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The interplay between early social interaction, language and executive function development in deaf and hearing infants

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ABSTRACT

In this article, we review the influence of early social interaction on the development of executive function and language in infants. We first define social interaction, executive function and language and show how they are related in infant development. Studies of children born deaf are used to illustrate this connection because they represent cases where there has been a disruption to early social interaction and the development of intersubjectivity. Unlike other groups, the disturbance to development is known to be largely environmental rather than neuro-biological. This enables us to more accurately tease apart those impacts on EF that are associated with social interaction and language, since the potential confounds of disordered cognitive development are largely controlled for. The review offers a unifying model for how social, cognitive and linguistic development work together in early human development.

1. Introduction

The focus of this review article is on the interplay between three areas of cognitive development: early social interaction, language, and Executive Functions (EFs) in typically developing infants, and in infants born deaf. Research on deafness can help elucidate the facilitative role of social interaction in infancy on the subsequent development of language and EF. Infant development can be affected by a range of neuro-biological conditions (e.g. Autism Spectrum Disorder). In these situations, early social interaction can be disrupted and linked developments also delayed. The case with infant deafness is somewhat different. Although infant deafness can be complicated by additional disabilities, this only occurs in about 30 % of individuals (Chilosi et al., 2010; Fortnum, Marshall, & Summerfield, 2002). In these children language learning and cognitive development may have a neurobiological cause (e.g. Autism and deafness: Szarkowski, Mood, Shield, Wiley, & Yoshinaga-Itano, 2014). However, for the majority of deaf infants without such additional disabilities, early difficulties in establishing social interaction with their hearing parents have an environmental foundation. Subsequent developmental delays in language and EF stemming from this early disrupted experience sheds light on the general role of early social interaction in infant cognition.

There have been previous explorations of the relation between early social interaction, language and EF in older school-aged hearing and deaf children (Bishop, Nation, & Patterson, 2014; Jones et al., 2019) but much less is understood about this topic in infancy. One reason for this disparity is researchers generally characterise language as the use of words and phrases in communicative acts and inner speech, both of which facilitate and in turn are supported by EFs (Bishop et al., 2014). Inner speech is the use of language in the absence of overt articulation and is considered an important aspect of self-regulation (Alderson-Day & Fernyhough, 2015). There

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is however, an earlier period in the first 12 months before formal language has developed where through social interaction, infants begin to grasp the rules of communication e.g. turn-taking. By 18 months they have established that others have intentions which can be shared (Southgate, Chevallier, & Csibra, 2010; Tomasello, 2008). This realisation greatly increases infants' language learning abilities. Early social interaction also supports the emergence of the early EFs of attention control and inhibition. Language and EF thus can be related, not only because older children use inner speech in EF tasks, but also because early social interaction enables infants to develop solid foundations of EF and language. We argue that early social interaction is a facilitator of language and EF growth and disruption leads to delays in these cognitive developments.

In the following sections we first define EF, early social interaction, and language. Next, we describe research which has linked EF and early social interaction. Within this area, we focus on the first 2 years of life and the establishment of intersubjectivity. We outline the link between early social interaction, language, and EF in typically developing infants. Then, we describe a similar set of processes in infants who are born deaf and while without cognitive comorbidities often go on to have delayed EF and language. We discuss how studies of deaf infants can advance the understanding of the interplay between social interaction, language and EFs in all infants. We conclude with clinical applications of this proposed interplay.

2. Executive functions, social interaction, and language development

Executive Function (EF) is a multidimensional construct that includes a set of higher order, top-down cognitive processes related to monitoring, reasoning and control. As the current paper focuses on infancy, the EFs that are largely reviewed for this age are inhibition and attention control. Mature EFs develops throughout childhood and enable us to coordinate mental processes and manipulate information, solve novel problems, sequence information, and generate new strategies to accomplish goals in a flexible way (Elliott, 2003; Funahashi, 2001). EFs relate to a range of cognitive, social and emotional outcomes (Diamond, 2013). Much EF research focuses on three areas: the resistance to interference (inhibition); the ability to flexibly shift from one mental frame of focus to another (cognitive flexibility); and the ability to hold and manipulate information in the mind (working memory). It has been suggested that these three EFs underlie other executive abilities such as planning and cognitive fluency (Miyake & Friedman, 2012). A further distinction exists in the literature between 'cool' versus 'hot' EF. Cool EF is associated with tasks of working memory or attention switching. In contrast, hot EF is linked to situations that are emotionally-laden or contain a motivational significance (Zelazo & Carlson, 2012).

The focus of this paper is on social interaction and its impact on language and EF. There are several social-cognitive concepts that grow out of early interaction. Intersubjectivity is a cognitive process whereby individuals come to share each other's intentions and ideas (Bruner, 1983; Trevarthen & Hubley, 1978) and facilitates the establishment of meaningful and reciprocal exchanges between individuals (Crossley, 1996). Infants benefit from interaction which is linked to their focus of attention rather than the parent directing the child's attention. This step requires joint attention, which is the active coordination with another person of shared attention to objects or events (Adamson, 1995; Trevarthen & Aitken, 2001). During infant development, two forms of joint attention have been described: coordinated joint engagement and symbol-infused joint engagement. Coordinated joint engagement is the joint focus of the infant and the adult on objects or events and is evident from around 9 months of age (Prezbindowski, Adamson, & Lederberg, 1998). The second type of joint attention is a later development, emerging between 18–36 months. Here, children are more able to jointly attend to objects *and* to manipulate language and symbolic gestures related to those objects (Cejas, Barker, Quittner, & Niparko, 2014; Prezbindowski et al., 1998). A final aspect of social-interaction is turn-taking where adult and child are in synchrony (Feldman, 2012). This synchrony means the adult's language or behavioural response is contingent on the infant's attempts to communicate and is captured in the term 'successful conversational turn' (Hirsh-Pasek et al., 2015).

All of these parts of social interaction lead to intersubjectivity, and influence future formal language development. While clearly related, we distinguish between the previously described aspects of social interaction and future language development. In the current context, language refers to children's cognitive ability to comprehend and produce words and phrases for symbolic communication and inner speech. Language development is characterised both by rapid improvements across the first 3 years, as well as individual variation. Once children have begun to use words and sentences for social interaction, language gradually becomes a meta-cognitive tool in the form of inner speech and an important element in self-regulation during EF related tasks (Vygotsky, 1962).

To preview the argument proposed in the current article, we consider early social interaction a facilitator of future language and EF development. Early interactions are initially socially-communicative and occur when the infant is not using any recognisable language forms. However, during the first 24 months infants gradually build their understanding of words from this social interaction, and develop ways of symbolically expressing their ideas with language. During this same early period of life, the regulating nature of social interaction also fosters the infant's development of EF.

At this point, two important questions remain: 1. What is the role of early infant-parent interaction on the development of EF and language? And 2. How does deafness advance our understanding of this interplay?

2.1. Synopsis of EF development

The emergence and development of EF is an important part of infants' and children's lives (Blair, 2016; Carlson, Zelazo, & Faja, 2013; Cuevas & Bell, 2014; Cuevas, Rajan, & Bryant, 2017; Garon, Bryson, & Smith, 2008; Wu, Liang, Lu, & Wang, 2017). The skills that later in childhood become EFs emerge during the first year of life from reactive to more self-regulatory behaviours (Diamond, 1991a; Garon et al., 2008; Welsh & Pennington, 1988). The regulation of eye movements (Johnson, 1995) and manual searching for hidden objects in an object permanence experiment (Diamond, 1991b) appear in infancy as antecedents of more complex EF skills that

develop gradually. There is evidence that early EF abilities at this point are quite immature and are most successful in basic and controlled testing contexts which reduce cognitive and emotional load (Anderson, 2002; Best, Miller, & Jones, 2009; Willoughby, Blair, Wirth, & Greenberg, 2010). Paralleling the emergence and growth of social communication and language, EF development is characterised both by rapid improvements across the first 3 years, as well as individual variation.

Early milestones in EF have been documented. For example, basic inhibitory control is observed towards the end of the first year and undergoes rapid development across the toddler period and into the preschool years. Inhibition is also characterised by much individual variation (Diamond, 2002; Wolfe & Bell, 2007). Inhibition is implicated in toddlers being able to regulate their behaviour in accordance with external demands and the challenges of conflict, delay, and compliance (e.g., pausing fun games or waiting for meals: Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Kopp, 2002). More complex EFs, such as planning and self-monitoring, develop beyond infancy throughout childhood and adolescence (Best & Miller, 2010; Best et al., 2009).

3. The interplay between early social interaction, EF and language

There is considerable interest in how early social interactions link to language and EF. From a review of the literature, we propose that social interaction is a facilitator of language and EF development as schematised in Fig. 1.

Several previous studies have concentrated on the role of language, either through labelling or inner speech, in helping children to self-regulate during EF tasks (Carlson, Davis, & Leach, 2005; Hughes & Ensor, 2005; Hughes, 1998; Milligan, Astington, & Dack, 2007; Wolfe & Bell, 2003). Kirkham, Cruess, and Diamond (2003) demonstrated that 3-year-olds who were asked to label the relevant sorting dimension on an EF card-sorting task performed better than children who only heard the experimenter label the relevant dimension. Kirkham et al. (2003) argued the tendency to persist with the original dimension (attentional inertia) at this age was resisted more successfully because attention was redirected verbally by their own labelling of the relevant dimension change.

In two longitudinal studies, the verbal ability of 2 year olds was related to later individual differences in EF (Carlson, Mandell, & Williams, 2004; Hughes & Ensor, 2009). In the latter of these studies, Hughes and Ensor (2009) followed children from infancy through to 5 years and showed that early verbal ability predicted improvements in EF across time points. Finally, Gandolfi and Viterbori (2020) found that measures of inhibition at 24–32 months were longitudinally associated with language production measures collected 12 months later.

However, all of this research concentrates on children who already have enough language to label and manipulate information in cognition. A second set of research studies has looked at an earlier period of development, and how the emergence of language and EF abilities are functionally intertwined during social interactions. As shown in the top part of Fig. 1, the emergence of social communication during infant-parent interaction sets up a framework for the infant to learn language and supports early EF development. The next section explores this relationship in more detail.

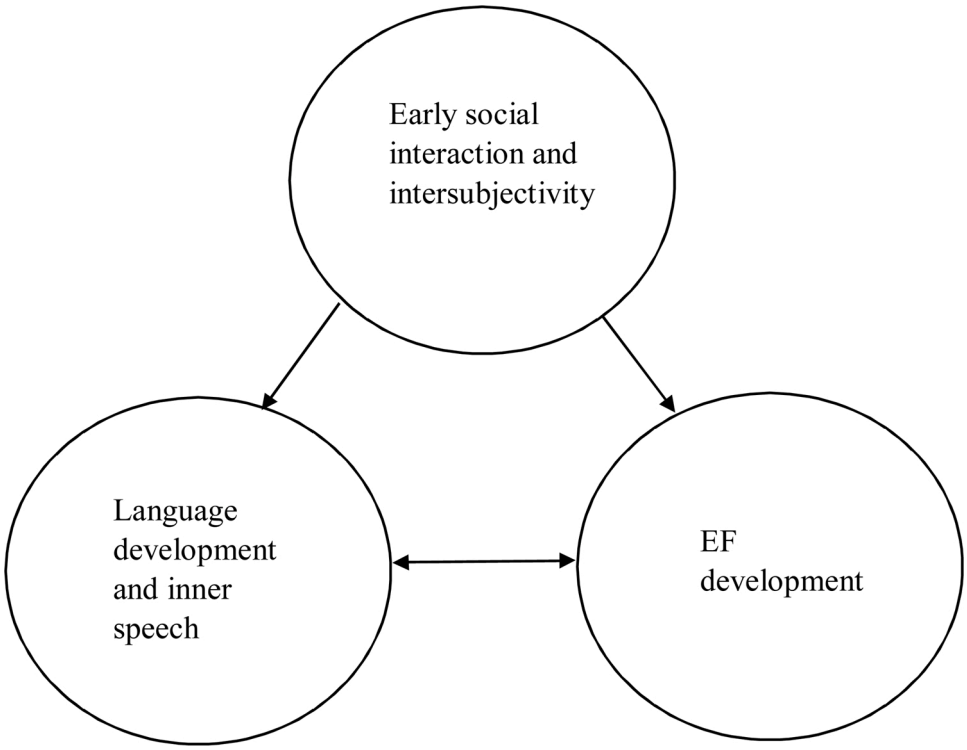

Fig. 1. The relationships between early social interaction on EF and language development.

3.1. Intersubjectivity: the emergence of language and EF abilities are functionally intertwined during early social interaction

Intersubjectivity refers to the establishment of meaningful and reciprocal exchanges between individuals (Crossley, 1996). Intersubjectivity develops between the infant and the parent by contingent interaction and scaffolding. This is a continuous process with linked and relevant responses from the adult to infant communicative or play actions (Bornstein, Tamis-LeMonda, Hahn, & Haynes, 2008). Parent scaffolding is the adult filling in gaps and adding to the child's attempt to communicate (Hirsh-Pasek & Burchinal, 2006). These behaviours are the ingredients of early social interaction and in turn support language development. In parallel they are also linked to an infant's use of early EFs (Hughes & Ensor, 2009) to sustain communicative interactions, regulate their own behaviours, inhibit distraction, cooperate and engage (Shonkoff & Phillips, 2000).

Bruner (1983) described intersubjectivity as appearing very early, starting with neonatal imitation (mirroring facial gestures). Next, infants go beyond mirroring others' faces to displaying their first reciprocation e.g. smiling during face-to-face exchanges at around 2 months of age (Vincini, Jhang, Buder, & Gallagher, 2017). It may be worth noting here, that there is a debate around what constitutes reciprocation (versus global arousal). Nevertheless, Vincini et al. (2017) conclude that there is some evidence for differential gesture, and speculate that there is a pathway between early social perception and the development of social cognition. By 9 months, typically developing infants engage in triadic, intentional communication with others about objects (Trevarthen & Aitken, 2001). Eventually at 20 months, they begin to negotiate with others about things and the self as shared representations (Southgate et al., 2010; Tomasello, 2008). This last part of intersubjectivity is related to the development of shared attention.

Shared attention describes parents' and children's coordinated attention to each other and to a third object or event (Akhtar & Gernsbacher, 2007). Many researchers argue shared attention is strongly related to future language development; the adult shares and is responsive to the infant's focus of attention. Importantly any responses from the adult are linked to the child's focus of attention. This means adult language is contingent i.e. dependent, on the infant's focus of attention or actions (Tomasello, 2008). For example, if the infant picks up a jigsaw piece and the adult says 'put it here' the adult's language links to the child's current mental state and thus establishing a shared representation is more possible. Indeed, research into vocabulary growth highlights the importance of the parent following the infant's lead, rather than the parent directing the child's attention.

There are several predictors of future success in language development that originate in early social interaction. These are the infant's ability to reciprocate, share attention and intentionally communicate with interested family members (Beuker, Rommelse, Donders, & Buitelaar, 2013; McKean et al., 2016) and infants' engagement, as manifested in communicative attempts (Boundy, Cameron-Faulkner, & Theakston, 2016). Infants that also attempt to communicate socially, will shape adult's responses in the form of contingent language (Donnellan, Bannard, McGillion, Slocombe, & Matthews, 2020; Tamis-LeMonda, Kuchirko, & Song, 2014). For example, Vallotton (2009) found 11 month infants who gestured more, elicited greater responsiveness from caregivers during daily interactions, confirming that infants play an active role in shaping interactions and eliciting social interaction. These social behaviours predict language development outcomes. Thus, the research highlights the importance of both following the child's initiatives and directing the child's attention for early language development. These aspects may differentially impact expressive and receptive vocabulary.

Researchers of EF development have described the same set of early social communication features as important. For example, synchronicity ("we are doing this together") has been highlighted as a positive function for early attention and inhibitory control (Bernier, Carlson, & Whipple, 2010). Feldman (2012) argued synchronous mother-infant behaviours are seen to have an important neuro-biological foundation with positive outcomes for self-regulation. In the context of Feldman (2012) these behaviours are seen in closely timed gaze and vocalizations, and through matching of affect and touch. In the EF literature this behaviour, overlaps with what was described as a language development facilitator previously, and is referred to as 'maternal scaffolding' (Bernier et al., 2010; Neale & Whitebread, 2019). Hughes and Ensor (2009) argued early social interaction through maternal scaffolding with infants at 2 years of age is linked to the development of early emotional and cognitive regulation. This relationship was then observed longitudinally whereby individual differences in maternal scaffolding predicted individual differences in children's EF performance at age four years. Hughes, White, and Ensor (2014) made the interesting observation that early EF skills once up and running, are likely to enhance children's ability to cooperate and engage in social interactions such as shared proto-conversations and early pretend play. Indeed, there has been some recognition in the EF literature that children's early family context and early environments for learning and self-regulation are important factors in explaining variability of EF development (Carlson, 2003; Shonkoff & Phillips, 2000). This variability of outcome will be highlighted in the following section on social interaction in families with deaf infants.

Parent behaviours in the realm of social interactions with infants can therefore facilitate EF development by providing children with opportunities to develop their cognitive, linguistic, emotional, and self-regulatory skills (Gauvain, 2001). Studies highlight the role of different parenting behaviours in young children's EF development (Bernier et al., 2010; Bibok, Carpendale, & Müller, 2009; Hughes & Ensor, 2009). In a sample of primarily low-income 2-year-olds Hughes and Ensor (2005; 2009) reported that positive parent control, responsiveness, and connected-talk predicted better EF skills in the children. However, the children's verbal skills could explain EF variability. More recent work has established the role of parental social interaction through scaffolding, independent of more general child skills, including language and intelligence (Bernier et al., 2010; Bibok et al., 2009)

Finally, Morasch and Bell (2011) reported that infant inhibitory control was related to toddler verbal ability and the contingency of maternal language. By experiencing contingent and responsive interactions, infants were more likely to recognize their own influence on the environment. This in turn improves an infant's sense of agency and might increase their motivation to learn how to control and interact with their external world, which then leads to increased practice with EF skills. Although writing in the context of maternal sensitivity and infant emotion regulation, Morasch & Bell's (2011) description of contingency and the parent following the infant's lead strongly overlaps with scaffolding and contingent talk, reviewed in the previous section on the establishment of intersubjectivity

and the foundations of language development (Vallotton & Ayoub, 2011).

To summarise the research to this point; there is considerable interest in how early social interactions link to EF and language development. Several studies have concentrated on the explicit role of language as inner speech in helping older children to implement meta-cognitive strategies during EF tasks (e.g. Kirkham et al. (2003). These inner speech studies concentrate on children who are already in command of language with which they can label and manipulate information in cognition (Marcovitch & Zelazo, 2006; Vygotsky, 1962). A second set of research studies has looked at an earlier period of development and how the emergence of social interaction, EF and language abilities are functionally intertwined during the first 12 months (Lewis & Carpendale, 2009). It thus follows that variation in the quality of these early interactions, or more severe disruptions to early social interaction, could have effects on both EF and language. This points to shared protective and risk factors in language and EF development.

4. Early disruptions to the underpinnings of EF and language

There exists a range of disruptions to infant development stemming from neuro-biological and environmental causes. However, it is not clear from studies of children with developmental disorders stemming from neuro-biological causes whether EF or language deficits stem from wider cognitive differences (Bishop et al., 2014). As previously described in the introduction, in around 30% of cases, infant deafness can be complicated by additional co-morbid disabilities (Chilosi et al., 2010; Fortnum et al., 2002). While co-morbidity also exists between language and cognition in children born deaf (e.g. Szarkowski et al., 2014), the majority of deaf children have normal non-verbal cognitive ability, in contrast to their delayed language skills (Marschark & Hauser, 2008). In the current paper, only studies of deaf children without comorbidities have been included in the review. While it is difficult to rule out all cognitive co-morbidities present in infant deafness, studies exclude children with obvious early additional disabilities through standardised assessments of sensory, motor and cognitive developmental milestones (Marschark & Hauser, 2008). Once these exclusion criteria have been applied, studies of early social-interaction and deafness report major difficulties in the development of intersubjectivity, joint attention, contingency and scaffolding. These same aspects of early social-interaction predict language and EF development in hearing infants. Consequently, it is important to understand further how deafness disrupts early social-interaction and leads to cognitive differences. This population offer a unique window into the associations between social-interaction, language and EF from which we can explore reasons for variability in typical development.

4.1. Neo-natal deafness

In the United Kingdom, 2 in 1000 live births experience deafness or 12,000 children per annum. Fifty per cent of deafness is identified by 4–6 weeks of age with families generally entering into intervention programmes between 8 and 20 weeks of age. Deaf infants are heterogeneous: 90–95 % of deaf infants are born to hearing parents (Mitchell & Karchmer, 2006), with no experience of deafness. In these families, a particular early issue is the establishment of communicative routines. The remaining 5–10 % are born to deaf parents who generally can provide immediately accessible social-interaction. Secondly, the majority of deaf children have no comorbid cognitive impairment but experience significant challenges to the perception and production of spoken language (Levine, Strother-Garcia, Hirsh-Pasek, & Golinkoff, 2016; Mason et al., 2010). Cognitive development is also affected by infant deafness. Although to our knowledge there are no papers as yet addressing very early EF skills in deaf *infants* (younger than 36 months), there are a number of studies that focus on EF development in deaf *school aged* children (Beer et al., 2014; Botting et al., 2017; Dye & Hauser, 2014; Figueras, Edwards, & Langdon, 2008; and Hall, Eigsti, Bortfeld, & Lillo-Martin, 2017 with deaf children of deaf parents; Jones et al., 2019; Pisoni, Kronenberger, Roman, & Geers, 2011; Vissers & Hermans, 2018). All of these studies excluded deaf children with additional disabilities. The combined findings from these studies report deaf children performing significantly poorer on all EF tasks in comparison with their hearing peers. Further, Botting et al. (2017) and Jones et al. (2019) showed language scores (both sign and spoken language) mediated group differences in EF skill, but the reverse pattern was not evident. Strengthening the importance of successful early social interaction, deaf children with deaf parents, although a small sample, perform better on some (working memory), but not all (planning), EF tasks (Dye & Hauser, 2014; Marshall et al., 2015). We next review studies on the quality of social interaction experienced by deaf infants and relate this to the delays reported in language and EF development.

4.2. Early social interaction experiences of deaf infants

This review proposes that early social interaction facilitates EF and language development and in this light deaf infants without any comorbidity will generally have reduced access to the surrounding spoken language of hearing parents. In addition to reduced access to language, neo-natal deafness also represents a major risk factor for early social interaction (Levine et al., 2016). Parents are more able to recognise and understand infant's attempts to communicate when they have some experience of how deaf infants differ in this respect compared to their hearing peers. Scaffolding infants' attempts to communicate (Hirsh-Pasek & Burchinal, 2006) is not unique to parents who use spoken language. The 5 % of deaf infants with deaf parents experience communication from adults who intuitively use visual-tactile strategies during interaction to indicate interest and support visual perception of language (Harris, 2010). This small group of infants experience good, early social interaction and develop normal intersubjectivity (Roos, Cramér-Wolrath, & Falkman, 2016). For example with joint attention, deaf infants of deaf parents at 9 months of age already have good mastery of gaze control (Bosworth & Stone, 2021) and by 24 months, have learned to look to their parents' faces more often than hearing-peers (Lieberman, Hatrak, & Mayberry, 2014).

In the wider EF literature, success of early synchronous interaction is linked to the growth of early EF skills (Bernier et al., 2010;

Feldman, 2012). Although a very small sample size, deaf infants with deaf parents go on to demonstrate generally good EF skills (Dye & Hauser, 2014; Hall, Eigsti, Bortfeld, & Lillo-Martin, 2018; Marshall et al., 2015). Marshall et al. (2015), reported comparable success with the Corsi block working memory test with a sample size of 8 native signers, however the authors also reported lower performance on other visual working memory tests in native signers compared to hearing peers. While these findings reinforce the general point of early social interaction as a protective factor for language and EF developmental delay, it is worth nothing that the population of native signers is very small compared to the large group of deaf infants with hearing parents.

In contrast, many studies have reported that early social interaction between deaf infants and their typically hearing parents is often disrupted and effortful (DesJardin & Eisenberg, 2007; Harris, 2010; Moeller & Tomblin, 2015; Wedell-Monnig & Lumley, 1980). Differences between deaf-hearing dyads and dyads with the same hearing status (including deaf parent-deaf-infant) have been observed in the following ways: deaf infants' ability to notice and react to hearing parents' intentions to communicate (Kelly, Barnard, Morgan & Matthews, 2020); hearing parents' skills in adapting to the deaf infant (e.g. amount of scaffolding or responses related to the child's interest); and the reciprocal relationship between deaf infant and hearing parent e.g. the amount of joint attention and the number of conversational turns (Morgan et al., 2014; Prezbindowski et al., 1998). In general, deaf parents are skilled at scaffolding the development of intersubjectivity in their deaf infants during the first 18 months of life (Roos et al., 2016), but when hearing parents attempt to sign with their deaf infants they are often less fluent (Lu, Jones, & Morgan, 2016).

Hearing parents will also use natural vocal and gestural cues (e.g., gasps, exclamations and points) to regulate interaction, alert the hearing infant to a topic of interest, and initiate joint attention (Gogate, Bahrick, & Watson, 2000). This sensitivity can enable infants to understand how communicative acts can direct others' attention. In a recent study, Kelly, Bannard, Morgan, and Mathews (2020) compared the early communicative behaviours of deaf infants whose parents were hearing with matched, typically-hearing dyads. Deaf infants produced fewer pre-linguistic communicative behaviours during interaction and were also more likely to miss parent reinforcement of their early communication. This builds on earlier research which showed deaf-hearing dyads were more likely to experience break-downs in early joint attentional episodes (Prezbindowski et al., 1998). Joint attention has received much attention in the research on social interaction in deaf infants (Cejas et al., 2014; Depowski, Abaya, Oghalai, & Bortfeld, 2015; Prezbindowski et al., 1998; Roos et al., 2016). Deaf-hearing dyads vary therefore in their ability to perceive each other's attempts to interact and this has an impact on the development of joint attention and turn taking, both of which have been identified as an important early predictor of EF development (Hughes & Ensor, 2009).

Differences between parents with deaf and hearing infants have also been documented for joint attention and contingent conversational skills. Studies of deaf infants with hearing parents report delays in developing coordinated, symbol-infused joint attention (joint attention with language) compared with hearing peers and these differences increase over time. For example, Cejas et al. (2014) reported a threefold difference for interactions with symbol-infused joint attention in 36-month-old hearing children over same aged deaf children. Roos et al. (2016) studied 18 month old deaf infants with deaf and hearing mothers and reported the hearing mothers were less able to appropriately direct a young child's attention or establish joint attention (see also Depowski et al., 2015). Roos et al. (2016) observed that deaf mothers established and directed joint attention more successfully via visual-tactile ways of communicating with deaf infants. Furthermore, both deaf and hearing parents who used a combination of signs and speech with their deaf infants were more able to establish joint attention, however symbol-infused attention was only observed with deaf mothers using a sign language. Chen, Castellanos, Yu, and Houston (2019) examined attentional patterns of deaf and hearing toddlers with hearing parents to investigate joint attention in what they termed 'temporal synchrony'. This meant a label for an object was provided at the same time as the object was in the infant's focus of attention. The quantity of sustained attention was comparable between groups but was less temporally synchronized in the deaf group. Levine, Avelar, Golinkoff, Hirsh-Pasek, and Houston (2020) make the important observation that hearing parents may well be adapting their interactions to the language skills of the child. Indeed, they note that deaf infants and children with better language skills spent more time in symbol-infused joint engagement with their parents. Several studies in the wider EF literature have linked symbol-infused interaction with increased cognitive and behavioural self-control (e.g. Carlson et al., 2005).

A final important difference observed in hearing parent-deaf infant communication is the use of contingent language. In wider research on hearing infants, parents who stimulate their children to be more active in learning about their environment, while positively scaffolding their children's actions with contingent language, show most EF benefits (e.g. Devine, Bignardi, & Hughes, 2016). Adult contingent language also leads to more successful conversational turns and predict child language skills in hearing (Gilkerson et al., 2017; Hirsh-Pasek et al., 2015) and deaf infants (Dirks, Stevens, Kok, Frijns, & Rieffe, 2020; Morgan et al., 2014; Vandam, Ambrose, & Moeller, 2012). Morgan et al. (2014) recorded naturalistic conversations of hearing parents with deaf and hearing infants at 24 months of age. There were no differences in the number of attempted conversational turns made by parents of both groups, however hearing parents with deaf infants were significantly less successful in maintaining turns with a contingent topic. Dirks et al. (2020) examined the quantity and quality of parental interaction with toddlers with moderate deafness compared with toddlers with normal hearing. Deaf toddlers were exposed to an equivalent amount of interaction, but parents used shorter utterances, less high-level facilitative language techniques, and less mental state language. Early interaction studies also highlighted the role of following the infant's lead rather than the parent directing the child's attention. Providing infants with opportunities to explore the physical context of the interaction and take the lead in the interaction has also been related to the growth of self-regulation (Vallotton, 2009). Fagan, Bergeson, and Morris (2014) showed hearing mothers of deaf infants used more directives (e.g. say 'cat', sit here) and prohibitions (e.g. no, don't open it) than mothers of age-matched hearing children. Thus, the quality of parent communication leads to deaf infants having less opportunities for language learning but also, as Morasch and Bell (2011) described, less practice with EF skills around influence and agency on their environment.

In conclusion, the current proposal is that variation in early social interaction underlies the considerable individual differences

observed in language and EF development in both hearing and deaf infants. Studies of deaf infant-hearing parent communication and a small number of deaf infant-deaf parent studies highlight the connections inherent in this interplay, as well as, emphasise protective and risk factors for explaining variability. It also provides support for the focus on early social interaction as a protective factor in hearing infants with difficulties. Further research will allow us to better understand the source of the variability in language and EF outcomes. In the wider study of infancy, more longitudinal studies are required on the impact of early social interaction for EF, as well as clinical trials of early interventions on both early communication and EF skills. Studies of deaf children without cognitive comorbidities, potentially play an important role in this research. Unlike most other clinical groups, the cause of language and EF delays are largely known to be environmental and sensory in origin. This enables us to more accurately tease apart impacts on EF that are associated with social interaction and language, without the confounding development difficulties seen in other clinical samples. The final section describes current interventions for social interaction with deaf infants and parents.

5. Clinical implications of the language EF interplay

Traditionally, speech and language therapy with deaf infants has focused on improving auditory perception, speechreading, speech production, vocal characteristics and understanding and use of language (Rayes, Al-Malky, & Vickers, 2019). Findings that hearing parents are more directive in their communication style with deaf infants (Fagan et al., 2014) perhaps follows from interventions for deaf children that often focus on the child's production of language forms. As better understanding of early communication dynamics and deafness is unfolding e.g. Moeller, Carr, Seaver, Stredler-Brown, and Holzinger (2013), more consideration is been given to the everyday social communication experiences of deaf infants and their families (Bergeron, Berland, Demers, & Gobeil, 2020; Holzinger et al., 2020).

Within the wider field of Developmental Language Disorder, clinicians work with parents to enhance the following skills: joint engagement, connectedness, contingent talk, use of open-ended questions and re-casting of children's utterances in more complex and diverse ways. These same techniques have also been shown to predict future language development in infants born deaf (Cruz, Quittner, Marker, DesJardin, & CDaCI Investigative Team, 2013). For example, in a promising small size randomised control trial, Roberts (2019) evaluated an early social interaction intervention for parents with deaf 6- to 24- month-olds. Parents in the intervention group increased the frequency with which they followed the infant's lead and their use of connected turns. These behavioural changes in parents were shown to then increase communication skills in infants compared to the control group. Nicastri, Giallini, Ruoppolo et al. (2020) evaluated the effects of a training programme to develop strategies to empower and promote early social interaction skills in parents of 14 deaf infants aged 26 months at cochlear implant. The study also had a matched no-treatment control group. Parents in the treatment group increased the quality of interaction significantly more than controls, with positive effects on children's vocabulary development that persisted for a further 36-month period post-intervention. As recommended in principle five of the international consensus statement on family-centred early intervention in deafness from Moeller et al. (2013), clinicians working with families of deaf children should be focusing on facilitative family-child interactions within everyday routines and play. Particular focus on developing parents' skills in responsiveness, in waiting and observing their child's play, commenting using contingent talk, and maintaining connected turns may prove particularly beneficial. For the focus of this review article, it is not yet known if these types of parent interventions have an impact on deaf infants' emerging EF skills, such as in their attentional and inhibitory control (for debates around benefits of EF training see Wass, Scerif, & Johnson, 2012). In one of the only studies to touch on this question, Nicastri, Giallini, Amicucci et al. (2020) reported positive significant relations between early EF skills (response shifting, inhibitory control, and attention flexibility) and early hearing parent-deaf child language intervention.

6. Conclusions

The focus of this review article was on the interplay between early language and cognitive development. The relationship proposed was: early control and regulation behaviours that will become EF are influenced by the twin protective factors of good social-communication leading to intersubjectivity and typical language development. There is a clear link between infant-parent social communication and its interplay with EF (e.g. Devine et al., 2016). We also know that language, via private speech, in older children acts as a meta-cognitive tool during EF tasks (e.g. Müller, Zelazo, Hood, Leone, & Rohrer, 2004). A review of studies of deaf infants with deaf and hearing parents highlights the association between early social interaction and delays in language and EF. The paper reinforces the complex interplay between cognitive, social, and linguistic skills in early human development. Future interventions for parents with deaf infants should include activities which foster interaction and shared intention as a pre-cursor to early EF and language development.

Declaration of Competing Interest

The authors report no declarations of interest.

References

Adamson, L. B. (1995). *Communication development during infancy*. Madison, WI: Brown and Benchmark.

Akhtar, N., & Gernsbacher, M. A. (2007). Joint attention and vocabulary development: A critical look. *Language and Linguistics Compass, 1*(3), 195–207. https://doi.org/10.1111/j.1749-818X.2007.00014.x.

Alderson-Day, B., & Fernyhough, C. (2015). Inner speech: Development, cognitive functions, phenomenology, and neurobiology. *Psychological Bulletin, 141*(5), 931–965. https://doi.org/10.1037/bul0000021.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82. https://doi.org/10.1076/chin.8.2.71.8724.

Beer, J., Kronenberger, W. G., Castellanos, I., Colson, B. G., Henning, S. C., & Pisoni, D. B. (2014). Executive functioning skills in preschool-age children with cochlear implants. *Journal of Speech, Language, and Hearing Research, 57*(4), 1521–1534. https://doi.org/10.1044/2014_JSLHR-H-13-0054.

Bergeron, F., Berland, A., Demers, D., & Gobeil, S. (2020). Contemporary speech and oral language care for deaf and hard-of-hearing children using hearing devices. *Journal of Clinical Medicine, 9*(2), 378. https://doi.org/10.3390/jcm9020378.

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulatory to self- regulatory: Early parenting precursors of young children's executive functioning. *Child Development, 81*(1), 326–339. https://doi.org/10.1111/j.1467-8624.2009.01397.x.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660. https://doi.org/10.1111/j.1467-8624.2010.01499.x.

Best, J. R., Miller, P. H., & Jones, L. L. (2009). Executive function after age 5: Changes and correlates. *Developmental Review, 29*(3), 180–200. https://doi.org/10.1016/j.dr.2009.05.002.

Beuker, K. T., Rommelse, N. N., Donders, R., & Buitelaar, J. K. (2013). Development of early communication skills in the first two years of life. *Infant Behavior & Development, 36*(1), 71–83. https://doi.org/10.1016/j.infbeh.2012.11.001.

Bibok, M. B., Carpendale, J. I., & Müller, U. (2009). Parental scaffolding and the development of executive function. *New Directions for Child and Adolescent Development, 123*, 17–34. https://doi.org/10.1002/cd.233.

Bishop, D. V. M., Nation, K., & Patterson, K. (2014). When words fail us: Insights into language processing from developmental and acquired disorders. *Philosophical Transactions of the Royal Society B, 369*, Article 20120403. https://doi.org/10.1098/rstb.2012.0403.

Blair, C. (2016). Developmental science and executive function. *Current Directions in Psychological Science, 25*(1), 3–7. https://doi.org/10.1177/0963721415622634.

Bornstein, M., Tamis-LeMonda, C., Hahn, C.-S., & Haynes, M. (2008). Maternal responsiveness to young children at three ages: Longitudinal analysis of a multidimensional, modular and specific parental construct. *Developmental Psychology, 44*(3), 867–874. https://doi.org/10.1037/0012-1649.44.3.867.

Bosworth, R. G., & Stone, A. (2021). Rapid development of perceptual gaze control in hearing native signing infants and children. *Developmental Science*, e13086. https://doi.org/10.1111/desc.13086.

Botting, N., Jones, A., Marshall, C., Denmark, T., Atkinson, J., & Morgan, G. (2017). Non-verbal executive function is mediated by language: A study of deaf and hearing children. *Child Development, 88*, 1689–1700. https://doi.org/10.1111/cdev.12659.

Boundy, L., Cameron-Faulkner, T., & Theakston, A. (2016). Exploring early communicative behaviours: A fine-grained analysis of infant shows and gives. *Infant Behavior & Development, 44*, 86–97. https://doi.org/10.1016/j.infbeh.2016.06.005.

Bruner, J. S. (1983). *In search of mind: Essays in autobiography*. New York: Harper & Row.

Carlson, S. M. (2003). Executive function in context: Development, measurement, theory, and experience. *Monographs of the Society for Research in Child Development, 68*(3), 138–151. https://doi.org/10.1111/j.1540-5834.2003.06803012.x.

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*(6), 1105–1122. https://doi.org/10.1037/0012-1649.40.6.1105.

Carlson, S. M., Davis, A. C., & Leach, J. G. (2005). Less is more: Executive function and symbolic representation in preschool children. *Psychological Science, 16*(8), 609–616. https://doi.org/10.1111/j.1467-9280.2005.01583.x.

Carlson, S. M., Zelazo, P. D., & Faja, S. (2013). Executive function. In P. D. Zelazo (Ed.), *The Oxford handbook of developmental psychology (Vol. 1): Body and mind* (pp. 706–743). Oxford University Press.

Cejas, I., Barker, D. H., Quittner, A. L., & Niparko, J. K. (2014). Development of joint engagement in young deaf and hearing children: Effects of chronological age and language skills. *Journal of Speech, Language, and Hearing Research, 57*, 1831–1841. https://doi.org/10.1044/2014_JSLHR-L-13-0262.

Chen, C.-h., Castellanos, I., Yu, C., & Houston, D. M. (2019). Effects of children's hearing loss on the synchrony between parents' object naming and children's attention. *Infant Behavior & Development, 57*. https://doi.org/10.1016/j.infbeh.2019.04.004. N.PAG-N.PAG.

Chilosi, A. M., Comparini, A., Scusa, M. F., Berrettini, S., Forli, F., Battini, R., et al. (2010). Neurodevelopmental disorders in children with severe to profound sensorineural hearing loss: A clinical study. *Developmental Medicine & Child Neurology, 52*, 856–862. https://doi.org/10.1111/j.1469-8749.2010.03621.x.

Crossley, N. (1996). *Intersubjectivity: The fabric of social becoming* (Volume 4). London: Sage Publications.

Cruz, I., Quittner, A. L., Marker, C., DesJardin, J. L., & CDaCI Investigative Team. (2013). Identification of effective strategies to promote language in deaf children with cochlear implants. *Child Development, 84*(2), 543–559. https://doi.org/10.1111/j.1467-8624.2012.01863.x.

Cuevas, K., & Bell, M. A. (2014). Infant attention and early childhood executive function. *Child Development, 85*(2), 397–404. https://doi.org/10.1111/cdev.12126.

Cuevas, K., Rajan, V., & Bryant, L. J. (2017). Emergence of executive function in infancy. In S. A. Wiebe, & J. Karbach (Eds.), *Executive function: Development across the life span* (1st ed., pp. 11–28). New York: Routledge.

Depowski, N., Abaya, H., Oghalai, J., & Bortfeld, H. (2015). Modality use in joint attention between hearing parents and deaf children. *Frontiers in Psychology, 6*, 1556. https://doi.org/10.3389/fpsyg.2015.01556.

DesJardin, J. L., & Eisenberg, L. S. (2007). Maternal contributions: Supporting language development in young children with cochlear implants. *Ear & Hearing, 28*(4), 456–469. https://doi.org/10.1097/AUD.0b013e31806dc1ab.

Devine, R. T., Bignardi, G., & Hughes, C. (2016). Executive function mediates the relations between parental behaviors and children's early academic ability. *Frontiers in Psychology, 7*, Article 1902.

Diamond, A. (1991a). Frontal lobe involvement in cognitive changes during the first year of life. In K. R. Gibson, & A. C. Petersen (Eds.), *Brain maturation and cognitive development: Comparative and cross-cultural perspectives* (pp. 127–180). New York: Hawthorne.

Diamond, A. (2002). Normal development of prefrontal cortex from birth to young adulthood: Cognitive functions, anatomy, and biochemistry. In D. T. Stuss, & R. T. Knight (Eds.), *Principles of frontal lobe function* (pp. 466–503). Oxford University Press.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*, 135–168. https://doi.org/10.1146/annurev-psych-113011-143750.

Diamond, A. (1991b). Neuropsychological insights into the meaning of object concept development. In S. Carey, & R. Gelman (Eds.), *The epigenesist of mind: Essays on biology and cognition* (pp. 67–110). Erlbaum: Hillsdale.

Dirks, E., Stevens, A., Kok, S., Frijns, J., & Rieffe, C. (2020). Talk with me! Parental linguistic input to toddlers with moderate hearing loss. *Journal of Child Language, 47*(1), 186–204. https://doi.org/10.1017/S0305000919000667.

Donnellan, E., Bannard, C., McGillion, M. L., Slocombe, K. E., & Matthews, D. (2020). Infants' intentionally communicative vocalizations elicit responses from caregivers and are the best predictors of the transition to language: A longitudinal investigation of infants' vocalizations, gestures and word production. *Developmental Science, 23*, Article e12843. https://doi.org/10.1111/desc.12843.

Dye, M. W., & Hauser, P. C. (2014). Sustained attention, selective attention and cognitive control in deaf and hearing children. *Hearing Research, 309*, 94–102. https://doi.org/10.1016/j.heares.2013.12.001.

Elliott, R. (2003). Executive functions and their disorders. *British Medical Bulletin, 65*, 49–59. https://doi.org/10.1093/bmb/65.1.49.

Fagan, M., Bergeson, T., & Morris, K. (2014). Synchrony, complexity and directiveness in mothers' interactions with infants pre- and post-cochlear implantation. *Infant Behavior & Development, 37*(3), 249–257. https://doi.org/10.1016/j.infbeh.2014.04.001.

Feldman, R. (2012). Parent–infant synchrony: A biobehavioral model of mutual influences in the formation of affiliative bonds. *Monographs of the Society for Research in Child Development, 7*, 42–51. https://doi.org/10.1111/j.1540-5834.2011.00660.x.

Figueras, B., Edwards, L., & Langdon, D. (2008). Executive function and language in deaf children. *Journal of Deaf Studies and Deaf Education, 13*(3), 362–377. https://doi.org/10.1093/deafed/enm067.

Fortnum, H. M., Marshall, D. H., & Summerfield, A. Q. (2002). Epidemiology of the UK population of hearing-impaired children, including characteristics of those with and without cochlear implants—Audiology, aetiology, comorbidity and affluence. *International journal of audiology, 41*(3), 170–179. https://doi.org/10.3109/14992020209077181.

Funahashi, S. (2001). Neuronal mechanisms of executive control by the prefrontal cortex. *Neuroscience Research, 39*(2), 147–165. https://doi.org/10.1016/S0168-0102(00)00224-8.

Gandolfi, E., & Viterbori, P. (2020). Inhibitory control skills and language acquisition in toddlers and preschool children. *Language Learning, 70*, 604–642. https://doi.org/10.1111/lang.12388.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin, 134*(1), 31–60. https://doi.org/10.1037/0033-2909.134.1.31.

Gauvain, M. (2001). *The social context of cognitive development*. New York, NY: Guilford Press.

Gilkerson, J., Richards, J. A., Warren, S. F., Montgomery, J. K., Greenwood, C. R., Kimbrough Oller, D., et al. (2017). Mapping the early language environment using all-day recordings and automated analysis. *American Journal of Speech-Language Pathology, 26*, 248–265. https://doi.org/10.1044/2016_AJSLP-15-0169.

Gogate, L. J., Bahrick, L. E., & Watson, J. D. (2000). A study of multimodal motherese: The role of temporal synchrony between verbal labels and gestures. *Child Development, 71*, 878–894. https://doi.org/10.1111/1467-8624.00197.

Hall, M. L., Eigsti, I. M., Bortfeld, H., & Lillo-Martin, D. (2017). Auditory deprivation does not impair executive function, but language deprivation might: Evidence from a parent-report measure in deaf native signing children. *The Journal of Deaf Studies and Deaf Education, 22*(1), 9–21. https://doi.org/10.1093/deafed/enw054.

Hall, M. L., Eigsti, I. M., Bortfeld, H., & Lillo-Martin, D. (2018). Executive function in deaf children: Auditory access and language access. *Journal of Speech, Language, and Hearing Research, 61*(8), 1970–1988. https://doi.org/10.1044/2018_JSLHR-L-17-0281.

Harris, M. (2010). Early communication in sign and speech. In M. Marschark, & P. E. Spencer (Eds.), *Oxford handbook of deaf studies, language, and education* (Volume 2, pp. 316–330). New York, NY: Oxford University Press.

Hirsh-Pasek, K., & Burchinal, M. (2006). Mother and caregiver sensitivity over time: Predicting language and academic outcomes with variable- and person-centered approaches. *Merrill-Palmer Quarterly, 52*, 449–485. https://doi.org/10.1353/mpq.2006.0027.

Hirsh-Pasek, K., Adamson, L. B., Bakeman, R., Owen, M. T., Golinkoff, R. M., Pace, A., et al. (2015). The contribution of early communication quality to low-income children's language success. *Psychological Science, 26*, 1071–1083. https://doi.org/10.1177/0956797615581493.

Holzinger, D., Dall, M., Sanduvete-Chaves, S., Saldaña, D., Chacón-Moscoso, S., & Fellinger, J. (2020). The impact of family environment on language development of children with cochlear implants: A systematic review and meta-analysis. *Ear and Hearing, 41*(5), 1077–1091. https://doi.org/10.1097/AUD.0000000000000852.

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *British Journal of Developmental Psychology, 16*, 233–253. https://doi.org/10.1111/j.2044-835X.1998.tb00921.x.

Hughes, C., & Ensor, R. (2005). Executive function and theory of mind in 2 year olds: A family affair? *Developmental Neuropsychology, 28*(2), 645–668. https://doi.org/10.1207/s15326942dn2802_5.

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function? *New Directions for Child and Adolescent development*, (123), 35–50. https://doi.org/10.1002/cd.234.

Hughes, C., White, N., & Ensor, R. (2014). How does talk about thoughts, desires, and feelings foster children's socio-cognitive development? Mediators, moderators and implications for intervention. In K. H. Lagattuta (Ed.), *Children and emotion: New insights into developmental affective sciences* (pp. 95–105). Basel, Switzerland: Karger.

Johnson, M. (1995). The inhibition of automatic saccades in early infancy. *Developmental Psychobiology, 28*, 281–291. https://doi.org/10.1002/dev.420280504.

Jones, A., Atkinson, J., Marshall, C., Botting, N., St Clair, M. C., & Morgan, G. (2019). Expressive vocabulary predicts nonverbal executive function: A 2-year longitudinal study of deaf and hearing children. *Child Development, 91*(2), e400–e414. https://doi.org/10.1111/cdev.13226.

Kelly, C., Bannard, C., Morgan, G., & Mathews, D. (2020). Early pragmatics in deaf and hard of hearing infants. *Pediatrics, 146*(Sup. 3), S262–S269. https://doi.org/10.1542/peds.2020-0242E.

Kirkham, N. Z., Cruess, L., & Diamond, A. (2003). Helping children apply their knowledge to their behavior on a dimension-switching task. *Developmental Science, 6*(5), 449–476. https://doi.org/10.1111/1467-7687.00300.

Kochanska, G., Murray, K., Jacques, T. Y., Koenig, A. L., & Vandegeest, K. A. (1996). Inhibitory control in young children and its role in emerging internalization. *Child Development, 67*(2), 490–507. https://doi.org/10.2307/1131828.

Kopp, C. (2002). Commentary: The co-developments of attention and emotion regulation. *Infancy, 2*, 199–208. https://doi.org/10.1207/S15327078IN0302_5.

Levine, D., Strother-Garcia, K., Hirsh-Pasek, K., & Golinkoff, R. M. (2016). Language development in the first year of life: What deaf children might be missing before cochlear implantation. *Otology & Neurotology, 37*, 56–62. https://doi.org/10.1097/MAO.0000000000000908.

Levine, D., Avelar, D., Golinkoff, R. M., Hirsh-Pasek, K., & Houston, D. (2020). Foundations of language development in deaf and hard-of-hearing infants: Cognitive and social processes. In M. Marschark, & H. Knoors (Eds.), *The Oxford handbook of deaf studies in learning and cognition*. New York: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190054045.013.31.

Lewis, C., & Carpendale, J. I. (2009). Introduction: Links between social interaction and executive function. *New directions for child and adolescent development, 123*, 1–15. https://doi.org/10.1002/cd.232.

Lieberman, A. M., Hatrak, M., & Mayberry, R. I. (2014). Learning to look for language: Development of joint attention in young deaf children. *Language, Learning and Development, 10*(1), 19–35. https://doi.org/10.1080/15475441.2012.760381.

Lu, J., Jones, A., & Morgan, G. (2016). The impact of input quality on early sign development in native and non-native language learners. *Journal of Child Language, 43*(3), 537–552. https://doi.org/10.1017/S0305000915000835.

Marcovitch, S., & Zelazo, P. D. (2006). The influence of number of a trials on 2-year-olds' behavior in two a-not-B-type search tasks: a test of the hierarchical competing systems model. *Journal of Cognition and Development, 7*, 477–501. https://doi.org/10.1207/s15327647jcd0704_3.

Marschark, M., & Hauser, P. C. (Eds.). (2008). *Deaf cognition: Foundations and outcomes*. New York, NY: Oxford University Press.

Marshall, C., Jones, A., Denmark, T., Mason, K., Atkinson, J., Botting, N., et al. (2015). Deaf children's non-verbal working memory is impacted by their language experience. *Frontiers in Psychology, 6*, 527. https://doi.org/10.3389/fpsyg.2015.00527.

Mason, K., Rowley, K., Marshall, C. R., Atkinson, J., Herman, R., Woll, B., et al. (2010). Identifying specific language impairment in deaf children acquiring British sign language: Implications for theory and practice. *British Journal of Developmental Psychology, 28*, 33–49. https://doi.org/10.1348/026151009X484190.

McKean, C., Law, J., Mensah, F., Cini, E., Eadie, P., Frazer, K., et al. (2016). Predicting meaningful differences in school-entry language skills from child and family factors measured at 12 months of age. *IJEC, 48*, 329–351. https://doi.org/10.1007/s13158-016-0174-0.

Milligan, K., Astington, J. W., & Dack, L. A. (2007). Language and theory of mind: Meta-analysis of the relation between language ability and false-belief understanding. *Child Development, 78*, 622–646. https://doi.org/10.1111/j.1467-8624.2007.01018.x.

Mitchell, R. E., & Karchmer, M. A. (2006). Demographics of deaf education: More students in more places. *American Annals of the deaf, 151*(2), 95–104. https://doi.org/10.1353/aad.2006.0029.

Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four General conclusions. *Current Directions in Psychological Science, 21*(1), 8–14. https://doi.org/10.1177/0963721411429458.

Moeller, M. P., & Tomblin, J. B. (2015). An introduction to the outcomes of children with hearing loss study. *Ear and Hearing, 36*(1), 4S–13S. https://doi.org/10.1097/AUD.0000000000000210.

Moeller, M. P., Carr, G., Seaver, L., Stredler-Brown, A., & Holzinger, D. (2013). Best practices in family-centered early intervention for children who are deaf or hard of hearing: An International consensus statement. *The Journal of Deaf Studies and Deaf Education, 18*(4), 429–445. https://doi.org/10.1093/deafed/ent034.

Morasch, K. C., & Bell, M. A. (2011). The role of inhibitory control in behavioral and physiological expressions of toddler executive function. *Journal of Experimental Child Psychology, 108*(3), 593–606. https://doi.org/10.1016/j.jecp.2010.07.003.

Morgan, G., Meristo, M., Mann, W., Hjelmquist, E., Surian, L., & Siegal, M. (2014). Mental state language and quality of conversational experience in deaf and hearing children. *Cognitive Development, 29*, 41–49. https://doi.org/10.1016/j.cogdev.2013.10.002.

Müller, U., Zelazo, P. D., Hood, S., Leone, T., & Rohrer, L. (2004). Interference control in a new rule use task: Age-related changes, labeling, and attention. *Child Development, 75*(5), 1594–1609. https://doi.org/10.1111/j.1467-8624.2004.00759.x.

Neale, D., & Whitebread, D. (2019). Maternal scaffolding during play with 12- to 24-month-old infants: Stability over time and relations with emerging effortful control. *Metacognition and Learning, 14*, 265–289. https://doi.org/10.1007/s11409-019-09196-6.

Nicastri, M., Giallini, I., Ruoppolo, G., Prosperini, L., de Vincentiis, M., Lauriello, M., et al. (2020). Parent training and communication empowerment of children with cochlear implant. *Journal of Early Intervention, 43*(2), 117–134. https://doi.org/10.1177/1053815120922908.

Nicastri, M., Giallini, I., Amicucci, M., Mariani, L., de Vincentiis, M., Greco, A., et al. (2020). Variables influencing executive functioning in preschool hearing-impaired children implanted within 24 months of age: An observational cohort study. *European Archives of Otorhinolaryngology*. https://doi.org/10.1007/s00405-020-06343-7. Advance online publication.

Pisoni, D. B., Kronenberger, W. G., Roman, A. S., & Geers, A. E. (2011). Measures of digit span and verbal rehearsal speed in deaf children after more than 10 years of cochlear implantation. *Ear & Hearing, 31*(1 Suppl), 60S–74S. https://doi.org/10.1097/AUD.0b013e3181ffd58e.

Prezbindowski, A. K., Adamson, L. B., & Lederberg, A. R. (1998). Joint attention in deaf and hearing 22 month-old children and their hearing mothers. *Journal of Applied Developmental Psychology, 19*(3), 377–387. https://doi.org/10.1044/2014_JSLHR-L-13-0262.

Rayes, H., Al-Malky, G., & Vickers, D. (2019). Systematic review of auditory training in pediatric cochlear implant recipients. *Journal of Speech Lang & Hearing Research, 62*, 1574–1593. https://doi.org/10.1044/2019_JSLHR-H-18-0252.

Roberts, M. Y. (2019). Parent-implemented communication treatment for infants and toddlers with hearing loss: A randomized pilot trial. *Journal of Speech, Language, and Hearing Research, 62*, 143–152. https://doi.org/10.1044/2018_JSLHR-L-18-0079.

Roos, C., Cramér-Wolrath, E., & Falkman, K. W. (2016). Intersubjective interaction between deaf parents/deaf infants during the infant's first 18 months. *Journal of Deaf Studies & Deaf Education, 21*(1), 11–22. https://doi.org/10.1093/deafed/env034.

Shonkoff, J. P., & Phillips, D. A. (Eds.). (2000). *From neurons to neighborhoods: The science of early childhood development*. Washington D.C: National Academies Press (US).

Southgate, V., Chevallier, C., & Csibra, G. (2010). Seventeen-month-olds appeal to false beliefs to interpret others' referential communication. *Developmental Science, 13*(6), 907–912. https://doi.org/10.1111/desc.2010.13.

Szarkowski, A., Mood, D., Shield, A., Wiley, S., & Yoshinaga-Itano, C. (2014). A summary of current understanding regarding children with autism spectrum disorder who are deaf or hard of hearing. *Seminars in Speech and Language, 35*(4), 241–259. https://doi.org/10.1055/s-0034-1389097.

Tamis-LeMonda, C. S., Kuchirko, Y., & Song, L. (2014). Why is infant language learning facilitated by parental responsiveness? *Current Directions in Psychological Science, 23*(2), 121–126. https://doi.org/10.1177/0963721414522813.

Tomasello, M. (2008). *Origins of human communication*. Cambridge, MA: MIT Press.

Trevarthen, C., & Aitken, K. J. (2001). Infant intersubjectivity: Research, theory, and clinical applications. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 42*(1), 3–48. PMID: 11205623.

Trevarthen, C., & Hubley, P. (1978). Secondary intersubjectivity: Confidence, confiding, and acts of meaning in the first year. In J. Lock (Ed.), *Action, gesture and symbol* (pp. 183–229). London: Academic Press.

Vallotton, C. (2009). Do infants influence their quality of care? Infants' communicative gestures predict caregivers' responsiveness. *Infant Behavior & Development, 32*(4), 351–365. https://doi.org/10.1016/j.infbeh.2009.06.001.

Vallotton, C., & Ayoub, C. (2011). Use your words: The role of language in the development of toddlers' self-regulation. *Early Childhood Research quarterly, 26*(2), 169–181. https://doi.org/10.1016/j.ecresq.2010.09.002.

Vandam, M., Ambrose, S., & Moeller, M. (2012). Quantity of parental language in the home environments of hard-of-hearing 2-year-olds. *Journal of Deaf Studies and Deaf Education, 17*, 402–420. https://doi.org/10.1093/deafed/ens025.

Vincini, S., Jhang, Y., Buder, E. H., & Gallagher, S. (2017). Neonatal imitation: Theory, experimental design, and significance for the field of social cognition. *Frontiers in psychology, 8*, 1323. https://doi.org/10.3389/fpsyg.2017.01323.

Vissers, C., & Hermans, D. (2018). Social-emotional problems in deaf and hard-of hearing children from an executive and theory and mind perspective. In H. Knoors, & M. Marschark (Eds.), *Evidence-based practices in deaf education* (pp. 455–476). New York, NY: Oxford University Press.

Vygotsky, L. S. (1962). Thought and word. In L. Vygotsky, E. Hanfmann, & G. Vakar (Eds.), *Studies in communication. Thought and language* (pp. 119–153). Massachusetts: MIT Press. https://doi.org/10.1037/11193-007.

Wass, S. V., Scerif, G., & Johnson, M. H. (2012). Training attentional control and working memory: Is younger, better? *Developmental Review, 32*(4), 360–387. https://doi.org/10.1016/j.dr.2012.07.001.

Wedell-Monnig, J., & Lumley, J. M. (1980). Child deafness and mother-child interaction. *Child Development, 51*(3), 766–774. PMID: 7418512.

Welsh, M. C., & Pennington, B. F. (1988). Assessing frontal lobe functioning in children: Views from developmental psychology. *Developmental Neuropsychology, 4*(3), 199–230. https://doi.org/10.1080/87565648809540405.

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: Psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22*(2), 306–317. https://doi.org/10.1037/a0018708.

Wolfe, C. D., & Bell, M. A. (2003). Working memory and inhibitory control in early childhood: Contributions from physiology, temperament, and language. *Developmental Psychobiology, 44*(1), 68–83. https://doi.org/10.1002/dev.10152.

Wolfe, C. D., & Bell, M. A. (2007). The integration of cognition and emotion during infancy and early childhood: Regulatory processes associated with the development of working memory. *Brain and Cognition, 65*(1), 3–13. https://doi.org/10.1016/j.bandc.2006.01.009.

Wu, M., Liang, X., Lu, S., & Wang, Z. (2017). Infant motor and cognitive abilities and subsequent executive function. *Infant Behavior and Development, 49*, 204–213. https://doi.org/10.1016/j.infbeh.2017.09.005.

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6*(4), 354–360. https://doi.org/10.1111/j.1750-8606.2012.00246.x.