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Developmental Variability and Developmental Cascades: Lessons From Motor and Language Development in Infancy

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Abstract

The first year of life is punctuated by explosions of growth in motor and language abilities. This is not a coincidence. The notion of developmental cascades provides a conceptual framework for considering ways in which advances in one component of a developing system can exert far-reaching and lasting change in other domains. In this article, I review evidence for the cascading effects of early motor advances on the developing communication and language system and describe how differences in the timing of these advances may have consequences for these effects.

Keywords

infancy, motor development, language development, developmental cascades, autism

Babies' first words are among the most eagerly awaited events of infancy. Because first words are an impressive accomplishment in their own right, it is easy to lose sight of the fact that this achievement is firmly embedded in advances and refinements in another domain, the motor system. During the first year, infants begin to reach for and explore objects, sit independently, crawl, stand, cruise, and walk—achievements that transform the way they experience their own bodies and the objects and people with whom they interact. These transformations have significant implications for the developing language system.

Historically, language and motor development were studied in separation. Indeed, to demonstrate that language advances are not simply a product of neuromotor maturation, early child-language researchers deliberately excluded motor development from consideration as a potential influence on language (see Iverson, 2010). Yet this approach is completely disconnected from the reality that development occurs in and through mutually interacting systems (e.g., Thelen, 2002). As a result, there has been a recent surge of interest in studying links between motor and language development in infancy and in exploring the downstream, cascading effects of motor achievements on infants' developing language skills. Overall, this work has revealed that the acquisition of new motor skills provides infants with enhanced access to their environments and new opportunities for learning; this then sets the stage for progressively more sustained and sophisticated interactions with objects and people that support the development of language.

This view of cascading developmental effects has implications for how to think about the consequences of early-emerging developmental variabilities and delays. My colleagues and I have used this framework to guide a series of longitudinal studies of infants who have an older sibling with a diagnosis of autism spectrum disorder (ASD) and thus an elevated likelihood (EL)[1] of developing ASD (Ozonoff et al., 2011) and other developmental differences (Charman et al., 2017). Our strategy, illustrated in Figure 1, has been to follow EL infants from very early in life to the age of 36 months, when ASD or language delay can be reliably identified. We also typically collect data from a comparison sample of infants with typical ASD likelihood (TL infants; younger siblings of neurotypically developing children).

Using a combination of clinical and standardized assessments administered at age 3, we classify EL infants into three outcome groups: (a) infants who receive an

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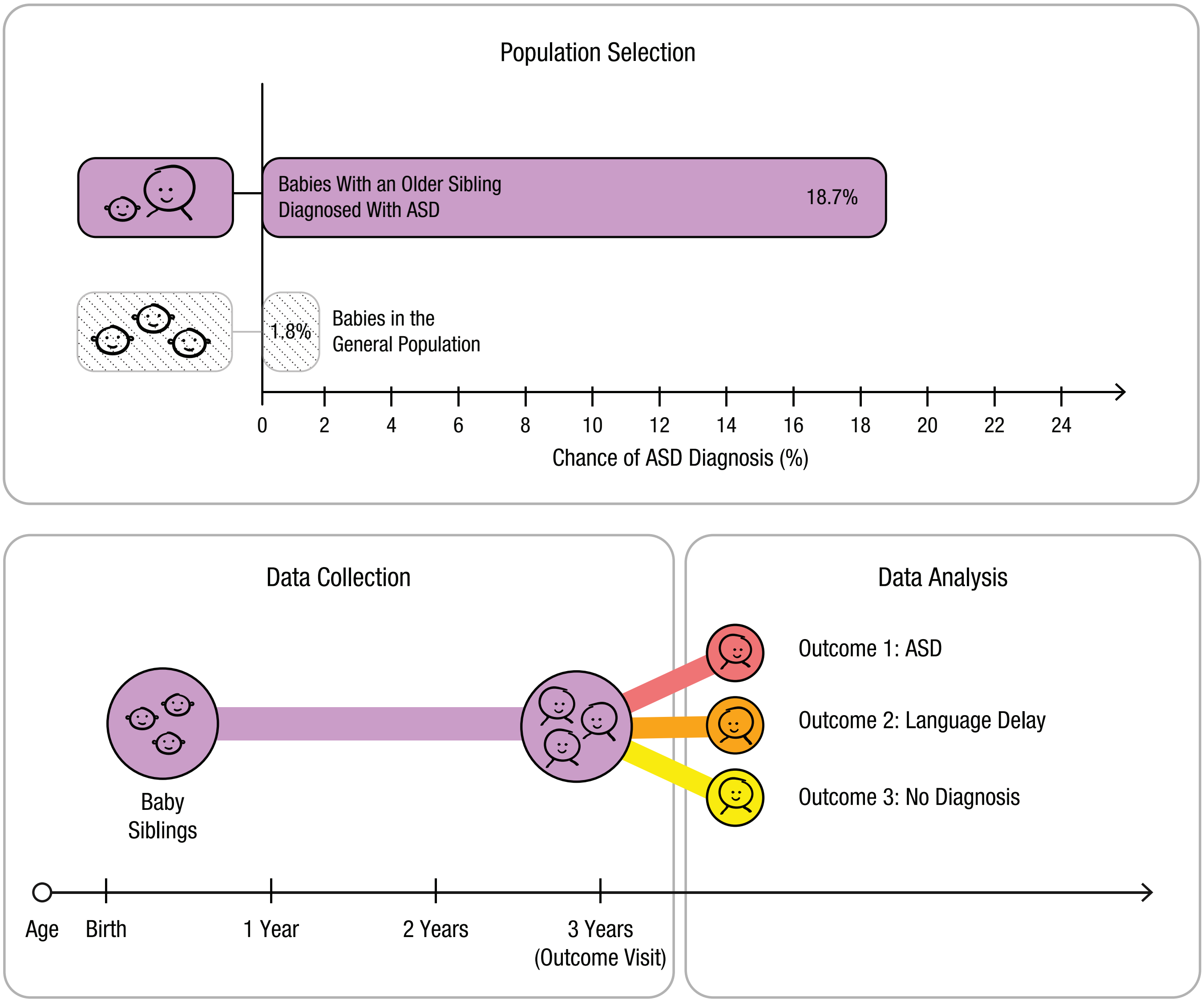

Fig. 1. Depiction of the rationale (upper panel) and general strategy (lower panel) for longitudinal studies of infants with an older sibling diagnosed with autism spectrum disorder (ASD). Because the autism recurrence rate for these *baby siblings*, or *elevated-likelihood* infants, is 18.7% (Ozonoff et al., 2011), about 10 times the 1.8% base rate in the general population, it is possible to follow a relatively small sample (e.g., 133 infants) longitudinally from early infancy to obtain a subgroup (e.g., approximately 24) of infants who receive an ASD diagnosis at age 3 that is large enough to study. In addition, a substantial subgroup of baby siblings who do not receive an ASD diagnosis at age 3 will have language delay (Charman et al., 2017). Once outcome status at age 3 is known, researchers can return to the data gathered earlier to determine whether there were developmental differences between those infants who were later given an ASD diagnosis, those who later exhibited language delay, and those who received no diagnosis.

ASD diagnosis, or EL-ASD infants; (b) infants with language delay but no ASD diagnosis, or EL-LD infants; and (c) infants with no diagnosis. EL-LD and EL-ASD infants have become a focus of our research because they exhibit heightened variability in both motor and language development, and a substantial number show early delays in motor development.

In this article, I discuss what we have learned from EL infants about cascading influences of early motor development on the emergence of communication and language. After describing the concept of developmental cascades and its implications for the study of developmental delay and difference, I review current evidence for the cascading effects of development and delay in sitting and walking on aspects of emerging communication and language.

Developmental Cascades

That development is inherently complex is uncontroversial. However, developmental scientists often minimize this complexity by focusing on developmental

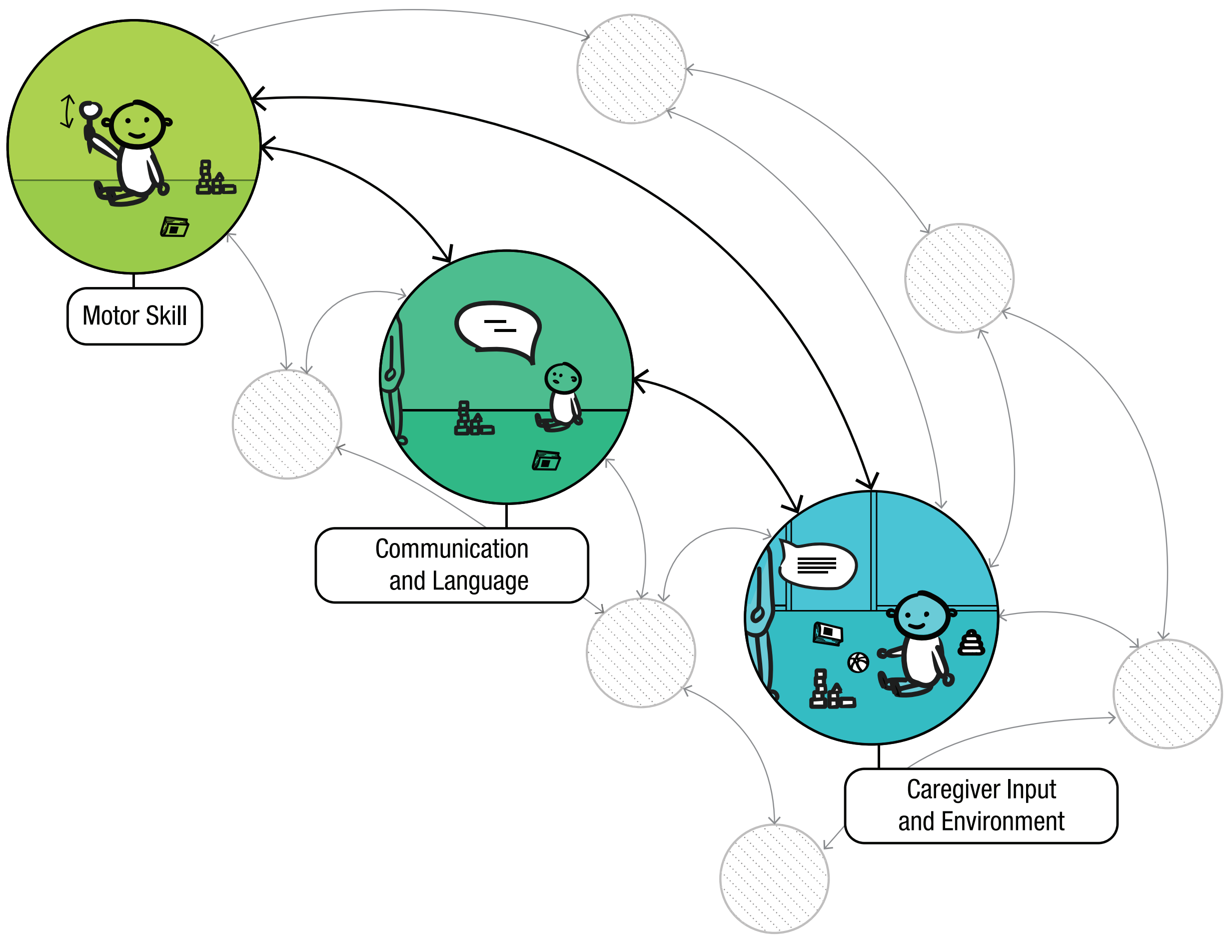

Fig. 2. Schematic of one of the developmental cascades discussed in this article. Advances in motor skill (independent sitting, object manipulation) have cascading effects on infants' developing communication systems (sitting supports object-focused interactions with social partners). A moving, active infant who is engaged with objects and other people elicits rich communicative input from caregivers. Moreover, these transactions at any given moment are reciprocal, as indicated by the bidirectional arrows. For example, just as advances in an infant's motor and language skills change the infant's environment, the environment can have cascading effects on the infant's developing motor and language skills. A caregiver may notice the infant's increased and more effective exploration of objects and thus provide additional or more complex objects to the infant; as the infant plays with those objects, opportunities for communication about them arise, and this stimulates additional caregiver-infant exchanges around the objects and further opportunities for the infant to act. Finally, all of these cascades unfold in developmental time. As change occurs in one system, the activity of other systems and the infant's interactions with the environment are also changing, which leads to further changes within and across systems over time. Shaded gray circles represent other systems that are also changing during development but are not the focus of this article.

change in a domain of interest studied in isolation. Although this approach has yielded valuable data, it ignores an important fact of ontogenesis: In a complex system, developmental domains do not, in fact, exist in isolation. At any given moment in time, change is occurring both within and across multiple domains, as the child interacts with an environment that is also constantly changing (Fig. 2). Developmental changes in one domain can have far-reaching, cumulative, cascading effects on development in others—even those that are seemingly unrelated—and on the environment in which development in those domains occurs. These effects can be direct or indirect; they can be multidirectional; and they can span multiple timescales (momentary, developmental; Thelen & Smith, 1994). This is the notion of *developmental cascades*, and it provides a valuable framework for conceptualizing individual variability and change over time (Masten & Cicchetti, 2010).

Although empirical support for this theoretical framework has been somewhat limited until relatively recently, it has a rich history in the field of developmental science. The contemporary articulation of the developmental cascades perspective owes much to work of Gilbert Gottlieb, Esther Thelen, and Joseph Campos. In outlining a probabilistic-epigenesis view of development, Gottlieb (1983) highlighted the fact that genetic activity is both influenced by and dependent on the influences of neural activity, behavior, and the physical, social, and cultural aspects of the environment, and that behavioral development reflects continuous interactions at these different levels of analysis. In developing a dynamic systems perspective, Thelen (1995) argued that "developmental change . . . arises within a context as a product of multiple, developing elements" (p. 82; see also Thelen, 1992). Each component of the developing system has its own trajectory of change, but the interdependence between subsystems means that the activity of one component alters the trajectories of the others. Thelen's work on the stepping reflex and the development of reaching provides elegant empirical illustrations of these principles. Finally, Campos and his colleagues (e.g., Campos et al., 2000) have provided detailed characterizations of links among the onset of crawling, locomotor experience, changes within the infant in other domains (e.g., perception, socioemotional development), and changes in the organization of the infant-caregiver dyad.

The idea of developmental cascades also provides a rich perspective from which to study the potentially far-reaching effects of emerging differences and delays in one domain of development on development in other domains and on the child's environment. Despite their inherent complexity, developmental delays and differences are often conceptualized as characteristics of the child. By contrast, thinking in terms of developmental cascades invites consideration of the potentially far-reaching effects of emerging differences and delays in one domain on development both within that domain and in other domains and on the child's environment (e.g., Karmiloff-Smith, 1998). In our work, my colleagues and I have used this framework to explore whether even relatively small perturbations in motor development, a domain not traditionally linked to language and communication, may trigger a cascade of direct or indirect downstream effects on the developing communication and language systems.

Two Developmental Cascades: The Transition to Sitting and the Onset of Walking

In our longitudinal studies, we have harnessed the extensive variability observed in motor and language development in EL infants to demonstrate that delays in these domains have cascading, far-reaching developmental consequences.

Sitting, object exploration, communication, and caregiver input

Although there is surprisingly little direct evidence on the full pathway relating sitting, object exploration, caregiver input, and communication in neurotypically developing infants, the literature on neurotypical development allows us to piece together the following story. When infants begin to sit without support, they gain a new and expanded view of their surroundings that increases their visual access to the physical and social environment. With hands no longer used for support and free to move, infants can combine looking at objects with holding, mouthing, and transferring them to learn about their properties, construct categories foundational for word learning and language, and elicit relevant language input from adults, because caregivers are more likely to label objects when they are being held, looked at, and manipulated by the infant (West & Iverson, 2017).

How might this cascade unfold in EL infants? As a group, EL infants achieve the independent-sitting milestone later than TL peers, and even after the milestone has been achieved, they spend significantly less time in this posture (Leezenbaum & Iverson, 2019). EL infants, in other words, are slower to consolidate sitting skills (i.e., coordinating balance and perceptual information in the upright position). This reduces their opportunity to explore objects in ways that permit effective information extraction because exploring objects while sitting is, in effect, a multitasking problem. Infants must maintain balance and remain upright as they reach for, grasp, and manipulate objects using destabilizing movements of the hands and arms that place significant demands on posture control. When infants work harder to remain stable while sitting, they have fewer resources available to devote to simultaneous object exploration (see also Woods & Wilcox, 2013). And, indeed, EL infants new to unsupported sitting spend less time grasping objects than their TL counterparts do (Mlincek et al., 2020).

How might this reduction in object exploration impact the development of communication and language? One area where these effects appear to be evident is the development of play actions and gestures involving object manipulation (e.g., holding a phone to the ear; Sparaci et al., 2018). These actions and gestures emerge toward the end of the first year, are produced during interactions with caregivers, index emerging symbolic abilities, and are closely related to the development of language (Bates et al., 1979). In EL-LD and EL-ASD infants, who have known vulnerabilities in communication and language, growth in actions and gestures involving object manipulation from the age of 8 to 14 months is slowed relative to that of peers, and repertoires are smaller (West et al., 2020). Because caregivers frequently respond verbally to infants' actions and gestures (Bornstein & Tamis-LeMonda, 1989), slower growth and smaller repertoires reduce caregivers' opportunities to provide verbal input to the infant (Leezenbaum et al., 2014).

In addition, caregivers' responses often contain language about the object on which the infant is currently focused. This makes these responses powerful moments for word learning, and any reduction in the infant's opportunities to access these moments has cascading implications for language learning. Thus, for example, both EL-LD and EL-ASD infants show slower growth in expressive vocabularies across the first 2 years than do TL infants (Iverson et al., 2018), and EL-ASD infants, compared with TL and other EL infants, show different relations between actions and gestures, on the one hand, and word comprehension, on the other (Roemer et al., 2019). Thus, although early differences in the development of sitting and object exploration may seem, at first glance, to be far afield from language development, the pathway just described suggests that these differences may significantly influence the emergence of early communicative behaviors and caregiver input in ways that may not benefit language learning.

Walking, language, and caregiver input

The emergence and development of walking once again radically alters infants' experience with and ability to explore the environment. Whereas the worldview of crawling infants is dominated by the floor, walking infants have enhanced visual access to distally located and elevated objects and caregivers' faces (Kretch et al., 2014). They can explore environments more efficiently, carry objects while locomoting more frequently, and cover greater distances while doing so (Adolph & Hoch, 2019).

In neurotypical development, this transition to walking is also accompanied by qualitative and quantitative shifts in the infant's communication. When infants begin to walk, they become more active in initiating social interaction (Clearfield et al., 2008), spend more time interacting with caregivers, produce more adult-directed vocalizations and gestures (Clearfield, 2011), and engage in more moving bids (showing or offering an object while moving; Karasik et al., 2011). Combining communicative behaviors with locomotion enhances communicative potential by initiating moments of shared attention to objects known to be valuable for language learning (e.g., Tomasello & Farrar, 1986). It is not surprising, therefore, that there is growing evidence of increased language growth following the onset of walking independent of infant age (e.g., Walle & Campos, 2014).

Although a boost in language growth occurs after walking begins, the mechanisms that underlie this boost remain unknown. One possibility is that it arises at least in part from changes in adults' communicative behavior triggered by the emergence of the infant's walking. Caregivers can now respond to more sophisticated and directed communicative bids by the infant (West & Iverson, 2021), and they appear to do so with more sophisticated language. Thus, in one study, mothers of 13-month-old crawling infants and mothers of 13-month-old walking infants responded in similar ways to stationary social bids, but in response to moving bids, the mothers of walking infants were significantly more likely than the mothers of crawling infants to respond with language encouraging their infant to act on the objects (Karasik et al., 2014). Because walking infants produced more moving bids, they heard more action-related language than did crawlers. In addition, once infants begin to walk, caregivers' speech is more likely to contain object labels and action verbs during bouts of walking than during bouts of crawling (Schneider & Iverson, 2021). In short, the onset of walking produces a cascade of multidirectional interactions influencing the development of the infant's communication and language as well as the infant's language environment.

How might this cascade be evident in the development of EL infants exhibiting delays in both gross motor development and communication and language development? To address this question, we examined growth in word comprehension in relation to walking experience (West et al., 2019) across seven monthly observations spanning the transition from crawling to walking. EL-LD and EL-ASD infants, on average, began walking about a month and a half later than TL infants (13.14 and 13.15 months, respectively, vs. 11.76 months). Across all observations, according to parent report, TL infants added 11.35 new words per month, on average, but this increase was attenuated in the EL-LD group (6.2 words per month) and radically attenuated among the EL-ASD infants (1.85 words per month). We also examined change in vocabulary from the session prior to the onset of walking to the final observation, to assess additional growth as the infants gained walking experience. On average, the number of new words understood per month increased at a rate beyond the baseline rate by 18.78 words in the TL group and by 7.65 words in the EL-LD group; the EL-ASD group showed no significant additional vocabulary growth after the onset of walking (see Fig. 3, which also shows results for EL infants with no diagnosis at age 3). Thus, despite the fact that the EL-LD and EL-ASD infants in this sample were older than the TL infants at the onset of walking, it did not appear to trigger the same boost in vocabulary growth seen in the TL infants.

Why might we have observed an attenuated relationship between the onset of walking and a vocabulary boost in EL-LD infants and the absence of such a relationship in EL-ASD infants? One possibility is that major shifts in infant communication described for neurotypical

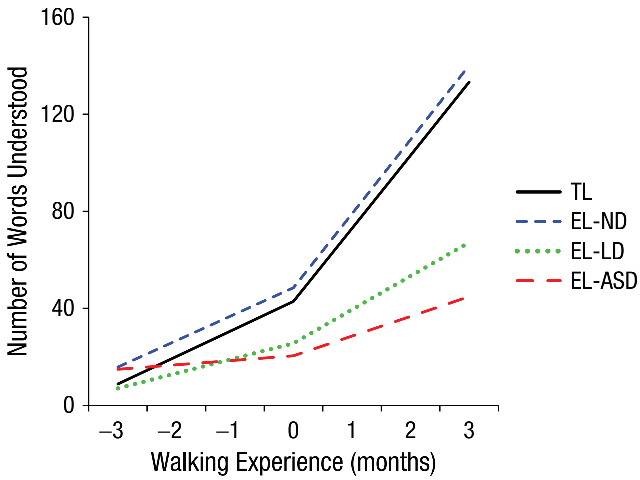

Fig. 3. Estimated growth trajectories for the number of words understood over seven monthly observations surrounding the onset of walking. Results are shown for younger siblings of neurotypically developing children (TL infants) and three subgroups of infants with an elevated likelihood of autism spectrum disorder (ASD): those who had a diagnosis of ASD at age 3 (EL-ASD infants), those who exhibited language delay but did not have a diagnosis of ASD at age 3 (EL-LD infants), and those who had no diagnosis at age 3 (EL-ND infants). From "The Relation Between Walking and Language in Infant Siblings of Children With Autism Spectrum Disorder," by K. L. West, N. B. Leezenbaum, J. B. Northrup, and J. M. Iverson, 2019, *Child Development*, *90*(3), p. e364. Copyright 2019 by John Wiley and Sons. Reprinted with permission.

infants at the onset of walking may be less evident in EL-LD and EL-ASD infants, a possibility supported by a recent study. Whereas TL infants doubled their rates of vocalization, gesture, and adult-directed communication across the transition to walking, patterns of change for EL-LD infants were modest, and EL-ASD infants showed almost no growth in any of these behaviors over time (West, 2019). In the absence of an explosion of communication at the transition to walking, an infant's opportunity to receive sophisticated linguistic input from caregivers, input well tailored to the child's own communications, is reduced.

A second possibility has to do with how infants use their new walking skills to expand access to the environment. As does the transition to sitting, the transition to walking demands allocation of attentional resources at the expense of those available for other tasks (Berger et al., 2017). For EL infants with motor delays, walking may require even greater resources over a more extended period of time. Slower improvement in walking skill may therefore equate to less frequent and effective use of walking to explore the environment and difficulty in integrating walking with communicative behavior to produce the moving communicative bids most effective in eliciting sophisticated responses from caregivers and enriching the language-learning environment.

Conclusion

The first 2 years of life are punctuated by explosions of new skills and behaviors. As infants become increasingly skilled actors and movers, they also become more skilled communicators. This is not a coincidence. All of this change takes place in an infant who is engaged in a constant back-and-forth with an environment changing in response to the infant's actions and communications. Action and movement, in other words, support environmentally mediated opportunities for communication and learning that are critical for the development of language. What happens, then, when there is early variability and delay in the emergence of fundamental motor skills? From a developmental cascades perspective, this variability and delay has consequences for the child's interactions with the objects and people in the environment, and those consequences, in turn, have consequences for the development of language. This perspective provides a framework for considering these consequences as they unfold, over time, in the complex, dynamic system that is the development of the child.

Recommended Reading

Adolph, K. E., & Hoch. J. E. (2019). (See References). A comprehensive, highly accessible review of what is known about infant motor development and its relevance for psychology as a field.

Iverson, J. M. (2018). Early motor and communicative development in infants with an older sibling with autism spectrum disorder. *Journal of Speech*, *Language*, *and Hearing Research*, *61*(11), 2673–2684. A review discussing motor, communication, and language development in infants with an elevated likelihood of autism spectrum disorder and the interrelations among these areas of development in more detail than in the current article.

Karmiloff-Smith, A. (1998). (See References). A classic article representing an early articulation of the view that understanding delayed or atypical development requires an understanding of the dynamic, complex, and multiply determined nature of development.

West, K. L. (2019). Infant motor development in autism spectrum disorder: A synthesis and meta-analysis. *Child Development*, *90*(6), 2053–2070. Reports evidence from two meta-analyses indicating that (a) motor ability differs significantly in infants with autism spectrum disorder compared with neurotypical infants and (b) motor ability and communication are related in infants with autism.

Transparency

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Note

1. Literature focusing on the infant siblings of children with ASD has typically referred to them as “high risk,” referring to a heightened biological probability of receiving an eventual ASD diagnosis. Unfortunately, the terms “risk” and “high risk for ASD” are deeply intertwined with the medical model view of autism, and thus they carry necessarily negative connotations (e.g., Fletcher-Watson et al., 2017). For many autistic people, autism reflects (sometimes severe) impairments in a host of different skills, but for many others, autism is a valued part of their identities (e.g., Dunn & Andrews, 2015), and for these people, the term “risk” and person-first language are problematic and stigmatizing. For these reasons, in this article, I use the terms “elevated likelihood” and “EL infants” when referring to infants with an older sibling with an ASD diagnosis.

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