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When language comes too late: Developmental implications of delayed sign language exposure

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Abstract

Deaf children born to hearing parents—who represent the majority of deaf children—often do not have full access to the spoken language input around them and may not receive early exposure to a sign language, placing them at risk for delayed access to a natural language. When deaf children have early access to an accessible language environment, they can achieve developmental milestones comparable to their hearing peers. But delayed or inconsistent access to accessible language may affect language development and related cognitive and socioemotional outcomes. In this article, I synthesize evidence from around the world on delayed exposure to sign language within children's broader accessible language experiences and discuss spatial cognition as a particularly informative domain for understanding how language access may shape broader cognitive development. I argue that equitable language development for deaf children requires policy shifts toward universal access to bilingual-bimodal interventions as the foundation of ethical and effective support systems.

Keywords early language deprivation, language development, cognitive and socioemotional development, deaf children

Children acquire language with remarkable ease when exposed consistently and early in life (Hagoort, 2019). However, deaf children born to hearing parents, who represent approximately 95% of the deaf population (Mitchell & Karchmer, 2004), are at risk of facing profound challenges in accessing linguistic input from birth. Restricted or inconsistent access to an accessible language during early development may create cascading developmental risks, beginning with language and extending to cognitive (e.g., Beer et al., 2010; Gentner et al., 2013; Hall et al., 2017; Kritzer, 2009; Peterson, 2004; Santos & Cordes, 2022; Shusterman et al., 2022; Walker et al., 2024) and socioemotional (e.g., Atik & Karadöller, 2025; Chapman & Dammeyer, 2017) domains. In this article, I synthesize these interconnected challenges and outline evidence-based pathways to move forward.

Language acquisition trajectories of deaf children

Typically developing children achieve critical linguistic milestones in a predictable order. For instance, babbling emerges at 4 to 6 months, first words at 10 to 12 months, and two-word combinations around 2 years, culminating in near-adult sentence complexity by 4 to 5 years (Siegler & Alibali, 2004). Deaf children with deaf parents who are exposed to sign language from birth in the home environment develop language in ways that parallel those of hearing children. They achieve typical developmental milestones, including manual babbling (Marentette & Mayberry, 2000), the production of first signs (Newport & Meier, 1985), and age-appropriate grammatical complexity (Baker & Woll, 2009; Meier & Newport, 1990; Morgan, 2014; Ortega, 2017; Petitto & Marentette, 1991). These parallel trajectories demonstrate conclusively that the human capacity for language acquisition is not tied to spoken language but can unfold across different modalities when children have access to natural language from birth (Karadöller et al., 2024a, 2024b, 2025a, 2025b; Meier & Newport, 1990; Newport & Meier, 1985; Petitto & Marentette, 1991). Like all natural languages, sign languages are fundamentally valuable for human development; for deaf children in particular, their distinct advantage lies in being perceptually accessible from the beginning of life; enabling natural language acquisition; and supporting later access to communication, education, and social participation (Hall et al., 2019).

Many deaf children are at risk for delayed or incomplete access to a fully accessible language (Lillo-Martin & Henner, 2021; Lillo-Martin et al., 2020; Mayberry, 1993). When a deaf or hard-of-hearing child is born into a hearing family, the child's accessible communication needs may not match the language environment at home. That is, deaf children may not fully access the spoken language around them, even with hearing aids or cochlear implants, because these devices may not provide optimal hearing outcomes immediately or may not always result in optimal

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hearing or speech outcomes (Hall et al., 2019; Kral et al., 2016). But the degree of risk varies with children's hearing levels and auditory access, with children with limited access to spoken language facing greater urgency for early sign language support.

Moreover, hearing parents typically do not know a sign language to communicate with their children (Mitchell & Karchmer, 2004). For many hearing parents, learning to sign is a second-language learning process that requires time, structured instruction, sustained support, and opportunities to use the language in everyday family interactions (Chen Pichler, 2021, 2022; Lieberman et al., 2024; Oyserman & de Geus, 2021; Pontecorvo et al., 2025; Snoddon, 2015, 2020; Zarchy & Geer, 2023). Thus, although hearing parents can learn sign language when appropriate resources are available, their children often do not receive rich and immediate sign language input during the earliest periods of their development (Humphries et al., 2012). For some children, particularly when early family supports are limited or unavailable, enrollment in a deaf school may mark the first sustained exposure to a signing environment (İlkbaşaran, 2015). Before such sustained exposure to a conventional language, many deaf children with hearing parents rely on *homesigning*, gestural communication systems developed within the family that, while functional for basic interaction, are very idiosyncratic and lack the structural properties of a full natural language (Goldin-Meadow, 2013).

The risk of delayed or inconsistent language access is shaped not only by families' hearing status but also by unequal access to support systems. These inequalities do not map neatly onto simple distinctions between families in low- and high-income countries; rather, they operate across and within national contexts through differences in socioeconomic resources; geography; school placement; access to hearing technologies; family-centered sign language instruction; and opportunities to interact with fluent signing peers, teachers, and deaf adults (Murray et al., 2019; Terry & Rance, 2023; World Federation of the Deaf, 2024).

Next, I examine how delayed or inconsistent access to an accessible language relates to language, cognitive, and socioemotional development, then present empirical evidence from around the world outlining pathways forward.[1] Because much of the evidence on delayed sign language exposure concerns spatial language and spatial cognition, with emerging work also highlighting numerical development, I treat these domains as theoretically informative cases for examining how early language access may shape broader developmental outcomes.

Developmental risks associated with delayed or inconsistent sign language exposure

Although my focus is on the developmental implications of delayed sign language exposure, I interpret these outcomes within children's broader early language experiences, in which the timing of exposure to accessible language is one important component rather than an isolated determinant (Hall et al., 2019; Mayberry et al., 2024; Mayberry & Kluender, 2018). Early access to an accessible language provides a critical foundation for language (Karadöller et al., 2024; Mayberry et al., 2002), cognitive (Flaherty & Senghas, 2011; Langdon et al., 2020; Schick et al., 2007; Spaepen et al., 2011), and socioemotional (Chapman & Dammeyer, 2017) development. In contrast, delayed or inconsistent access has been associated with less robust outcomes across language (Boudreault & Mayberry, 2006; Hall et al., 2019; Karadöller et al., 2017, 2021, 2024; Mayberry, 1993; Newport, 1990), cognitive (Beer et al., 2010; Kritzer, 2009; Peterson, 2004; Santos & Cordes, 2022; Shusterman et al., 2022; Walker et al., 2024), and socioemotional (Atik & Karadöller, 2025; Mann et al., 2015) development. The studies I review vary in children's hearing levels, age of first exposure to accessible language, quality of input, family language background, and educational placement, making it difficult to identify a single estimate of the magnitude of delay. Instead, they point to patterned risks in later-emerging and linguistically mediated domains.

Implications of delayed sign language exposure for language development

Some studies indicate resilience in early lexical development and basic combinatorial patterns after delayed exposure to sign language (Berk & Lillo-Martin, 2012; Ramirez et al., 2013) as well as convergence in basic word order under some conditions (Cheng & Mayberry, 2019; Mayberry & Kluender, 2018), but in studies comparing late sign-learning children and adolescents with children who have signed from birth (with groups matched for duration of sign language exposure), this convergence remains domain specific and does not extend uniformly to length of utterances or grammatical complexity. For instance, delayed sign language exposure has been associated with less robust performance in language development across several domains (e.g., Lillo-Martin & Henner, 2021; Lillo-Martin et al., 2020), with effects persisting into adulthood (e.g., Boudreault & Mayberry, 2006; Karadöller et al., 2017, 2021, 2024; Mayberry, 1993). Deaf adults who acquired sign language during childhood demonstrated less robust performance than did deaf adults who acquired sign language from birth in several aspects of linguistic processing and production, including grammatical judgments (Boudreault & Mayberry, 2006), recall of complex sentences (Mayberry, 1993), and the use of complex linguistic structures to encode spatial relations (Karadöller et al., 2017, 2024) and motion events (Newport, 1988, 1990).

For instance, in one study, when describing static spatial relations between objects (e.g., a pencil that sits to the left of a jar), signers predominantly used structures called classifier constructions that represented the size and shape properties of objects as well as the spatial configuration among them (Emmorey, 2002; Perniss et al., 2015; Zwitserlood, 2012). In these constructions, handshapes depicted the size and shape properties of objects (e.g., an elongated index finger for a pencil, a round handshape for a jar) and the positioning of the hands in relation to each other depicted the spatial configurations of the objects. Although these constructions map visual properties onto signing space in a relatively straightforward and highly iconic way, they are morphologically complex because they require signers to select appropriate handshapes and coordinate both hands in space.

In more recent work, 8-year-olds who began to sign late and had 2 years of exposure to sign language at school used classifier constructions significantly less frequently than their age-matched peers who learned to sign from birth; instead, they use simpler

[1] For the sociodemographic characteristics of the studies reviewed herein, please see Table S1 in online materials.

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forms, such as index finger points, to indicate the locations of objects (Karadöller et al., 2017, 2024). These patterns do not necessarily indicate a failure to communicate spatial relations; rather, they suggest reduced access to morphologically complex conventional forms, with spatial meanings conveyed through less specified yet communicatively viable strategies. This interpretation echoes the distinction that communicative success and conventional linguistic structure should not be conflated, and that reduced mastery of conventional forms does not imply an absence of meaningful communication (Koulidobrova & Chen Pilcher, 2021).

In contrast, studies of deaf children without access to systematic language input who did not reliably produce even pointing gestures when describing spatial locations (Gentner et al., 2013) illustrate a more severe end of the language access continuum. Overall, enduring differences in the complex aspects of language development have been linked to delayed or inconsistent access to accessible linguistic input during early development (Hall et al., 2019; Lillo-Martin & Henner, 2021; Lillo-Martin et al., 2020). This pattern is consistent with critical-period accounts, which suggest that early language experience interacts with maturation to support later linguistic development (Mayberry, 2007; Mayberry & Kluender, 2018). Recent evidence further points to an inflection point around the end of early childhood for the development of complex sentence structure (Mayberry et al., 2024). Taken together, these findings suggest selective rather than uniform language delays, with greater vulnerabilities in later-emerging, morphologically complex, and conventionalized structures.

Implications of delayed sign language exposure for cognitive development

These linguistic vulnerabilities cascade into broader cognitive systems, with spatial and numerical cognition emerging as interconnected domains that appear particularly sensitive to delayed or inconsistent language access. Thus, delayed or inconsistent exposure to a sign language has been associated with variability in executive function (Hall et al., 2017; Hauser et al., 2008), working memory (Beer et al., 2010), spatial cognition (Gentner et al., 2013; Karadöller et al., 2021; Pyers et al., 2010), and numerical development (Kritzer, 2009; Santos & Cordes, 2022; Shusterman et al., 2022; Walker et al., 2024). Among these cognitive domains, the latter two may be particularly sensitive to delayed or inconsistent language access since both rely on relational representations often supported by language, such as mappings between objects, locations, and quantities (Loewenstein & Gentner, 2005; Spelke, 2017).

Early exposure to an accessible language may play a foundational role in the development of spatial cognition, particularly by helping children encode, compare, and retain relational information about objects and locations. In one study, deaf children who lacked early access to a conventional language performed significantly worse than hearing peers on nonlinguistic spatial mapping tasks, underscoring the role of language in structuring relational spatial representations (Gentner et al., 2013). In another study, of Turkish Sign Language, children's use of spatial language, encompassing sign, speech, and speech plus gesture, significantly predicted their subsequent spatial memory performance (Karadöller et al., 2021). This finding suggests that richer spatial linguistic encoding may support the formation and retention of spatial representations, with implications for children who experience delayed access to sign language. In yet another study, of Nicaraguan Sign Language, individuals with access to a more conventionalized spatial language system outperformed signers exposed to an earlier, less conventionalized form of the language on spatial reasoning tasks involving landmark and relational representations (Pyers et al., 2010). Together, these findings suggest that delayed or inconsistent access to linguistic structures for encoding space may limit opportunities to develop and use relational spatial representations efficiently.

Numerical development is closely intertwined with language, which provides cultural symbols and concepts for numbers and shapes the mental processes underlying numerical reasoning (Berteletti et al., 2026). This close relation between language and number suggests that delayed or inconsistent access to an accessible language may have important implications for numerical cognition. In a recent study, researchers investigated whether language modality (American Sign Language [ASL] versus spoken English) or the timing of sign language exposure (early versus delayed) were associated with numerical mapping skills (the ability to mentally map numbers onto an internal, spatially organized representation) in 9-year-olds (Walker et al., 2024). While language modality did not affect numerical mapping skills, early language access was a critical predictor of numerical skills for deaf children. Similarly, in another study, researchers examined oral deaf and hard-of-hearing English-speaking preschoolers. Children who did not know a sign language performed less optimally than their hearing peers on numerical discrimination and number knowledge (Santos & Cordes, 2022). However, group differences in numerical tasks disappeared when researchers considered the amount of time children had auditory access to spoken language input through hearing technology. Together, these studies suggest that numerical development is supported not by a particular language modality, but by early, sustained, and sufficiently rich access to a usable language.

Implications of delayed sign language acquisition for socioemotional development

Early and consistent access to sign language has been identified as a key protective factor for the social-emotional development of deaf and hard-of-hearing children (Atik & Karadöller, 2025; Chapman & Dammeyer, 2017; Courtin, 2000; Peterson, 2004). When families establish meaningful sign language communication at home, children are more likely to experience accessible everyday interactions, which support healthier psychosocial and emotional outcomes (Calderon & Greenberg, 2011; Hauser et al., 2010; Humphries et al., 2017). Children's emotional development is closely intertwined with their language development (Kalland et al., 2022), a relation observed not only in typically developing hearing children but also in deaf children exposed to a sign language from birth (Rieffe, 2012; Rieffe & Terwogt, 2006). Research comparing deaf children with late exposure to sign language to hearing peers has documented several differences in emotional development, with late-signing deaf children having more difficulty discriminating (Rieffe, 2012), expressing (Rieffe & Terwogt, 2006), and attributing emotions (Gray et al., 2007). These findings suggest that deaf children with delayed access to a natural language may follow a distinct trajectory of emotional development

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relative to hearing children. However, it remains unclear whether these differences stem from deafness itself, differences in modality between sign and speech, or late language exposure.

To address this question, a recent study compared deaf children exposed to sign language from birth with deaf children who acquired sign language later, examining their emotion recall and their channels of emotional expression (Atik & Karadöller, 2025). After viewing a silent emotion-laden video, 8-year-old late- and native-signing deaf children retold the story in Turkish Sign Language. Late signers recalled fewer emotions and produced fewer signs and facial expressions than native signers, whereas productions of nonsign hand movements and head/body movements did not differ between groups. These results suggest that late exposure to sign language undermines deaf children's ability to retell emotions, highlighting the critical role of early language access in the development of emotion recall and expression. This work also suggests that early access to sign language supports deaf children's social-emotional development, with selective differences in emotional recall and linguistic and facial emotion expression rather than in nonsign bodily channels.

Bimodal-bilingual education and intervention for deaf children and parents

Following diagnosis of deafness, educational approaches vary across contexts, ranging from those that primarily support spoken language to bimodal bilingual approaches that promote both sign and spoken language. Depending on the approach, children may also receive hearing technologies, such as hearing aids, cochlear implants, and speech therapy, although availability, timing, and quality of these supports vary widely (Hall et al., 2019). While hearing technologies and speech therapy benefit some children, spoken language outcomes remain highly variable and frequently suboptimal for most deaf children (Ching et al., 2017; Dettman et al., 2016, 2021; Gagnon et al., 2021; Ganek et al., 2012; Geers et al., 2017; Hall et al., 2019; Humphries et al., 2012; Niparko et al., 2010; Peterson et al., 2010; Pontecorvo et al., 2023; Sosa & Bunta, 2019; Szagun & Schramm, 2016; Wie, 2010; Yoshinaga-Itano et al., 2018), leaving many children at continued risk of language deprivation.

Bilingual-bimodal education (i.e., concurrent exposure to sign and spoken language) emerges as an empirically validated alternative, scaffolding robust language development regardless of auditory capacity (Henner & Robinson, 2023; Pontecorvo et al., 2023). At the same time, studies have raised concerns that early sign language exposure might compromise spoken-language outcomes (Geers et al., 2017; Giraud & Lee, 2007). These concerns are important to address because spoken-language development is a central goal for many families and professionals (e.g., speech language therapists). However, this claim has been challenged by prior critiques (e.g., Lillo-Martin et al., 2023) and by converging empirical evidence that sign language exposure does not necessarily hinder, and may support, spoken and written language development in deaf children (Davidson et al., 2014; Delcenserie et al., 2024; Goodwin & Lillo-Martin, 2019; Hassanzadeh, 2012; Park et al., 2013). Rather, some studies suggest that outcomes are shaped by multiple factors, including auditory access, family input, age at intervention, and the quality and consistency of language support.

Consistent with this view, researchers have found that deaf children with cochlear implants who are exposed to a sign language from birth through deaf signing parents had spoken English outcomes comparable to hearing peers (Davidson et al., 2014; Delcenserie et al., 2024; Goodwin & Lillo-Martin, 2019), with speech articulation skills equivalent (Park et al., 2013) or even superior to (Hassanzadeh, 2012) those of deaf children with cochlear implants who were not exposed to a sign language. Complementing this work, ASL proficiency has been positively associated with written English outcomes among deaf children (Hoffmeister, 2000; Hoffmeister et al., 2022; Mayberry, 2007).

In one study, which assessed children from 8 to 60 months old, researchers directly evaluated two competing claims regarding bilingual language development in deaf children who used cochlear implants: that acquiring ASL might impede the development of spoken English or that ASL exposure may actually support it (Pontecorvo et al., 2023). ASL was positively associated with spoken English vocabulary, with ASL vocabulary explaining unique variance in spoken English vocabulary above and beyond hearing status. Children with larger ASL vocabularies were also more likely to score within the average range on spoken English vocabulary tests for hearing monolingual peers than were children with smaller ASL vocabularies. When considering children's vocabulary outcomes across both languages, the study pointed to a bilingual advantage (Bialystok et al., 2010; Hoff et al., 2012; Pearson et al., 1993).

This pattern also parallels unimodal bilingual development, in which early exposure to two languages is not inherently detrimental and can support successful language development when children receive input in both languages (Hoff, 2015). Although causal interpretations cannot be drawn, these findings are inconsistent with the notion that ASL acquisition hinders the development of spoken English (Geers et al., 2017; Giraud & Lee, 2007) and instead align with empirical evidence that early exposure to ASL can facilitate spoken language outcomes for deaf children (Delcenserie et al., 2024; Hoffmeister, 2000; Hoffmeister et al., 2022; Mayberry, 2007).

When lexical knowledge distributed across both languages is considered jointly, bimodal bilingual children may demonstrate access to a wider range of underlying concepts than monolingual children assessed in a single language. This broader conceptual repertoire is thought to support cognitive processes such as flexible meaning representation and cross-domain integration, while potentially facilitating socioemotional development by enabling more effective communication and social engagement. In this sense, bimodal bilingualism may not function as a developmental impediment, but rather as a resource that supports multiple dimensions of early development in deaf children.

Another approach to mitigating the risk of language deprivation in deaf children involves providing systematic sign language education for hearing parents, as well as providing deaf children with rich, accessible linguistic environments during early childhood and throughout formal schooling (Caselli et al., 2021; Delcenserie et al., 2024; Humphries et al., 2012; Murray et al., 2019; Terry & Rance, 2023). However, for parental sign language education to be effective, families need more than just access to courses. They also need sustained support, consistent professional guidance, and usable learning materials that allow language learning to begin at home and become integrated into regular family

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interactions (Lieberman et al., 2024; Ritmeester et al., 2026; Snoddon, 2015, 2020; Zarchy & Geer, 2023).

Interventions that support hearing parents in learning a sign language should not define success as parents becoming native-like signers when their children are infants. Rather, success should be understood as maximizing children's opportunities for rich, accessible, and sustainable language experiences throughout their development, even when sign language exposure begins after birth. Hearing parents who begin learning a sign language with their children are themselves second-language learners, and their early input will necessarily differ from that of native-signing deaf parents (Chen Pichler, 2021, 2022; Lieberman et al., 2024; Pontecorvo et al., 2025). While evidence for this approach is encouraging, particularly for vocabulary growth when deaf children with hearing parents are exposed to sign language early (Caselli et al., 2021; Delcenserie et al., 2024), we know less about how early parent-provided signing input supports later-emerging, higher-level language abilities. Thus, the effectiveness of parent-focused sign language support likely depends not only on whether sign language is offered, but also on the intensity, duration, accessibility, and integration of that support in everyday family interactions (Ritmeester et al., 2026; Snoddon, 2015, 2020; Terry & Rance, 2023; Zarchy & Geer, 2023).

In a few countries (e.g., Sweden), state-supported parental sign language instruction gives children exposure to the national sign language from an early age (Holmström, 2022). At the same time, such an approach should be considered in light of pediatric cochlear implantation and mainstream education, which have changed many deaf children's access to deaf schools, signing peers, and fluent sign language environments (Dammeyer & Ohna, 2021; Holmström & Schönström, 2017). These shifts illustrate that access to parental sign language instruction and signing environments depends not only on whether such provisions exist, but also on how consistently they are implemented. In many contexts, such supports remain absent, limited, or unevenly implemented despite decades of advocacy by the World Federation of the Deaf, national deaf organizations, and allied stakeholders (World Federation of the Deaf, 2024).

Conclusions

The evidence I have reviewed converges on a central insight: Delayed or inconsistent language input may put deaf children at risk, although the nature and degree of this risk vary depending on children's hearing levels, individuals' auditory access through hearing technologies, family resources, school placement, and opportunities for signed or spoken language input. Such variation is important because delayed language access does not refer to a single experience, but to a continuum ranging from incomplete or inconsistent access to more severe forms of language deprivation. Accordingly, preventing language deprivation requires more than informing families about the benefits of early language access; it also requires recognizing that parental decisions are shaped by medicalized views of deafness (Mauldin, 2014), professional guidance, family values (DesGeorges, 2016; Porter et al., 2018), and practical constraints, while reducing the barriers that families face in accessing spoken and sign language supports (Murray et al., 2019; Terry & Rance, 2023; World Federation of the Deaf, 2024).

The developmental outcomes I have reviewed are shaped not by language modality per se, but by the timing, quality, consistency, and accessibility of children's early language experiences. This broader lens moves the focus beyond a simple early-versus-late distinction to the broader language environments that shape children's developmental outcomes. Therefore, ensuring early, sustained, and inclusive access to sign language through accessible interventions represents not only a linguistic imperative but also a developmental and ethical one.

Early bilingualism confers lifelong socio-communicative advantages, enabling individuals to navigate both deaf and hearing communities with ease. Despite this, systemic implementation of bilingual-bimodal approaches remains scarce around the world, often due to persistent and outdated biases. In synthesizing empirical evidence on the consequences of delayed sign language exposure to an accessible language across language, cognitive, and socioemotional domains, I argue that equitable development for deaf children requires a policy shift toward universal access to bilingual-bimodal practices as the foundation of ethical and effective support systems.

Supplementary material

Supplementary material is available at *Child Development Perspectives* online.

Author contributions

Dilay Z. Karadöller (Conceptualization, Resources, Writing—original draft, Writing—review & editing)

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Conflicts of interest

None declared.

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