2006; Vásquez, 2003), recruited cultural resources of elementary school children from non-dominant groups in a modest digital environment of game playing. The program also recruited college students as mentors, who came to learn directly about the language and intellective resources these children brought to problem solving. Relationship building, supports for self-efficacy, and the recruitment of students' cultural repertoires were central to program success. The research found strong impacts across sites on literacy development in the schools students attended, although the project did not work directly in them. Winn (2010) has documented restorative justice practices, including in sites with pre-incarceration adolescent girls, where literacy practices were employed to facilitate relationship building and identity wrestling, again recruiting everyday knowledge and repertoires of youth from minoritized communities.

Collectively, these studies illustrate how attention to relationship building, socializing efficacious identities, recruiting prior repertoires of knowledge and language, especially among youth and adults from minoritized communities, have achieved positive academic and psycho-social outcomes. They illustrate further how knowledge development unfolds in diverse environments that were designed to recruit repertoires of prior knowledge.

## *Re-visiting Our Understanding of Culture*

All of these programs of research illustrating the recruitment of everyday repertoires take place in communities that represent what some call non-dominant communities. They serve well as exemplars because they help us interrogate one of the conundrums around how research communities, and other institutions of power, conceptualize the affordances of different cultural practices. The history of scientific racism that we briefly discussed in the Introduction typically used biological explanations to justify assumptions about hierarchies of human communities. Those historical efforts have been followed by "deficit theories" based on deficit attributions ascribed to practices associated with minoritized communities and those living in poverty (Bereiter & Engelmann, 1966; Herrnstein & Murray, 1994; Payne, 1999). Yet, diversity of pathways of human development is one of the powerful insights we gather from examining more modern studies of brain science and human evolution. Diversity of pathways is normal and indeed generative. Moreover, people belong always to multiple cultural communities, each with different affordances and different meanings and significance for the individual. Lamination is a useful metaphor for thinking about the ways that cultural practices and beliefs disperse across contexts (e.g. Alim's, 2009, examination of rap in the USA, China, South Africa).

## Conclusions

We have argued for the need to understand the complex interactions among biological processes (including neuro-physiological processes) derived from our evolutionary roots as these are taken up, adapted, and transformed through people's participation in different cultural practices, within and across time periods. We have shown that these processes are so fundamental to human beings that they are already evident in infancy. We offer the metaphor of the braid of human development to capture these intricate and complex intertwinings. There is still much to be learned about how these processes operate, including a deeper understanding of the important function(s) that the diversity of culture and environments have in human development. This challenge cannot, however, be taken up without first acknowledging that a key feature of human uniqueness, and a source of strength of the human species, is simply this: Our development across the lifespan, and our past and future survival, are centrally connected to our participation in diverse cultural practices.

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