The influence of social interaction on the development of deictic gestures in infancy

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Katharina Kaletsch

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Promotionsprüfungsausschuss

Vorsitzende:	Prof. Dr. Anja Riesel
1. Dissertationsgutachter:	Prof. Dr. Ulf Liszkowski
2. Dissertationsgutachterin:	Prof. Dr. Carina Lüke
1. Disputationsgutachterin:	Prof. Dr. Nale Lehmann-Willenbrock
2. Disputationsgutachterin:	Prof. Dr. Jenny Wagner

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Abstract

Infant deictic gestures, particularly infant index-finger pointing, are early manifestations of referential communication and are predictive of language development. Despite the social nature of gestures, research investigating the influence of social interaction experiences on infants' gesture development is limited and results are inconsistent. Two social learning mechanisms and their parental behavioral correlates are of particular interest. First, parents' relevant referential uptake in response to infants' interest and communication possibly facilitates infants' communicative development (Cameron-Faulkner et al., 2015; Ger et al., 2018). Second, parents' own referential gestures (i.e., pointing) are a pertinent behavior through which infants learn via imitation (Liszkowski et al., 2012; Rüther & Liszkowski, 2023). However, other studies did not confirm the relationship between parent and infant pointing (Ger et al., 2023; Matthews et al., 2012; Salo et al., 2019). For this dissertation, I examined the causal effects of parental responsiveness and pointing on infants' gesture development. In Study 1, I present a novel remote paradigm to observe infant pointing, parental responsiveness, and pointing in a natural interactional setting. In Study 2, parents received specific instructions regarding their responsiveness and their pointing frequency to assess whether 12-month-old infants directly adapt their pointing frequency to parental behavior. In Study 3, I investigated the relationship between infants' pointing frequency and parental behavior in the context of a longitudinal parent-based training. The one-month training targeted parental responsiveness and pointing in interaction with their 12-month-old infants. Study 4 examined the influence of parental responsiveness and pointing on the development of infants' showing and pointing gestures from seven to ten months of age. The included training group was instructed to respond contingently to infants' interest and communication. Results of Study 1 showed that infants' pointing frequency, parental responsiveness and pointing in the remote paradigm were comparable to established laboratory-based methods. Infants in Study 2 increased their pointing frequency directly in

reaction to increased parental responsiveness and independently of parents' pointing frequency. Parental responsiveness emerged as a longitudinal predictor of infants' pointing frequency and contributed to the promoting effect of training in Study 3. In Study 4, infants' development of showing and pointing gestures was differentially predicted by parental behavior. Training exclusively promoted infants' showing gestures. I conclude that infants' deictic gesture development is influenced by social interactional experiences, such as parental responsiveness and parental pointing, in interaction with infants' social cognitive development.

Keywords: Gesture development, pointing, responsiveness, social interaction, infant communication training

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1. Introduction

Human communication is characterized by its complexity and exceptional level of flexibility (Tomasello, 2010). In the context of human communication, language occurs as the primary concept. It can reasonably be argued that language represents the pinnacle of communicative development. By employing and combining most arbitrary sound signals, humans can refer to absent entities and abstract concepts such as ‘freedom’ or ‘seconds’ (Borghi et al., 2021; Luchkina & Waxman, 2023). While children typically master the subtleties of language at school age, infants across cultures engage in communication from an early age (Cote & Bornstein, 2021). A thorough understanding of the evolutionary and ontogenetic origins of language requires an investigation of the developmental trajectories that lead from infants’ innate social orientation to gestural communication and on to language acquisition. In the subsequent section, I discuss early developmental milestones relevant to human communication development and their occurrence in other primates that have not evolved a comparable natural language system.

The profound social motivation of infants (Grossmann & Johnson, 2007; Liszkowski & Rüther, 2021; Over, 2016) is demonstrated from birth in the dyadic reciprocal exchange of eye contact, facial expressions, and vocalizations between infants and parents[1] (Boiteau et al., 2021; Haviland & Lelwica, 1987; Lavelli & Fogel, 2002). It is proposed that this primary intersubjectivity shapes infants’ development, culminating in joint attention and ultimately in word learning (Moll et al., 2021; Terrace et al., 2022). Indeed, infants who displayed more reengaging behavior in a still-face paradigm showed more signs of joint engagement three months later (De Schuymer et al., 2011; Striano & Rochat, 1999). The relationship between early interactional experiences and later social

[1] Throughout the thesis I use the term parent to refer to the infants’ primary caregiver, independent of the exact family relations.

cognitive development is supported by the finding that infants who are securely attached and who experience low levels of maternal postpartum depression are more likely to demonstrate increased gaze following abilities at six and ten months of age (Astor et al., 2020). Moreover, dyadic interaction facilitates infants' perception of others as intentional, goal-directed agents (Reddish et al., 2019, Reddy, 2015; Rochat, 2007). The attribution of intentionality and mental states to an interaction partner is a prerequisite for joint attention and shared reference (Brandone, 2015; Tomasello et al., 2005; Woodward 2009). By considering others mental states, infants begin to expand situations of aligned attention with the element of joint attention around the age of nine months (Carpenter et al., 1998; Striano & Bertin, 2005; Tomasello et al., 2005). During joint attentional episodes, interaction partners share attention to an object and are recursively aware of their doing so (Kaplan & Hafner, 2006; Moore & Dunham, 2014; Tomasello, 1995). Tomasello and colleagues propose that the ability to engage in joint attention derives from a set of social cognitive skills termed 'shared intentionality'. Shared intentionality allows humans to form interpretations, understandings, and cooperative plans that they commonly agree on (Tomasello & Carpenter, 2007; for a current overview, see Chater et al., 2022). It is clear that a mutually shared attentional frame is essential for successful communication, as it allows for the resolution of ambiguity in prelinguistic and linguistic exchanges by inferring the speaker's intentions (Bohn & Frank, 2019; Liebal et al., 2009; Wilson & Carston, 2019). In chapter 1.1, I elaborate on infants' prelinguistic abilities to initiate and actively engage in episodes of joint attention.

In order to identify the early roots of human language, it is useful to briefly outline the relevant differences between humans and closely related species that did not develop a comparable natural language. Research yields evidence that non-human primates display a social orientation (Kano et al., 2018) and synchronize their body movements (Nishikawa et

al., 2021; Yu & Tomonaga, 2016). Moreover, vocal exchanges in bonobos depend on their maintained social bonds (Levréro et al., 2019). Non-human primates follow others gaze (Bettle & Rosati, 2019; Ferrari et al., 2000; Tomasello et al., 1998) and capuchin monkeys adapt their behavior to the goal-directed intentions of an experimenter (Phillips et al., 2009). However, these sophisticated social skills are less pronounced in non-human primates compared to humans (for an overview, see Carpenter & Call, 2013). For example, Wolf & Tomasello (2019) found a positive effect of co-oriented attention to a video on subsequent physical closeness in non-human primates. In a second set of studies (Wolf & Tomasello, 2020), they introduced a moment of gaze exchange into the sequence of co-oriented attention. While human infants showed a preference for proximity to the partner with whom joint attention was apparently established via gaze exchange, non-human primates did not discriminate between the two conditions.

Given these pronounced social cognitive abilities in humans, it is plausible that the development of human communication followed a different pathway than that of non-human primates. Non-human primates use imperative gestures to achieve their individual goals, such as requesting food, which can be considered a form of social manipulation (for an overview, see Voelter et al., 2017). The sharing of attention of interest in the absence of specific individual goals (declarative communication) is argued to be absent (Bullinger et al., 2011; Call & Tomasello, 1994; Hobaiter & Byrne, 2014; Liebal & Call, 2012; Liszkowski et al., 2009; Tomasello & Carpenter, 2005) or rare (Lyn et al., 2011; Wilke et al., 2022) in non-human primates. In contrast, humans frequently communicate declaratively and experience neural activation in reward-related brain regions when initiating episodes of joint attention (Schilbach et al., 2010). In addition to sharing attention and interest, humans communicate cooperatively to provide helpful information (Liszkowski, Carpenter & Tomasello, 2008). The ability to share interest and information

is not tied to linguistic competence, as infants do so via gestures (Boundy et al., 2016; Liszkowski et al., 2004) that are also used by non-human primates. Tomasello (2022) concluded that humans differ from non-human primates in their ability to recursively coordinate attention (joint attention) and in their motivation to collaboratively share attention (Call et al., 2000).

While these social cognitive underpinnings of language acquisition are evident in most humans, their development is characterized by high interindividual differences. Joint attentional abilities typically begin to develop from nine months of age, with pronounced individual variations (Mundy et al., 2007). For instance, the ability to initiate joint attention with an index-finger pointing gesture emerges between nine and thirteen months of age (Rüther & Liszkowski, 2023). These differences subsequently manifest in language acquisition, as joint attention abilities are predictive of language competence (for meta-analyses, see Bottema-Beutel, 2016 and Colonnesi et al., 2010).

The current dissertation examines the influence of early interaction experiences on infants' communication development. By investigating the factors that contribute to variations on the pathway to language proficiency, this dissertation offers insights into the unique human communicative system. It further provides an opportunity to address early communicative delays before they manifest as language impairments. In the following introductory sections, I explain my focus on infant deictic gestures as representatives of the early stage of declarative, referential communication. I then discuss potential influencing factors on infants' gestural development, with a focus on parental responsiveness and pointing. The introduction concludes with the main objective and the research questions of this dissertation. In chapters three to six, I present four empirical studies, with the aim of providing answers to the posed research questions. In the final chapter, I review the empirical results in the theoretical context of this dissertation.

1.1. Infant prelinguistic communication

This chapter offers an overview of infants' early communicative abilities and their proximity to language. It concludes by emphasizing the unique nature of infant gestures, particularly index-finger pointing, as a prelinguistic form of declarative, referential communication.

Immediately following birth, infants engage in dyadic communicative interaction with their social environment. This early face-to-face interaction is characterized by reciprocal and precisely coordinated turn-taking sequences between the infant and the parent (Hsu & Fogel, 2003). Although dyadic synchrony facilitates language learning (for an overview, see Harrist & Waugh, 2002), communication in the sense of (shared) reference is absent in this early interaction (for an overview, see Liszkowski, 2018a). The same limitation in terms of similarity to language applies to infant vocalizations that often occur during dyadic interaction. Infants vocalize from birth onward, producing reflexive sounds that gradually become speech-like during the first year of life (Nathani et al., 2006). Infant vocalizations from six months onward have been shown to predict language development (Goldstein et al., 2010; Lyakso et al., 2014; McGillion et al., 2017; Werwach et al., 2021). However, these predictions are constrained to infants' expressive vocabulary, indicating a potential correlation between early orofacial motor control and subsequent word production.

The capacity to comprehend and express language is inextricably linked to the ability to refer to an external entity in a way that is perceptible to others. In the second half of the first year of life, infants begin to do so through the use of deictic gestures. In addition to their referential function, gestures are analogous to language in that they can convey distinct communicative intentions (Begus & Southgate, 2012; Cochet & Vauclair, 2010; Liszkowski et al., 2006). Imperative communication is a shared trait among primates

and is evident in autistic children (Baron-Cohen, 1989; Mastrogiuseppe et al., 2014). It is therefore conceivable that the earliest emerging gesture is of an imperative nature. At approximately eight months of age, infants across cultures attempt to reach for objects that are clearly outside of their range (Blake et al., 1994; Veena & Bellur, 2015). The presence of this behavior is of particular interest because infants as young as six months are aware of the limits of their prehensile space (Rochat et al., 1999). Ramenzoni and Liszkowski (2016) demonstrated that infants increase their reaching attempts in the presence of a person. Moreover, infants expect the recipient to infer their intention and help them to obtain the object. Despite the social and referential intention of the reaching gestures, they are constrained to convey imperative communicative motives. The frequency of their occurrence remains relatively stable or decreases during development (Blake et al., 2005), and does not predict later language outcomes (Cameron-Faulkner, 2021).

At around nine months of age, infants begin to expand their communicative motives through the use of two additional gestures: whole-hand pointing and showing (Rüther & Liszkowski, 2023). Pointing with the flat palm morphologically resembles reaching gestures (Leavens & Hopkins, 1999). However, infants' body posture and their accompanying vocalizations serve as an indicator for the underlying communicative motive. A sitting back posture is associated with attention sharing, whereas a leaning forward upper body indicates the request for an object (Franco & Butterworth, 1996). Furthermore, declarative gestures are often accompanied by rising intoned vocalizations, while imperative gestures are characterized by flat intonation (Grünloh & Liszkowski, 2015). Infants employ whole-hand pointing in contexts of joint regard and frequently accompany the gesture with other communicative behaviors, such as gaze checking and vocalizations (Liszkowski & Tomasello, 2011). While whole-hand pointing definitively serves to communicate imperative and declarative motives, its relevance in the context of

language acquisition is limited for the following reasons. First, the frequency of whole-hand pointing increases during the first year of life, yet its proportional use in comparison to other gestures tends to decrease (Cochet & Vauclair, 2010; Ger et al., 2018; Liszkowski et al., 2012). Additionally, adults utilize whole-hand points primarily for specific purposes, such as indicating directions (Flack et al., 2018). Second, infants tend to point with the whole hand in requestive experimental conditions more frequently than in declarative conditions (Grünloh & Liszkowski, 2008). Like the requestive reaching gesture, whole-hand pointing is not correlated with an understanding of others referential intentions (Liszkowski & Tomasello, 2011). Third, with regard to its predictive value for language development, Lüke, Grimminger, et al. (2017) observed that 12-month-old infants who pointed exclusively with their whole hand were at risk for primary language delay one year later. Another study reported on the absence of a relationship between infants' whole-hand pointing and subsequent lexical processing (Ertaş et al., 2023).

The showing gesture emerges as a second relevant imperative and declarative gesture around nine months of age. Infants show objects by holding them into a person's visual field (Carpenter et al., 1998). The gesture is extended into a giving gesture depending on the interlocutor's reaction. It is challenging to determine infants' initial intention of the gesture (showing vs. giving). I concur with Cameron-Faulkner and colleagues (2015) in referring to this behavior as a HoG gesture (holdout and give, Boundy et al., 2016). Infants utilize HoG gestures to share their attention and interest in the object with their social partner (Boundy et al., 2019). HoG gestures do not correlate with reaching gestures (Cameron-Faulkner et al., 2015), but with pointing, suggesting the presence of a declarative motive (Guevara & Rodríguez, 2023; Rüther & Liszkowski, 2023). The presence of infant HoG gestures distinguishes autistic infants (absence of HoG gestures) from infants with and without other developmental delays (presence of HoG gestures;

Clements & Chawarska, 2010; Manwaring et al., 2017; Mastroguiseppe et al., 2015). In contrast to reaching and whole-hand pointing, the HoG gesture involves physical contact with the object of interest. In the absence of distal reference, HoG gestures may be regarded "as a proximal practice ground for later declarative behaviors" (Cameron-Faulkner et al., 2015, p. 584). The use of HoG gestures at 10 months has been demonstrated to predict language development at 18 months (Cameron-Faulkner et al., 2021; Choi et al., 2021), substantiating their relevance for communication development.

In conclusion, the majority of human infants use communicative gestures prior to their first birthday, demonstrating uniquely human social cognitive and motivational capacities. However, the specific gesture types differ considerably in their proximity to language. The relevant differentiating factors include the underlying communicative motives, the option to refer to distant and absent entities and the predictive value for language development. None of the aforementioned gesture types entirely fulfils these criteria. Consequently, the next chapter provides detailed information about index-finger pointing, the most extensively investigated prelinguistic gesture with pivotal importance for subsequent language development.

1.2. Infant index-finger pointing

Shortly before their first birthday, infants begin to point with their index-finger, with a few outstanding exceptions, such as lip-, nose-, or head-pointing (Cooperrider et al., 2018; Enfield, 2001). Index-finger pointing soon becomes the most common gesture in preverbal infant communication (Camaioni et al., 2004; Rüther & Liszkowski, 2023). Infants and adults across cultures use index-finger pointing in a multitude of communicative contexts (Kishimoto, 2017; Liszkowski et al., 2012; Salomo & Liszkowski, 2013; Tamis-LeMonda et al., 2012). Index-finger pointing emerges as a communicative behavior since infants adapt their pointing to the presence and reactions of their interaction

partner (Liszkowski et al. 2004, 2007). This communication conveys requestive, interrogative (Kovács et al., 2014), declarative and informative motives (Liszkowski, 2005). The importance of distinguishing the imperative and declarative motives of index-finger pointing is evident in the observation that the declarative form of index-finger pointing is associated with an understanding of others' intentions, while imperative index-finger pointing is not (Camaioni et al., 2004). Furthermore, Salo et al. (2019) provided evidence that infants' declarative index-finger pointing, not their imperative pointing, is related to later vocabulary. The specificity of these relations suggests that the morphological form of index-finger pointing per se is not a relevant factor in infants' communicative development. Instead, declarative index-finger pointing reflects infants' preparedness for referential cooperative communication (Lucca & Wilbourn, 2018; Salo et al., 2018).

The cooperative motive of pointing is most evident in a study by Liszkowski, Carpenter and Tomasello (2008), in which infants pointed to assist an adult in searching for an object. Remarkably infants adapted their pointing to the level of informedness of the adult. Infants further modify their point accompanying vocalizations to the attentional focus and the reaction of their interaction partner (Gros-Louis & Wu, 2012; Liszkowski, Albrecht, et al., 2008). This indicates that pointing in 12-month-old infants reflects an understanding of others' mental states. Moreover, infants exclusively point to the former location of a now absent object when they share common ground with their interaction partner (Bohn et al., 2018). The general ability to refer to absent entities on the basis of shared common ground is a key feature of human language, known as displacement (Auer, 1988). The relationship between pointing and language is further reinforced by the observation that index-finger pointing is generally more frequently accompanied by vocalizations than whole-hand pointing and HoG gestures (Liszkowski & Tomasello,

2011), and frequently coupled with speech-like vocalizations (Grünloh & Liszkowski, 2015). Children on the autism spectrum, who frequently experience challenges in language acquisition, demonstrate no difficulties with imperative pointing, but do not point for declarative reasons (Baron-Cohen, 1989).

In addition to differences from clinical populations, typically developing infants exhibit considerable variability in the onset and frequency of index-finger pointing. In a longitudinal study of 31 infants conducted by Rüther & Liszkowski (2023), six infants were observed to begin pointing at nine months of age, while five infants were not observed to point until the end of the study at thirteen months of age. The median age of emergence was 11 months, which is consistent with other research (Ger et al., 2023; Paulus et al., 2023). While determining the onset of pointing is relatively independent of the methodological context, the frequency of infant pointing is strongly dependent on the paradigm in use (Kaletsch & Liszkowski, 2024). Even within a paradigm, such as the decorated room, the frequency with which 12-month-old infants point during a five-minute observation is reported to vary from 0 to 32 points (Liszkowski & Tomasello, 2011). It is crucial to comprehend the factors that contribute to the variability in the age of emergence and frequency of infant index-finger pointing, as both are predictive of subsequent language development (for meta-analyses, see Colonnesi et al., 2010 and Kirk et al., 2022). Prior to discussing potential factors that influence the development of pointing in chapter 1.2.2, I provide details on the relationship between index-finger pointing and language development in the following chapter.

1.2.1. The relation between index-finger pointing and language development

Given the various communicative motives of declarative index-finger pointing, its absence in non-human primates, the language-like reference to distal and even absent entities, and the highly predictive value for subsequent language acquisition, index-finger

pointing is one of the earliest behavioral correlates of the origin of human language. At the neurophysiological level, the right-hand preference for pointing indicates the involvement of left hemispheric activation, which is known to be specialized for language (Esseily et al., 2011; Vauclair & Cochet, 2013). The age of emergence (Brooks & Meltzoff., 2008; Butterworth & Morisette, 1996, Lüke et al., 2019) as well as the frequency of infant index-finger pointing (Cochet & Byrne, 2016; Igualada et al., 2015, Lüke, Grimminger, et al., 2017) are predictive of subsequent language comprehension and production skills. Infants' pointing frequency at 14 months predicts infants' lexical processing efficiency at 18 months (Ertaş et al., 2023). Pointing to a specific object predicts the acquisition of the corresponding lexeme around three months later (Iverson & Goldin-Meadow, 2005). Furthermore, the combination of pointing gestures and words predicts the two-word stage on average 2.3 months later (Iverson & Goldin-Meadow, 2005; Özçalışkan & Goldin-Meadow, 2005). A delayed onset of index-finger pointing is indicative of language delay (Lüke, Grimminger, et al., 2017), and the absence of declarative index-finger pointing is as an early symptom of autism spectrum disorder (Camaioni et al., 2003).

Researchers investigated whether the concurrent and longitudinal relationship between pointing and language is of a correlational or causal nature. In a meta-analysis, Colonnesi et al. (2010) provided a synthesis of existing literature and identified three significant functions of pointing in language development. First, pointing paves the way for vocal reference and genuine symbolization (Werner & Kaplan, 1963). Second, pointing provides infants with early experience in influencing the mental states of others (Tomasello et al., 2007). Third, infant pointing elicits a verbal response from adults that is precisely tailored to infants' attentional focus, thus providing an ideal learning environment (Begus et al., 2014; Olson & Masur, 2015; Wu & Gros-Louis, 2014). A series of studies from Tamis-LeMonda and colleagues (1997, 1989 & 1999, for an overview, see Tamis-

LeMonda & Bornstein, 2002) provide evidence that the promoting function of responsive verbal input exceeds the influence of the total amount of language input. A reduced cognitive load might best explain improved language learning through parental responsiveness (Harris & Waugh, 2002). Verbal input that occurs in response to infants' attentional bids potentially facilitates the association between the language heard and the actual referent, as it does not require a shifting of infants' attention.

In chapter 1.2.3, I examine the role of parental responsiveness in the development of infant pointing, rather than as a mediator between pointing and language. I begin by summarizing the theoretical perspectives on the ontogenetic origins of infant pointing in the following chapter.

1.2.2. Theoretical accounts

Infant pointing represents a pivotal stage in communication development, functioning as a conduit between preverbal and verbal communication. Given the complexity of pointing, it is necessary to employ a multifactorial framework in order to explain the development of infant pointing. One rather unilateral theoretical perspective is the spontaneous onset account, which postulates that the emergence of pointing is based on the cognitive achievements of the infant (Butterworth, 2003). Considered infant factors are for example temperament (Ollas-Skogster et al., 2023; Salvadori et al., 2024; Vaughan et al., 2003), fine motor skills (Wang et al., 2014) and social cognitive abilities (social cognitive accounts, Cochet et al., 2016; Rüther & Liszkowski, 2020). In light of a growing body of research indicating the influence of interactional experiences on infant social cognitive and communicativeimbue development, it is unlikely that infant intrinsic factors sufficiently explain the aforementioned variability in infants' pointing development.

At the opposite end of the theoretical spectrum, it is assumed that the development of pointing is exclusively shaped by external factors, independent of infants' social

cognitive development. The hypothesis that parental behavior influences infants' gesture development is based on socialization accounts, which emphasize the role of the social environment in infants' development (Hunnius, 2022; Rocha et al., 2019). The central debate between different socialization accounts with regard to infant pointing concerns the question of whether infant pointing is socially motivated from the outset or rather serves non-social motives in the beginning. According to the social shaping perspective infant pointing begins as non-social behavior, such as failed reaching attempts (Vygotsky, 1978; Werner & Kaplan, 1963), touching (Kettner & Carpendale, 2018; O'Madagain et al., 2019) or as a general way to orient attention ('non-communicative pointing', Carpendale & Carpendale, 2010). These nonsocial behaviors are gradually shaped into social gestures through interaction with the social environment. Parental reactions to infants' nonsocial hand movements imbue them with communicative meaning, transforming them into communicative gestures in a dynamic interactional process. Independent of infants' initial behavior, social shaping accounts face a significant limitation. They do not offer an explanation of how and why parental behaviors generate seminal social learning forces, when they are irrelevant for infants' initial individual action goals. The benefit of parental attention alone is insufficient to account for the shaping process, as the gesture frequency of infants decreases when the elicited responses exclusively address the infant, while the intended referent is ignored (Boundy et al., 2019; Liszkowski et al., 2004 & 2007). Moreover, research has demonstrated that disruptive parental attention interferes with infants' focus of attention and inhibits joint attentional behaviors (Miller & Gros-Louis, 2013; Tomasello & Farrar, 1986).

A social constructivist perspective on infants' pointing development overcomes this limitation by synthesizing both aforementioned theoretical frameworks (Liszkowski & Rüther, 2021; Rohlfing et al., 2017). The social environment is proposed to influence the

development of infant pointing, but only when the infant is cognitively ready to process the input appropriately (e.g., goal-directedness, form joint goals). The key distinction between social shaping and social constructivist accounts lies in the assumption that parental influences exclusively unfold when parental behavior is pertinent to infants' own objectives. In the context of pointing, infants' associated objective must initially have a communicative motivation. Consequently, and in accordance with empirical findings on infants' referential communicative pointing intentions (as discussed in the introductory section of chapter 1.2), social constructivists consider infant pointing as a communicative act from the outset. Regarding its development, Liszkowski and Rüther (2023) proposed that pointing emerges from the most basic socially motivated interaction sequences, give-and-take routines such as breastfeeding. Building upon this foundation, more abstract offer/request and accept/reject sequences derive, which already include referential HoG gestures (offer). Subsequently, distal objects are included in this triadic exchange and the pointing gesture emerges. This developmental cascade is determined by the interplay of infant-level abilities and parents' precisely attuned behaviors. The social constructivist approach is supported by models of 'intuitive parenting' which claim that parents intuitively adapt their behaviors to infants' developmental progress (Papousek, 2002; Parsons et al., 2017). In the following chapter, I discuss infant and parent factors that potentially contribute to the development of infant pointing.

1.2.3. Factors influencing infants' pointing development

Several infant factors are considered as potentially relevant to communication development from spontaneous onset and social constructivist perspectives. Liszkowski and Rüther (2021) highlighted social cognition, interactive behaviors and motor skills as relevant infant-level predictors for the development of pointing. For successful referential communication, it is critical to establish a joint attentional frame. Thus, several studies

investigated the relationship between infants' attention following abilities and subsequent communication development (for an overview, see Çetinçelik et al., 2021). Brooks and Meltzoff (2005) reported that infants' ability to follow the gaze of others at 10 months of age predicts infant language scores eight months later (see also Delgado et al., 2002; Okumura et al., 2017; Tenenbaum et al., 2015). Regarding pointing, gaze following abilities are predictive of infants' pointing frequency one month later (Matthews et al., 2012). Rüther and Liszkowski (2023) found that infants' point following abilities at nine months of age predicted the age of emergence of index-finger pointing (see also Ger et al., 2023).

In a more general sense, Masek and colleagues (2021) proposed that infants' attentional abilities, such as sustained attention and attention shifting, are essential for engaging in dyadic interaction and, in turn, enable the infant to learn from the received input. In this reciprocal model, infants' attention skills serve as the foundation upon which contingent interaction shapes infants' communicative development. However, these basic attentional skills appear to be shaped by parental behavior. For example, Suarez-Rivera and colleagues (2019) reported that parents' touching and talking during object play with their infant was positively associated with infants' sustained attention. Other social cognitive abilities relevant to infants' prelinguistic communication are interactive behaviors, such as infant vocalizations (Burkhardt-Reed et al., 2021), or infant responses to parent communication (Kuchirko et al., 2018). In addition to social cognitive achievements, infants' motor development may impact communication development (Iverson, 2010 & 2022). For example, by six months of age, infants begin to sit independently, thereby enlarging the shared play space (Schneider et al., 2022) and the possibility for aligned visual attention with the parent (Franchak et al., 2018). Recently, infant temperament is considered as a potential additional influencing factor in infants'

communicative development (Bruce et al., 2022; Ollas-Skogster et al., 2023; Salvadori et al., 2024; Vaughan et al., 2003). Kucker et al. (2021) demonstrated that infant temperament and parental personality predict infants' subsequent language skills.

However, the relationship between parental personality and infant development is mediated by parenting practices (Bornstein et al., 2011; Vásquez-Echeverría et al., 2022). Rocha and colleagues (2020) reported on the influence of mother-infant interaction on several domains of infant development. With regard to socialization and social constructivist accounts on the development of infant pointing, two parental behaviors are particularly suited to facilitate the emergence of infant pointing. Firstly, parents respond to infants' signals from birth onward and possibly influence them accordingly (Frodi et al., 1978). Secondly, in accordance with the intuitive parenting account, the majority of parents begin to point for their 7-month-old infants (Liszkowski et al., 2012; Rüther & Liszkowski 2023), which may serve as a model for infants' own pointing. Evidence for the influence of both parental behaviors on infants' gesture development is provided by a training study of Romano & Kelly (2020). Three infants participated in training sessions with the experimenters, during which the infants experienced increased responses to their gestures and frequent modeling of gestures. The infants used more gestures after training, but the validity of the study is limited due to the small sample size and the lack of a control group. This area of research thus needs further investigation. In the following chapters, I review other empirical research examining the role of parental responsiveness and pointing in infants' pointing development.

1.2.3.1. Parental responsiveness. The theoretical construct of parental responsiveness is based on Ainsworth's concept of sensitive caregiving (Ainsworth et al., 1969). After identifying and interpreting infant cues, sensitive parents react promptly and appropriately to them. For example, during pregnancy, mothers respond to fetal

movements by touching their abdomen (Marx & Nagy, 2017). Immediately following birth, parents begin to respond to a multitude of infant social cues, including crying, gaze and touch (Beebe et al., 2010). The subtypes of parental responsiveness are classified according to the infant behavior that is considered a signal and range from 'behavior state matching' (Field et al., 1990; Noe et al., 2015) and 'dyadic synchrony' (Harrist & Waugh, 2002; Tschacher et al., 2014) to 'social contingency' (Nadel et al., 1999; Luchkina & Xu, 2022). Parental responsiveness is positively related to infants' secure attachment (Koehn & Kerns, 2018; Nievar & Bedcker, 2008), cognitive abilities (Landry et al., 2006; Masek et al., 2024; McFadden & Tamis-LeMonda, 2013) and language development (Baumwell et al., 1977; Borairi et al., 2021; Luchkina & Xu, 2022; Tamis-LeMonda et al., 2014). In light of the overall positive effect of parental responsiveness on infants' development, it seems reasonable to assume that infants' pointing development is similarly facilitated by parental responsiveness.

In terms of infants' pointing development, parental responsiveness is defined as parents' prompt, contingent and adequate reactions to infants' communicative signals. Prior to the emergence of pointing, parental responses provide the infant with insights about the referential nature of communication and establish joint attention, which facilitates infant learning (Landry et al., 2001). Once infants start to point, parental responses feedback that pointing successfully results in the intended establishment of joint attention. The social reinforcement learning hypothesis posits that the attainment of the desired outcome functions as a social reward, thereby encouraging the occurrence of the associated behavior (Ishikawa et al., 2020; Jones et al., 2011; Zeng et al., 2023).

Empirical research confirmed that parental responsiveness promotes infants' pointing development, both before and after its onset. Cameron-Faulkner et al. (2015) reported a positive correlation between parental responses to infant HoG gestures at 10

months and infants' subsequent pointing frequency. Furthermore, parents' relevant responses to 10-month-old infants' pointing were positively correlated with infants' pointing frequency at 12 months (Ger et al., 2018). With regard to the question of causality, research provided evidence that 12-month-old infants promptly adapted their pointing frequency in reaction to experimentally increased parental responsiveness during free play (Miller & Lossia, 2013). However, research has yet to substantiate the causality of the relationship between parental responsiveness and infant pointing. Moreover, no training study has evaluated the longitudinal effect of trained parental responsiveness on infant pointing development.

1.2.3.2. Parental pointing. Parental pointing provides a practice ground for infant imitation learning mechanisms (for an overview, see Meltzoff & Marshall, 2018). However, mere mimicry of parental pointing gestures, does not fully capture the underlying communicative complexity of infant pointing. Instead, experiences with parental pointing serve to guide infants' understanding of the communicative and referential aspects of human gestures (Liszkowski & Rüther, 2021; Tang et al., 2023). Thus, imitation learning in the context of infants' pointing development involves the complex imitation of the communicative intention and the gesture while transferring both into new interaction contexts (Dickerson et al., 2013, Yang et al., 2010). The preference of infants to imitate socially cued actions lends support to the assumption that imitation is an integral learning mechanism in the development of infant pointing (Brugger et al., 2007).

Empirical findings on the relation between parent and infant pointing vary. A longitudinal study by Rüther & Liszkowski (2023) provided evidence that parents' pointing frequency for their 8-month-old infants is predictive for infants' pointing onset. However, Ger et al., (2023) found no longitudinal prediction from parental pointing for their 8-month-old infants and infants' subsequent pointing frequency, without modeling

predictions for infants' pointing onset. The absence of longitudinal relations between parent and infant pointing frequencies is supported by other studies (Ger et al., 2018, Kishimoto, 2017). Results on cross-sectional relations between parent and infant pointing frequencies are equally ambiguous. In infants aged 11 and 12 months, positive relations between parent and infant pointing were found (Liszkowski et al., 2012; Liszkowski & Tomasello, 2011; Liszkowski & Rüther, 2023; Matthews et al., 2012; Rowe & Leech, 2019). In contrast, other studies observed no cross-sectional relationships between parent and infant pointing frequencies (Salo et al., 2019; Rowe, 2000). Training studies investigating the effect of increased parental pointing on infant pointing, do not clarify the contrasting findings. Rowe and Leech (2019) report an increase in infant pointing due to training, while Matthews and colleagues (2012) found no effect of training on infants' pointing status or frequency.

In reviewing the findings on the influence of parental pointing on infant pointing, it is essential to consider four underlying aspects. First, as with infants, the frequency of parental pointing depends on the paradigm in use. This is further discussed in the introductory sections of Study 1 and Study 4. It seems reasonable to posit that paradigms that most closely approximate parents' natural pointing behavior, are best suited to examine relations between parent and infant pointing. Second, it is plausible that the relationship between parent and infant pointing is not constant throughout infants' development. Parental pointing may influence infant pointing within specific periods of infants' development. Therefore, the point at which parental pointing is observed and the age at which infant pointing is considered as the outcome variable, both influence the findings. Third, it is conceivable that different social learning mechanisms influence infants' pointing onset and its frequency. Consequently, both variables should be considered separately. Fourth, parental communicative behaviors, such as pointing and

responding, and their influence on infant pointing are possibly interconnected. In particular, Essler and colleagues (2023) proposed that infants learn to imitate by being imitated by their parents. Parental imitation of infant behavior, in turn, is more frequently observed in responsive parents. Therefore, infants' abilities to imitate parental pointing gestures may be influenced by parental responsiveness, demonstrating the interrelation between both social learning mechanisms. As only Ger and colleagues (2018) considered parental pointing and responsiveness concurrently, other findings on the relation between parent and infant pointing might be mediated by parental responsiveness. These four aspects contribute to the contrasting results on the relationship between parent and infant pointing and explain the necessity of further research.

2. Rationale for the current thesis

Infant index-finger pointing is one of the earliest communicative behaviors in human ontogeny that resembles verbal reference. Pointing is therefore per se a relevant behavior to investigate the origins of human communication. By investigating the causal role of parental responsiveness and pointing on infant pointing, I unravel external developmental factors influencing one of the earliest uniquely human forms of communication. In addition, infants' pointing development is predictive for subsequent language abilities and is consequently a promising target for early communication interventions. Once the influence of parental responsiveness and pointing on infant pointing is understood, this link can be used to support infants at risk for communicative delays before they manifest. While the majority of researchers agree that parental behavior influences infants' pointing development, the influence of parental responsiveness and parental pointing has rarely been examined simultaneously. Furthermore, few studies explored the causal relationships among parental responsiveness, pointing and infant pointing.

The current dissertation comprises four independent studies that address six main research questions concerning the influence of parental responsiveness and pointing on infants' gestural development (see Table 1). The initial three studies evaluated the impact of parental behaviors on infants' pointing frequency. The subsequent study additionally examined infants' pointing status and the development of HoG gestures. Study 1 was of a methodological nature and included two experiments. Despite the necessity for remote observations during the Covid-19 pandemic, no online remote paradigm to observe infant pointing in natural interaction with their parent was established. In order to continue with my dissertation projects, we developed a corresponding remote method. Given the efficacy of the original decorated room paradigm (Liszkowski & Tomasello, 2011) in eliciting

infant and parent pointing in a natural interaction sequence, the new remote method was based on the original decorated room procedure. The natural interaction context was of particular importance as we planned to subsequently collect data on parental responsiveness and pointing. The objective of Study 1 was to examine whether the new remote method elicits spontaneous infant pointing and natural parent interaction with similar frequencies as the original decorated room paradigm. In both experiments, the participants were 12-month-old infants and their parents, with the aim of ensuring that the majority of infants were index-finger pointers. We invited the dyads to participate in a video-chat session during which they were presented with a series of age-appropriate stimuli via screen sharing. We instructed parents to interact with their infants as naturally as possible during the stimuli presentation. Data were recorded for a period of five minutes with the participants' webcam. To assess the applicability of the new design, we compared infant and parent behaviors with data from the original decorated room. Furthermore, we investigated whether infant pointing, parental responsiveness and parental pointing were cross-sectionally related. The results of Experiment 1 demonstrated that infants and parents spontaneously pointed in the remote decorated room. After adjusting the stimuli in Experiment 2, the data on infant pointing, parental responsiveness and parental pointing fell within the reported benchmarks of studies using the original decorated room paradigm. Parental responsiveness was cross-sectionally related to infant pointing, while no relation between infant and parent pointing was found. These findings indicated that the remote decorated room is a useful paradigm to observe infants' pointing in natural interaction with their parents.

In the second project, I examined the causality of the cross-sectional correlations between parental responsiveness, parental pointing and infant pointing. On the one hand, and in line with the intuitive parenting perspective, cross-sectional relations between infant

pointing and parent behavior may depend on parental adaptations to infants' gestural communication. For instance, an infant using only a few pointing gestures indicates to her/his parents that he/she is less engaged in communicative interaction at that moment (or in general). By accurately interpreting these infant signals, sensitive parents could adjust their responsiveness and pointing frequency to align with the infant's lower level of engagement. On the other hand, infants may adapt their pointing frequency to parental responsiveness and pointing. This second possibility would provide insight into the environmental factors that influence infants' pointing. To investigate which of the two proposed explanations is the most probable, we assigned 12-month-old infants and their parents to six experimental groups. The data were collected using the remote adaptation of the decorated room paradigm. Parents were either instructed to be especially responsive to infant pointing or they received no corresponding instruction. Additionally, we asked parents to point frequently, to avoid pointing or they received no instruction on parental pointing. In the event of group differences in infant pointing, we obtain evidence that infants adapt their pointing frequency to parental behaviors, which in turn shape infants' pointing development. Specifically, we hypothesized that increased parental responsiveness would enhance infant pointing. If imitation is an additional mechanism influencing infants' pointing frequency, we expected infants to point frequently when their parents were instructed to increase their pointing. Accordingly, we assumed that infants' would point less when parents decreased their pointing. The results indicated that infants' pointing frequency increased in accordance with increased parental responsiveness. Changes in parental pointing had no immediate effect on infants' pointing frequency. This study provided evidence for the promoting effect of parental responsiveness on infants' pointing frequency in a cross-sectional context. The results did not support the hypothesis of a direct cross-sectional relation between parent and infant pointing frequencies.

In Study 3, we examined the longitudinal relations between infant pointing, parental responsiveness, and parental pointing. Half of the sample was assigned to a training group, to assess the malleability of infant pointing in a longitudinal training context. For baseline data collection, we observed 12-month-old infants and their parents in the remote decorated room paradigm. Subsequently, dyads were randomly assigned to a control group or a training group. The training program involved parents establishing at least 15-minutes of daily triadic engagement at home to elicit infant pointing. When their infant pointed, parents were instructed to respond contingently. Parents were instructed to emphasize their response with a pointing gesture to increase parental pointing. After one month of training, we examined whether infants in the training group used more pointing gestures in the remote decorated room compared to infants in the control group. In a series of regression analyses, we sought to determine whether infants' pointing frequency post-intervention was best explained by infants' immediate adaptations to increased parent behaviors at t2 (see Study 2), longitudinal relations between infant and parent behaviors, or training. If training significantly increased relevant parental behaviors, we expected infants in the training group to point more frequently than infants in the control group. We further hypothesized that longitudinal training effects would exceed the cross-sectional relations between infant pointing and parental behaviors. The results indicated that infants in the training group exhibited a significantly higher pointing frequency at t2 compared to infants in the control group. Infants' pointing frequency was best explained by parental responsiveness and infant pointing at t1, parental pointing at t2, and group assignment. While parental responsiveness and training were positively related to infant pointing, parental pointing followed an inverse pattern. We concluded that parental responsiveness is a causal factor influencing infants' pointing frequency. Consequently, it can be posited that parental responsiveness is a particularly promising target for prelinguistic communication

interventions. Our findings challenge the notion that imitation is a significant social determinant for infants' pointing frequency.

Study 4 was conducted to investigate which parental factors contribute to an early emergence of infant pointing. To assess the possibility of promoting an early onset of infant pointing, we expanded the study with a training group. Furthermore, we examined whether the development of infant HoG gestures is based on the same learning mechanisms as infant pointing. We collected data on infant pointing in the remote decorated room and on infant HoG gestures during remote free play sessions. Given that infants typically begin to point at 11 months, we defined ten months as an early onset of pointing. Infants were seven months old at the baseline visit, which is an age at which parents usually begin to point for their infant. We collected data at four-week intervals for the following three months. Parents in the training group were instructed to create situations of shared interest with their infants for 15 minutes daily. We asked parents to respond contingently when their infants expressed interest in objects or events. 7-month-old infants rarely communicate their interest in external entities through active and recognizable initiation of joint attention (e.g., via gestures). Consequently, parents were instructed to generally join their infants' focus of attention. We refrained from including specific instructions on parental pointing, to prevent an inflationary increase in parental points (see Study 3). However, by emphasizing infants' gestural development, we anticipated an automatic increase in the frequency of parental gestures. The study design allows for the investigation of three research questions. First, we determined whether infants' early pointing status and frequency are predicted by parental responsiveness and parental pointing. Second, we analyzed whether infants' HoG status and frequency at the typical age of emergence are predicted by parental responsiveness and pointing. Third, we examined the effect of a training targeting parents' referential communication on infants'

early pointing and HoG development. We hypothesized that infants' early pointing status and frequency were predicted by parental responsiveness and pointing. Given the well-documented positive effect of parental responsiveness on infants' development, we expected that responsiveness is positively associated with infants' HoG status and frequency. To the extent that infants do not merely imitate parental pointing gestures, but gain a general insight into the function of reference by observing them, we expected that parental pointing promotes infants' HoG development. For both types of infant gestures, we expected a stronger effect for parental pointing during free play compared to the remote decorated room, as it better approximates parents' natural pointing frequency. If these predictions applied, we expected to observe training effects whenever parents successfully implemented our instructions. The results indicated that infants' early pointing status and frequency were predicted by parental pointing during free play. Training did not affect infants' early pointing development. Infants' HoG development was influenced by parental responsiveness and pointing. Infants in the training group were more likely to use HoG gestures and did so more frequently post-intervention compared to infants in the control group. In summary, the facilitating effect of parental responsiveness becomes evident at the age of the typical emergence of a specific gesture type. Parental pointing is an early influencing factor in infants' gesture development and goes beyond mere mimicry. The development of infant HoG gestures is influenced by similar social learning mechanisms as infant pointing and can equally be trained.

Table 1

Overview of the empirical studies

Study	Research question	Age (months)
1	Does the novel online remote paradigm elicit spontaneous infant pointing while preserving natural infant-parent interaction?	12
2	Do infants immediately adapt their pointing frequency to experimentally manipulated parental responsiveness and parental pointing?	12
3	Does a training targeting parental responsiveness and pointing affect infants' pointing frequency?	12 - 13
4	Do parental responsiveness and pointing influence infants' early pointing status and frequency?	7 - 10
4	Do parental responsiveness and pointing influence infants' HoG status and frequency?	7 - 10
4	Does a training targeting parental responsiveness affect infants' early pointing and HoG development?	7 - 10

In summary, this thesis presents a novel remote paradigm suitable for the collection of data on infant pointing, parental responsiveness, and parental pointing. Furthermore, evidence for causal cross-sectional and longitudinal relationships between parental responsiveness and infants' gesture development from the time of their typical emergence is presented. These results support the social constructivist hypothesis that parental behavior influences infants' development when it is relevant for infants' own intentions and attuned to infants' developmental status. Experience with parental pointing is identified as a relevant factor for infants' pointing and HoG development when measured in free play sessions. The findings support the assumption that the effects of parental pointing are not based on mere mimicry but on learning the referential function of gestures.

Parent-based trainings targeting parental responsiveness successfully promoted infants' gestural development and are promising candidates for early communication intervention.

All studies were conducted in accordance with the Declaration of Helsinki and approved by the local ethic committee of the University of Hamburg (see Appendix A). Data were collected between March 2020 and September 2023.

3. Study 1: A new remote paradigm to measure spontaneous pointing in infants and parents

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3.1. General Introduction

Pointing is a milestone in the emergence of referential communication (Bates et al., 1975) and predicts subsequent language and social-cognitive development (Colonnesi et al., 2010; Sodian & Kristen-Antonow, 2015; for an overview, see Liszkowski, 2018a). Researchers have used a variety of paradigms to observe and measure infants' pointing. Methods range from indirect measures, such as diary observations (Carpendale & Carpendale, 2010) and parent reports (Camaioni et al., 2004: Questionnaire on Pointing Gesture; Fenson, 2007: MacArthur-Bates Communicative Development Inventories), to direct measures, such as field observations (Salomo & Liszkowski, 2013) and standardized experimental elicitation (Butterworth et al., 2002; Camaioni et al., 2004; Liszkowski et al., 2004). Direct measures are advantageous, because they provide insight into the actual use and development of pointing behavior. Disadvantages are that naturalistic observations typically involve large variations in the observed settings, making comparisons difficult. Laboratory-based experiments often lack appropriate social situatedness due to relatively rigid settings, and are likely to misestimate the natural frequencies of social behaviors. In response to these challenges, Liszkowski & Tomasello (2011) introduced a promising,

easy-to-administer method that standardizes the observation setting while preserving the relative naturalness and social situatedness of pointing. The interaction-based decorated room elicits natural, spontaneous pointing from parents and infants in different cultural settings and populations (Ger et al., 2018; Liszkowski et al., 2012; Lüke, Grimminger, et al., 2017).

In the original decorated room paradigm, objects and pictures decorate the walls of a room, and remote-controlled cameras record the scene from different angles. Stimuli include pictures of objects and real objects that differ in their familiarity (for a detailed list, see Liszkowski et al., 2012). Parents carry their infants on their hips and are asked to look at the decoration items together for five minutes, without touching them. The resulting natural interaction between parent and infant is of particular relevance, because infant pointing is influenced by the presence and behavior of interactants (Franco et al., 2009; Liszkowski et al., 2004). Knowledge of parents' interactive behaviors also helps to address substantial individual variance in the onset and frequency of infant pointing. For example, the frequency of parent and infant pointing has been reported to be related (Matthews et al., 2012; Liszkowski et al., 2012; Liszkowski & Tomasello, 2011; Rowe & Leech., 2019; Rüther & Liszkowski, 2023; Salo et al., 2009), although other controlled studies have failed to find a direct relationship (Ertas et al., 2023; Ger et al., 2018; Lüke, Ritterfeld et al., 2017). Furthermore, parental responses to infant gestures have been reported to promote infant pointing frequency (Cameron-Faulkner et al., 2015; Ger et al., 2018; Kishimoto, 2017; Liszkowski et al., 2012; Miller & Lossia, 2013).

With the outbreak of the recent Covid-pandemic and the obligation to distance oneself from direct social interaction, the need for a comparable remote paradigm became apparent. In the current experiments, we developed a new remote paradigm that implements the advantageous methodological aspects of the decorated room paradigm, and

elicits spontaneous pointing in infants and parents in an interactive situation. An interaction-based remote paradigm is a promising tool even beyond pandemic times. It does not require setting up a costly laboratory, and time-consuming lab visits, as neither the users nor the participants need much more than a laptop with a stable Internet connection. The tool provides opportunities for large scale sampling, for worldwide, diversified data collection, and quick and easy risk screening, e.g., in case of language delay.

In the current remote decorated room, participants watched a slideshow of pictures and animated events presented via video interaction software (Skype) at an appropriate distance from the screen. We attempted to implement aspects of the original decorated room in terms of duration of data collection, self-paced inspection of stimuli, and return to stimuli. Additionally, we kept the instructions as similar as possible. Because we were not sure in advance what infants would point to, we varied the stimulus material along several dimensions. After Experiment 1, we optimized the stimulus material for Experiment 2.

3.2. Experiment 1

We invited 12-month-old infants and their parents because most typically developing infants are able to point with their index-finger pointing around their first birthday. We coded each infant pointing gesture according to hand shape and accompanying vocalizations, since not only the age of emergence (Carpenter et al., 1998), but also the frequency (Mundy et al., 2007), and infants' handshape (Lüke, Grimminger, et al., 2017) predict later language acquisition (for an overview, see Colonnesi et al., 2010). To account for the social situation between parents and infants that has been reported to be associated with infants' gesture use, we coded parental points and their reaction to infant pointing. Besides enabling us to evaluate whether the remote decorated room provides a comparable social environment to the original decorated room, it allows us to investigate

the reviewed relations between parental responsiveness and parental pointing and infant pointing.

As in the original decorated room, the stimulus material varied according to familiarity (familiar vs. novel) and style (real objects vs. pictures). Because the addition of sound and motion has been reported to increase pointing in live settings (Butterworth et al., 2002), and while watching television (Valkenburg & Vroone, 2004), we added this variation to our stimuli. Online remote studies cannot directly statistically be compared to in-presence interactional laboratory studies due to differences in stimuli, settings, and so on. Thus, we extrapolated parameters from previous findings with the original decorated room paradigm (Ger et al., 2018; Kishimoto, 2017; Liszkowski et al., 2012; Liszkowski & Tomasello, 2011; Rüther & Liszkowski, 2023) as benchmarks for the novel method. In addition, we used parameters reported in Choi et al. (2021) and Miller & Lossia (2013) for parental responsiveness. The results are descriptive and exploratory. If the new online remote method captured infant and parent behavior similarly to the established live methods, then we expected values to fall within the reported ranges.

3.2.1. Method

3.2.1.1. Participants. Due to the exploratory nature and limited resources during the pandemic, we planned to conventionally collect data from N = 30 dyads. This sample size is comparable to sample sizes in other studies on infant pointing (Choi et al., 2021; Ger et al., 2018: Kishimoto, 2017; Liszkowski & Tomasello, 2011; Liszkowski et al., 2012; Miller & Lossia 2013; Rüther & Liszkowski, 2023).

Twenty-four infant-parent dyads participated in Experiment 1 (11 female infants; 2 fathers). Six additional dyads were excluded from analyses due to technical difficulties or missed appointments. The mean age of the infants was 12 months and 17 days (*SD* = 9.1; range: 12;0 – 12;28). All infants were typically developing and born at full term. The

families lived in the German metropolis Hamburg at the time of data collection (from May 2020 to December 2020). Parents' age ranged from 30 to 43 years (M = 33.7, SD = 8.2), and 88% were their infant's primary caregiver. All participating parents spoke German, 25% of the infants (three females) were raised bilingual or multilingual. Twenty-two participating parents had at least a bachelor's degree. Six infants (two females) regularly attended a day care center. The families were recruited from a database of parents who had agreed to participate in developmental studies (see Appendix B), typically with a middle to high SES.

3.2.1.2. Set-up and stimuli. Data were collected using the video chat programs Skype or Zoom. Dyads faced the screen of their laptop or tablet, looking at different stimuli together for a maximum of five minutes. As shown in Figure 1, infants were seated on the lap of their parent or in a high chair next to their parent. Prior to testing, we asked parents to position the screen one meter away from the participants, beyond arm's length, in order to track all gestures of the dyad and to prevent the infants from touching the device. Webcams of the participants transmitted the scene while experimenters recorded their own screen via Quicktime or VLC Player. We asked participants to avoid distractions in the room, such as toys, people or pets, and to turn off distracting noises, such as a radio or smartphone, and to close the windows of the room. Infants were supposed not to eat, drink or use a pacifier during the test phase. We arranged suitable lighting conditions together with the parent before the recording started. For example, we asked the parent to close curtains or turn on lights and not to position the camera in front of a bright light source. If the experimenter could not see the infant's face and hands well during data collection, she asked the parent to reposition the camera until successful.

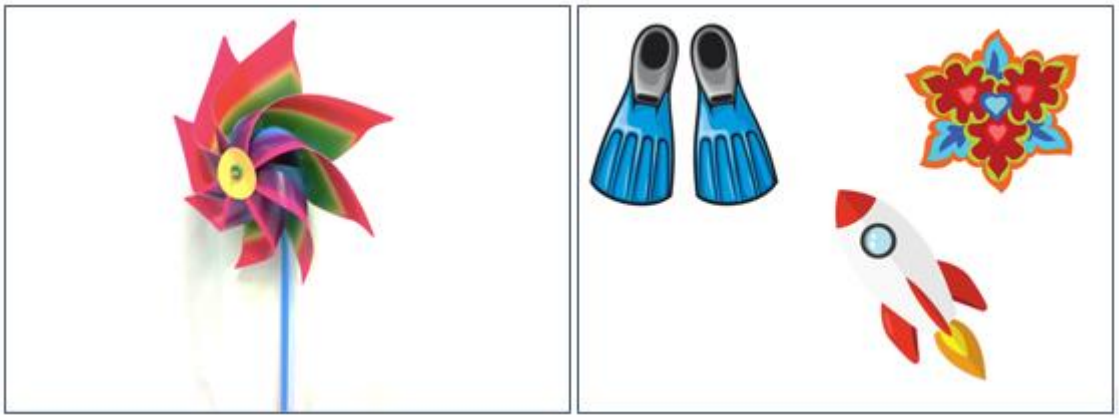
Figure 1

Infant pointing gestures in the remote decorated room

The presentation included 19 slides (analogous to the number of items in the original decorated room), five of which presented a video. Three videos repeated a short scene in a loop, two showed a short scene with additional audio signal and ended in a still frame after five seconds. The remaining slides varied in style and familiarity as in the original decorated room (see Figure 2). To account for the original variation between real objects and pictures, the slides showed either photographs of the original material in the live set-up or cartoon pictures. In terms of familiarity, familiar stimuli showed objects that infants were likely to know from their everyday lives (e.g., a dog). Infants probably encountered novel objects less frequently (e.g., a chessboard). In addition, the number of pictures presented on a slide ranged from one to three. Three stimuli were repeated to simulate the original decorated room in which dyads sometimes return to previously viewed objects.

Figure 2

Sample stimuli in Experiment 1, Study 1



Note. The first sample slide shows the photograph of one familiar object. The second sample slide shows three cartoon pictures of unfamiliar objects

3.2.1.3. Procedure. Prior to data collection, parents received an email with detailed information about the privacy policy (see Appendix C for sample parent information, consent forms and socioeconomic questionnaire of the KOKU) and general instructions concerning the setting and technical requirements (see Appendix D). Shortly before the appointment, parents received an invitation link to the online meeting. Together with the experimenter, the set-up was improved if necessary, with special attention to camera position and lighting conditions. Consent for video and audio recording was obtained verbally and videotaped.

As is standard, we did not mention the pointing gesture prior to data collection and fully debriefed parents after the presentation about the exact purpose of the study. We kept the instructions general to avoid biasing parents' behavior, and the experimenter read the instructions to the participants for standardization. Parents were told to "look at the following slides together with your son/daughter and act as naturally as possible". If parents had no further questions, the experimenter shared the screen, started the recording, and asked for consent again to preserve the response on video. At the end of the

presentation, the recording and screen sharing were stopped and the parents were fully debriefed. The local ethics committee of the authors' institution approved the study (see Appendix A).

Slide presentation. The presentation of the slides was individually tailored to the dyads' behavior. Each slide was shown for a minimum of five seconds, followed by the next slide if neither the infant nor the parent communicated during that time. Five seconds were added after each communicative behavior, up to a 30-second limit. We showed the next slide if the child looked away from the screen for more than three seconds. Parents were instructed to ask for the next slide if they felt the presentation was too slow or if the stimuli were in any way disturbing.

3.2.1.4. Coding and reliability. Data were coded using the Mangold Interact Lab Suite version 18.5.5.1. Three coders were trained on the coding scheme. For the main purpose of this study, we coded parent and infant pointing following Liszkowski and Tomasello (2011). Infant points were coded when the infant extended his or her arm halfway or fully toward the screen. They were classified as index-finger points when the index-finger was clearly extended relative to all other fingers. Throughout the whole presentation, we coded infants' vocalizations when they were voluntary and not fussy. We defined a point as accompanied by a vocalization when both occurred within one second. Parental pointing was coded when the index-finger was extended and directed toward the slides.

Responses to infant pointing included a conservative time criterion of two seconds after the child had pointed (Ger et al., 2018; Wu & Gros-Louis, 2014). Further time criteria can be found in Liszkowski et al., 2012 (10 seconds) and Kishimoto, 2017 (six seconds). Relevant response behaviors ranged from nodding and gestures, to supportive monosyllabic utterances ("hmhm") and complex utterances ("Yes, that's a dog jumping in

a suitcase."). Off-task activities were coded when the dyad was not engaged in the task, such as moving from the high chair to the parents' lap, eating, or touching the device. Fussiness was coded when the infant cried or became fussy. Dyads were excluded if infants were fussy for more than 90 seconds or if less than 180 seconds of undisturbed data collection was available for coding.

We calculated Cohen's kappa with a Mangold Interact tool. Trained researchers double coded 20% of all videos (6). Two identical codes, separated by a maximum of two seconds, were defined as a match. Kappas were excellent for infant index-finger pointing ($\kappa = 1$), accompanying vocalization ($\kappa = 0.89$), parental pointing ($\kappa = 0.9$), and parental responsiveness ($\kappa = 0.82$).

3.2.1.5. Analyses. Data were analyzed using IBM Software SPSS. Parental responsiveness depended on the occurrence of infant pointing and was therefore operationalized as the number of parental responses divided by the number of infant pointing gestures. To account for the individual time of data collection, infant and parent pointing was calculated per minute of undisturbed data collection (total duration minus off-task activities and infant fussing). We analyzed infant and parent behavior descriptively to assess the usability of the paradigm according to the benchmark parameters.

3.2.2. Results

Table 2 shows the benchmarks from previous studies with the original decorated room (left columns), the descriptive data of Experiment 1 (middle column), and Experiment 2 (right column). Eighteen infants pointed with their index-finger at least once, with an average frequency of less than one point per minute. Infant pointing frequency ranged from 0 to 16, for a total of 107 points. More than half of all index-finger points were accompanied by vocalizations. Hand points were rare and were not analyzed further (a total of seven points from five infants, 6% of all points).

Parents pointed more frequently than infants, $z = 3.06$, $p = .002$. All but one parent used the pointing gesture at least once. Parents responded to more than three-quarters of all infant points.

Table 2

Descriptive data of Study 1 and equivalent benchmarks from literature

	Original decorated room		Remote decorated room	
	Range	Mean	Experiment 1	Experiment 2
Number of infant index-finger pointers	58%[3] - 86%[2]	74%[2,3,7]	75%	81%
Infant index-finger pointing frequency per minute	0.83[3] - 2.8[7]	1.76[2-5,7]	0.86 (0.9)	1.46 (1.55)
Accompanying vocalization	34%[3] - 64%[4]	50%[2-5]	56% (34.52)	55% (39.33)
Number of pointing parents	92%[4] - 97%[7]	95%[4,7]	96%	79%
Parental pointing frequency per minute	1.77[4] - 3.33[2]	2.64[2-5,7]	1.99 (1.8)	1.57 (2.69)
Parental Responsiveness	65%[6] - 74%[2]	71%[1,2,6]	79% (28.75)	83% (25.47)

Note. Benchmarks from [1]Choi et al., (2021); [2]Ger et al., (2018); [3]Kishimoto, (2017); [4]Liszkowski & Tomasello (2011); [5]Liszkowski et al., (2012); [6]Miller & Lossia, (2013); and [7]Rüther & Liszkowski, (2023). Studies 1-5 used the original decorated room paradigm for data collection. In Study 6, data were collected in a free play session. Means of experiment 1 & 2 are reported with standard deviations in parentheses.

3.2.3. Discussion

The purpose of this experiment was to develop an easily accessible remote online format for observing infant gesture use during spontaneous interactions with their parent. The paradigm successfully elicited infant and parent pointing. Benchmark parameters from previous in-presence paradigms were largely comparable to the current data. The results suggest that the remote decorated room successfully discriminates between pointing and non-pointing infants. Parents responded to the expected amount of infant pointing, indicating a comparable social environment as in the original decorated room.

The frequency of infant pointing appeared to be slightly reduced compared to previous findings, perhaps reflecting a difference between in-presence and remote settings, or in the types of stimuli. Since infants accompanied their pointing with vocalizations about as often as expected from previous findings, we assume that pointing in the remote paradigm bears a comparable level of infant communicativeness. In order to increase the amount of infant pointing, we optimized the stimuli in Experiment 2 to test whether this would increase the frequency of infant pointing.

3.3. Experiment 2

In Experiment 2, we investigated whether changes in stimulus presentation and material increased the frequency of infant pointing. Little systematic is known about the characteristics of stimuli that elicit infant pointing. In terms of infant preference, faces and face-like stimuli attract infants' attention more readily than other stimuli across different situations and paradigms (Danko-McGhee, K., 2010; Gluckman & Johnson, 2013). Butterworth et al. (2002) found that the salience of a target, when accompanied by sound and motion, increased pointing in 16-month-old infants. Furthermore, in experimental in-presence settings, hide-and-seek-like revelation of objects has been shown to elicit pointing, e.g., when a hand puppet appears from behind a curtain (Liszkowski et al., 2004).

Thus, the interestingness of stimuli may be a proxy for the motivation to communicate about them.

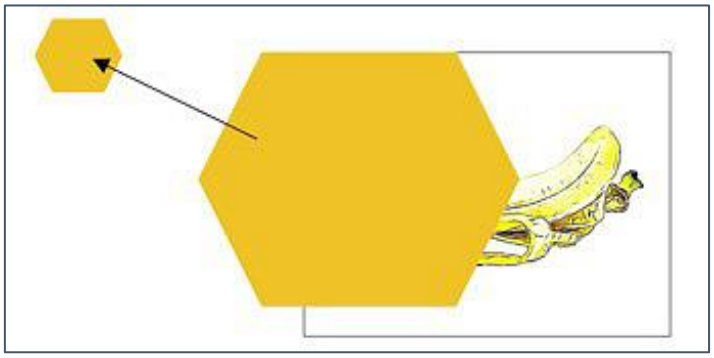
In line with these findings, the stimulus presentation in Experiment 2 included only interesting objects typically known and appreciated by infants (i.e., a banana). To maintain a comparable level of interestingness, stimuli were not repeated. Additionally, half of the slides contained a face or face-like stimuli. To digitally mimic the hide-and-seek-like appearance of objects, a superimposed hexagon shape initially covered each stimulus and then moved laterally to a corner of the slide. We expected an overall increase in the pointing frequency of infants compared to Experiment 1. Furthermore, if visual preference implies greater interest in a stimulus and leads to a higher likelihood of communicating about it, then faces should elicit more pointing than other stimuli.

3.3.1. Method

3.3.1.1. Participants. Families were recruited as in Experiment 1. Sample size was determined by power analyses allowing for justified comparisons between Experiment 1 and Experiment 2 with an independent t-test for unequal sample sizes, medium-large effect size (d = .7), and a power of 0.8 (planned N = 50, see Table SM.1 in the supplementary material section of this study). Forty-seven infant-parent dyads participated in Experiment 2 (23 female infants; 7 fathers). Three additional dyads were excluded from the analyses due to technical difficulties during data collection. Infants' mean age was 12 months and 16 days (SD = 9.1; range: 12;3 – 12;30). All participating parents spoke German, 28% of the infants were raised bi- or multilingual. Forty participating parents had at least a bachelor's degree.

Figure 3

Sample stimuli in Experiment 2, Study 1



Note. The hexagon revealed a familiar object without a face.

3.3.1.2. Set-up and stimuli. We collected data using the same set-up, procedure, and slide-advancement as in Experiment 1. The presentation included 18 slides plus one opening and one closing slide. Slides showed one familiar object without repetitions. Half of the slides showed a face or a face-like configuration. To maintain infants' level of attention, we presented one of three videos every fifth slide. For the same purpose, we added a brief attention-getting sound at the beginning of the slides at positions 3, 8, 13 and 18. A hexagon matching the dominant color of the stimulus covered it at the beginning of each slide (see Figure 3). After 1.5 seconds, the hexagon revealed the object by moving to another part of the slide while decreasing in size.

3.3.1.3. Coding and reliability. We coded the data and established the reliability as in Experiment 1. We calculated Kappa for infant index-finger pointing (κ = 0.88), accompanying vocalization (κ = .61), parental pointing (κ = .86), and parental responsiveness (κ = .77).

3.3.1.4. Analyses. First, we reported our descriptive results as in Experiment 1. Additionally, we supplemented each section with direct statistical comparisons between Experiment 1 and Experiment 2 using independent sample t-tests or non-parametric tests.

Differences in infants' pointing frequencies for stimuli with or without faces were tested with a dependent t-test. We combined data from both experiments to assess the cross-sectional relationship between infant pointing frequency and parental behavior. We conducted a negative binomial regression for count data (Green, 2021; Zeileis et al., 2008) on infants' index-finger pointing with parental responsiveness and pointing as predictors.

3.3.2. Results

Descriptive data of Experiment 2 are shown in the right column of Table 2 above. All but nine infants pointed with their index-finger at least once. Infants' pointing frequency ranged from 0 to 30, for a total of 336 points. More than half of all index-finger points were accompanied by vocalizations. Infants in Experiment 2 pointed on average 0.6 times more per minute, significantly different from infants in Experiment 1, $t(69) = -2.05$, $p = .042$. The number of infant pointers, $\chi^2(1) = .33$, $p = .56$, and the number of point-accompanying vocalizations did not differ between the two experiments, $t(37.77) = .06$, $p = .954$. As in Experiment 1, hand points were rare and were not analyzed further (a total of 33 points from 16 infants, 9% of all points). Stimuli with faces (M = .53, SD = .58) lead to a higher number of infant points than stimuli without faces (M = .37, SD = .53); t(46) = 2.75; p = .008.

Parents in Experiment 2 pointed as often as their infants did, $t(64) = -.20$, $p = .841$. All but 10 parents used the pointing gesture at least once. Parents responded to more than three-quarters of all infant points. Parents in Experiment 2 pointed at the same rate per minute as parents in Experiment 1, $t(69) = .699$, $p = .487$. The number of non-pointing parents was higher in Experiment 2, but not statistically significant, $\chi^2(1) = 3.55$, $p = .059$. Parents responded to a comparable number of infant points as in Experiment 1, $t(54) = -.544$, $p = .589$.

Table 3

Regression analysis of Study 1

	B (SE)	Exp(B)	95% CI, Exp (B)		p
			LL	UL	
Parental responsiveness	1.24 (.52)	3.46	1.25	9.54	**.016**
Parental pointing	-.02 (.01)	.98	.96	1.01	.229
Intercept	1.13 (.45)	3.09	1.29	7.43	**.012**
Goodness of Fit	*deviance* = 61.25		*df* = 53		*value/df* = 1.16

Note. N = 57, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

Parental responsiveness and pointing did not correlate, when we combined data from Experiment 1 and 2, $r = .07$, $p = .592$. The overall model predicting infants' pointing frequency with parental responsiveness and parental pointing was significant, $\chi2(2) = 6.31$, $p = .043$. Parental responsiveness is a facilitating factor for infants' pointing frequency, $\chi2(1) = 5.75$, $p = .016$, whereas parent and infant pointing were not cross-sectionally related, $\chi2(1) = 1.45$, $p = .229$. See Table 3 for regression coefficients.

3.3.3. Discussion

In Experiment 2, we adapted the stimuli to increase infants' pointing frequency. With the new set of stimuli, infants pointed almost twice as often as in Experiment 1. Infants and parents behaved similarly in both studies with respect to other variables. The regression analysis revealed a significant synchronous relation between parental responsiveness and infant pointing frequency, supporting the longitudinal findings in the original decorated room (Ger et al., 2018). We found no synchronous relationship between parent and infant pointing, adding to the mixed findings in the literature.

Infants pointed more frequently to stimuli depicting faces. It remains uncertain, whether the increased appearance of faces, the implementation of an uncovering element, or random stimulus features led to infants' increased pointing frequency in Experiment 2. Nevertheless, the significant difference between infants' pointing frequencies in both studies demonstrates an effect of stimulus selection and presentation on the occurrence of infant pointing and calls for standardization of settings in future studies.

3.4. General discussion

The purpose of this study was to first develop and then improve a remote, social paradigm for observing infants' gesture use. The remote online paradigm provided data comparable to the original decorated room. Importantly, it also captured the social dimension of parental responsiveness to infant pointing and parental pointing. Because pointing is a social act, it is important to preserve its social dimension when assessing it. This is particularly evident from the fact that parental responsiveness and infant pointing were cross-sectionally related. The new remote online decorated room paradigm represents the first successful implementation of a reliable remote tool to measure infants' pointing abilities as well as parental behavior, for scientific or diagnostic purposes.

Conceptually, it has been suggested that parental responsiveness promotes infant pointing (Ger et al., 2018; Liszkowski & Rüther, 2021; Tamis-LeMonda et al., 2014), which is supported by the results of the regression analysis. To make the results comparable across studies, it will be important to standardize the defined time window of a response. Setting a time interval that is too long could artificially increase responsiveness (e.g., Kishimoto, 2017; Liszkowski et al., 2012). In contrast to previous reports, the current study did not find a direct relation between parent and infant pointing frequency, which remains to be investigated (Liszkowski et al., 2012; Liszkowski & Tomasello, 2011; Mathews et al., 2012; Rüther & Liszkowski, 2023; Salomo & Liszkowski, 2013). One

possibility is that this relationship tends to be longitudinal, rather than synchronous, and/or is mediated by larger age ranges.

The current study is a first step toward an easily accessible tool that allows for data collection from diverse samples, longitudinal studies in the home environment, large-scale multi-laboratory studies, and cross-cultural research. For the latter, it will be important to consider access to, and familiarity with digital devices and communication, as well as the appropriateness of stimulus material. An exciting prospect is the development of a standardized diagnostic screening tool to identify delayed prelinguistic communication and risk of language delay as early as possible. Identifying emerging language difficulties at the nonverbal stage may provide an option for prevention rather than intervention.

3.5. Supplementary material

Table SM.1

Power analysis

t tests - Means: Difference between two independent means (two groups)		
Analysis:	A priori: Compute required sample size	
Input:	Tail(s)	= Two
	Effect size d	= .7
	α err prob	= .05
	Power (1-β err prob)	= .8
	Allocation ratio N2/N1	= 1.5
Output:	Noncentrality parameter δ	= 2.87
	Critical t	= 2.00
	Df	= 68
	Sample size group 1	= 28
	Sample size group 2	= 42
	Total sample size	= 70
	Actual power	= .81

Note. The power analysis was calculated with G*Power 3.1.9.4

4. Study 2: Infants adapt their pointing frequency to experimentally manipulated parental responsiveness but not parental pointing

This paper was submitted (2023) and revised (2024) in a slightly different version under Kaletsch, K. & Liszkowski, U. (2024). Infants adapt their pointing frequency to experimentally manipulated parent responsiveness but not parent pointing. *Infant and Child Development.*

4.1. Introduction

Index-finger pointing is a crucial milestone in the development of referential communication. Infants' pointing frequency is predictive of subsequent language development and risk for language delay (Colonnesi et al., 2010; Goldin-Meadow & Rowe, 2009; Lüke, Grimminger, et al., 2017; Salter & Carpenter, 2022). Given its developmental importance, several recent studies have investigated the ontogenetic origins and development of the pointing gesture (Cameron-Faulkner et al., 2021; Choi & Rowe, 2021; Ger et al., 2018, 2023; Matthews et al., 2012; Rüther & Liszkowski, 2023). The resulting theoretical perspectives can broadly be divided into spontaneous onset accounts (Butterworth, 2003), social shaping accounts (Carpendale & Carpendale, 2010) and social constructivist accounts (Liszkowski & Rüther, 2021). A central question is which, if any, parental behaviors promote the development of infant pointing. Identifying the social learning mechanisms that influence the development of pointing will advance our understanding of the foundations of human communication and language. It also offers intriguing prospects for early parent-based interventions to reduce the risk of language delay.

According to the spontaneous onset account, infant pointing develops independently of the infant's social interaction experiences (Butterworth, 2003), whereas shaping accounts claim the opposite. According to Carpendale and Carpendale (2010), pointing develops as parental reactions to infants' nonsocial behavior, such as touching, shape them into communicative behaviors. Synthesizing, Liszkowski and Rüther (2021) provided evidence that infant gestures are communicative from the outset and are influenced by social interaction once the infant is cognitively ready to adequately process the social input. Social shaping and social constructivist accounts discuss two main social learning mechanisms in the development of pointing (for an overview, see Liszkowski & Rüther, 2021). First, parents respond to infants' attentional bids (Carpendale & Carpendale, 2010), which facilitates communicative exchanges and thus infant pointing (Ger et al., 2018). Second, parents' own pointing may serve as a model from which infants learn through imitation (Rowe & Leech, 2019; Tomasello, 1999). However, to date, no study has systematically investigated both factors simultaneously in an experimental setting.

Infant communication elicits responses from their social partners (Kishimoto et al., 2007), which in turn influence infants' communicative exchanges, presumably by satisfying and enforcing infants' social goals and motives for communication (Liszkowski & Rüther, 2021). Indeed, findings on responsiveness emphasized rather consistently the positive influence of parental responsiveness on infant communication (Tamis-LeMonda et al., 2014) and pointing (Ger et al., 2018; Liszkowski et al., 2004). For example, Cameron-Faulkner and colleagues (2015) found a positive association between parents' relevant responses to infants' showing gestures at 10 months and infants' pointing frequency at 12 months. Ger and colleagues (2018) found a longitudinal relation between parents' contingent responses to the pointing gestures of their 10-month-old infants and infants'

pointing frequency at 12 months. However, research that examines the causal nature of this relationship is rare (but see Miller & Lossia, 2013).

With respect to imitation learning, several studies found cross-sectional correlations between parent and infant pointing (Liszkowski & Tomasello, 2011; Liszkowski et al., 2012; Matthews et al., 2012; Rüther & Liszkowski, 2023; Salomo & Liszkowski, 2013), while other studies failed to find this relationship (Ger et al., 2018 & 2023; Lüke, Ritterfeld, et al., 2017; Salo et al., 2019). Beyond correlations, one recent study reported training effects of increased parental pointing on later infant pointing (Rowe & Leech, 2019), but another intervention study found no training effects from parent to infant pointing (Matthews et al., 2012). Beyond the heterogeneity of study-specific designs and findings, however, an important caveat to the interpretation of imitation is that several, if not all, of these findings appear to be compatible with a responsiveness account. This is because increased parental gestural communication may also entail increased contingent responsiveness. Indeed, Liszkowski et al. (2012) found that only parent and infant pointing gestures that followed each other within 10 seconds were positively correlated. In contrast, parent and infant pointing gestures that were not preceded by a partner's point were not related. Similarly, Kishimoto (2017) found that it was not the overall rate of parental pointing that was related to infant pointing, but rather parents' ratio of responding relative to initiating points. These findings undermine strict imitation accounts and emphasize the role of contingent responsiveness. They call for nuanced research examining parental pointing and parental responsiveness.

The current study was designed to test whether infants' pointing frequency is casually and immediately affected by parental responsiveness, parental pointing, or both. Data were collected using a remote online adaptation of the decorated room paradigm (Kaletsch & Liszkowski, 2024). We invited 12-month-old infants and their parents because

most typically developing infants can point around their first birthday (Carpenter et al., 1998; Rüther & Liszkowski, 2023). To distinguish between the social learning mechanisms of positive reinforcement and imitation, we systematically manipulated two factors: (i) parental responsiveness to infant pointing and (ii) parental pointing frequency. In a between-subjects design across six experimental conditions, we instructed parents to be particularly responsive to their infants' pointing gestures, or they received no corresponding instruction. Further, we either asked parents to point a lot, not to point, or they received no specific instruction on pointing.

If infant pointing develops spontaneously, we did not expect to see an effect of experimentally manipulated parental behavior on infant pointing. If pointing is initially a nonsocial behavior, we may see effects of imitation learning, but not of parental responsiveness. Social shaping is a gradual process and does not occur within a five-minute time window. If pointing is communicative from the start and facilitated by responsive feedback, infants should point more when we instructed their parents to respond contingently to infants' pointing gestures. If imitation is the primary learning mechanism for infant pointing, we expected infants to point more when we instructed their parents to increase their own pointing. Correspondingly, infants should point less when parents were asked not to point.

4.2. Method

4.2.1. Participants

Families were recruited from a database of parents who had agreed to participate in developmental studies (see Appendix B). Due to a shortage of comparable research, the effect size was not known a priori. G*power analyses for a small medium effect size (f = .25) in a 2x3 ANOVA with a power of .80 yielded an N = 158 (see Table SM.2 in the supplementary material section). Anticipating drop-outs, as is common in infant studies,

we invited 170 dyads to participate. Data were excluded due to infant fussiness (N = 9), a high levels of off-task activity (N = 3), and inadequate set-up (N = 9). Unexpectedly, we had to exclude additional 18 dyads, because videos could not be coded due to technical difficulties during data collection. Data were collected during the pandemic with restrictions and limited resources. Accordingly the sample was not supplemented by further dyads. The final sample size included 131 infant-parent dyads (65 female infants, 112 mothers). Infants' mean age was 12m14d (SD = 7.77, range: 12m0d - 12m31d). Preliminary analyses showed no group differences in parental gender, age, or education, or infant age and gender. All infants were typically developing and born at full term. At the time of data collection, the families lived in the metropolis Hamburg and the surrounding area. Parental age ranged from 22 to 54 years (M = 33.11, SD = 8.73). All participating parents spoke the national language German, while 21% of all infants were raised bi- or multilingual. One hundred participating parents had at least a bachelor's degree and 83% were the primary caregiver of their infant. Forty-two infants regularly attended a day care center (20 females).

4.2.2. Procedure

Prior to the appointment participants received an email containing documents about the privacy policy, general instructions (see Appendix C for sample parent information, consent form and socioeconomic questionnaire of the KOKU), and technical requirements (see Appendix D). We collected data in an online video chat session in which dyads watched a presentation together on their screen for a maximum of five minutes. The slides were the same as in Experiment 1 of Study 1. They varied in terms of style (photographs vs. cartoons), familiarity (known vs. unknown objects), motion (picture vs. video), and number of stimuli presented (1-3). The duration of each slide was individually adapted to the dyads' behavior and ranged from five to thirty seconds. The dyads' behavior was

streamed via webcam at an appropriate distance to capture all gestures. For a detailed description of the remote decorated room, see Kaletsch & Liszkowski (2024).

In order to test our hypotheses, we asked parents to follow specific instructions during data collection (see supplementary material). As shown in Table 4, we instructed parents to respond contingently to their infants' pointing, without addressing a specific response type, or they received no specific responding instruction. In addition, parents were either asked to point a lot, not to point at all or they received no specific pointing instruction. We did not instruct parents not to respond at all to their infants' gestures, as pilot testing indicated that this was not feasible, and parents provided rather negative feedback to this instruction. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the authors' institution (see Appendix A).

Table 4

Experimental groups in Study 2

	Responding (+)	Responding (0)
Pointing (+)	P+R+ (*N* = 20)	P+R0 (*N* = 26)
Pointing (0)	P0R+ (*N* = 19)	P0R0 (*N* = 24)
Pointing (-)	P-R+ (*N* = 22)	P-R0 (*N* = 20)

Note. Responding is abbreviated by the letter R and pointing by the letter P. '+' indicates an instructional increase of the target behavior, '0' no specific instruction and '-' the inhibition of the target behavior.

4.2.2.1. Coding and Reliability. We coded data with the Mangold Interact Lab suite version 18.5.5.1. Infant and parent pointing was coded according to Liszkowski and Tomasello (2011). Infant pointing was coded as index-finger pointing if the index-finger was clearly extended relative to all other fingers. Parental pointing gestures were coded independently of hand shape. Responses to infant pointing included a conservative time criterion of two seconds after the infant pointed (Ger et al., 2018; Wu & Gros-Louis, 2014). We coded for contingent responses when parents non-verbally (gesturing, smiling) or verbally expressed a relevant uptake of the infants' gesture by addressing the infant, her or his communication, or the relevant slide. Considered behaviors ranged from nodding to gestures and utterances. Off-task activities were coded when the dyad was not engaged in the task for more than three seconds (e.g., looked away; became distracted). Fussiness was coded when infants cried for more than three seconds. Dyads were excluded if infants cried for a total of more than 90 seconds or if less than 180 seconds of undisturbed data collection was available for coding. The mean duration of undisturbed data collection was 289.97 seconds (*SD* = 29.53, range: 182.8 – 334.7).

We calculated Cohen's kappa using Mangold Interact software. Trained researchers double coded 20% of all videos (28). Two identical codes separated by a maximum of two seconds were defined as a match. Kappas were excellent for infant pointing (κ = .91), parental responsiveness (κ = 0.94) and parental pointing (κ = 0.98)

4.2.3. Analyses

We analyzed the data with IBM Software SPSS. To account for the individual duration of data collection, we calculated parent and infant pointing per minute. Parental responsiveness depended on the occurrence of infant pointing gestures. Therefore, we operationalized responsive behavior relative to the number of infant pointing gestures.

First, we tested for the effect of the different conditions on the frequency of infant pointing with a 2(responding) x3(pointing) ANOVA. Because one parent did not follow the instruction not to point (12 parental points), the corresponding dyad was excluded from the analysis. We verified the results on responsiveness by repeating the analyses with infants who pointed at least once during data collection (infant pointers), as non-pointing infants were not exposed to parents' responsive behavior.

Second, we examined whether parents successfully implemented the different instructions with two separate 2(responding) x3(pointing) ANOVAs on (i) parental responsiveness (ii) parental pointing. Planned contrasts were included for parental pointing (no pointing < no instruction < lots of pointing).

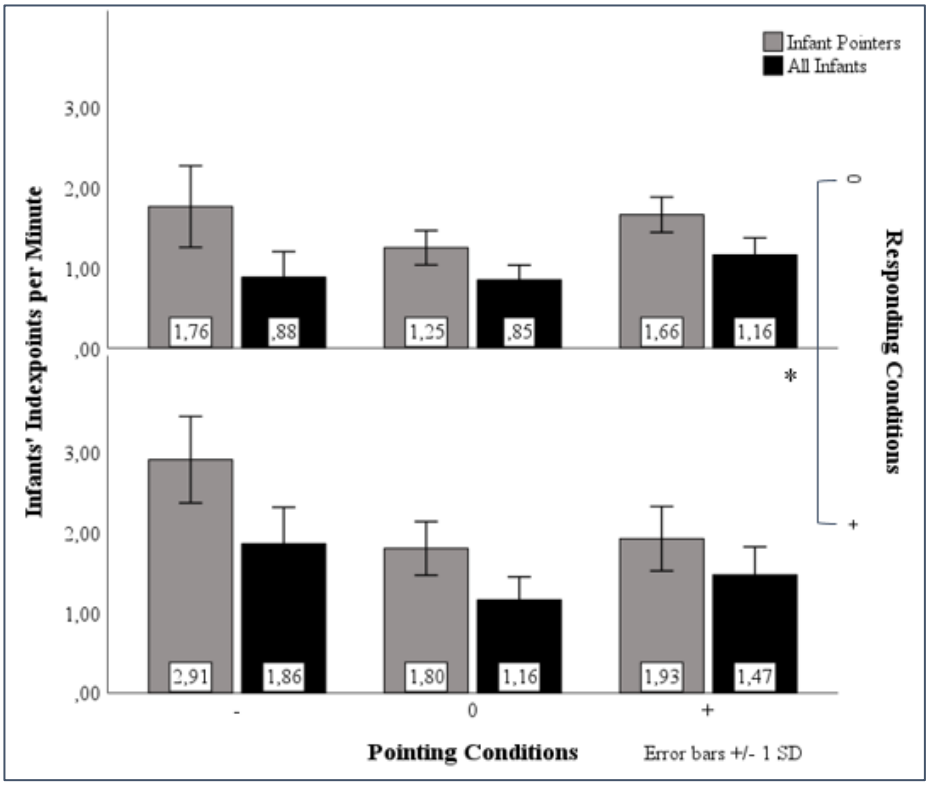
4.3. Results

4.3.1. Infant Pointing

Figure 4 shows infants' pointing frequencies across the six conditions. The 2x3 ANOVA on infants' index-finger pointing revealed a main effect of responding instructions, $F(1, 124) = 4.15$, $p = .044$, $\eta_p^2 = .03$, no effect of pointing instructions, $F(2, 124) = .74$, $p = .481$ $\eta_p^2 = .01$, and no interaction, $F(2, 124) = .64$, $p = .532$ $\eta_p^2 = .01$. Infants of parents who were instructed to respond to their infants' pointing gestures, pointed more frequently ($M = 1.49$, $SD = 1.71$) than infants of parents who received no corresponding instruction ($M = .97$, $SD = 1.13$).

Figure 4

Infants' pointing frequency in Study 2



For additional analyses addressing the effect of responding instructions, we included only infant pointers (N = 84). A corresponding 2x3 ANOVA on infant index-finger pointing confirmed the pattern of results with a main effect of responding instructions, $F(1,78) = 4.44$, $p = .038$, $\eta_p^2 = .05$, no effect of pointing instructions, $F(2,78) = 2.14$, $p = .125$, $\eta_p^2 = .05$, and no interaction, $F(2,78) = .67$, $p = .515$, $\eta_p^2 = .02$. A univariate ANOVA comparing the two superordinate responsiveness groups independent of pointing conditions confirmed that infant pointers used more pointing gestures when their parents received the instruction to be responsive (M = 2.21, SD = 1.69) than infant pointer of parents who did not receive the instruction (M = 1.54, SD = 1.09), $F(1, 82) = 4.76$, $p = .032$, $\eta_p^2 = .06$.

4.3.2. Parental Behavior

The 2x3 ANOVA on responsive behavior revealed a main effect of the instruction to respond to infant pointing, $F(1,88) = 5.98$, $p = 0.016$, $\eta_p^2 = .06$, no effect of pointing instructions, $F(2,88) = 1.78$, $p = .175$, $\eta_p^2 = .04$, and no interaction, $F(2,88) = 1.36$, $p = .262$, $\eta_p^2 = .03$). Parents in R+ conditions responded to 91% of infants' pointing gestures (*SD* = 15.68). Parents who received no specific instruction on responsiveness responded contingently to 81% (*SD* = 25.35) of their infants' pointing gestures.

The 2x3 ANOVA on parental pointing revealed no effect of responding instruction, $F(1,125) = .00$, $p = .98$, $\eta_p^2 = .00$, a main effect of pointing instructions, $F(2,125) = 103.64$, $p < .001$, $\eta_p^2 = .62$, and no interaction, $F(2,125) = .08$, $p = .92$, $\eta_p^2 = .00$. A priori defined contrasts confirmed that parents pointed significantly more when they were instructed to do so (*M* = 5.97, *SD* = 2.73) compared to parents who received no instructions on pointing behavior (*M* = 2.21, *SD* = 1.75). As expected, parents who were instructed not to point used the fewest pointing gestures (*M* = .07, *SD* = .37), *p's* < .001.

4.4. Discussion

The current study investigated whether different parental interaction styles have a direct effect on infants' pointing frequency. Specifically, we tested predictions from responsiveness and imitation accounts of communicative development. There are two main findings from the present study. First, changes in the amount of parental responsiveness to infant pointing had a direct promoting effect on infants' pointing frequency, independent of parental pointing. Second, changes in the frequency of parental pointing had no immediate effect on infants' pointing frequency.

The pattern of findings supports a social constructivist perspective on the development of infant pointing (Liszkowski & Rüther, 2021) and highlights the role of contingent responsive social interactions in enhancing infant communication and infant

pointing (Ger et al., 2018; Goldstein & Schwade, 2008; Tamis-LeMonda et al., 2014). Importantly, the current study goes beyond correlational patterns and experimentally establishes the role of responsiveness as a causal factor. In terms of the underlying mechanisms of this relationship, it is conceivable that when infants' perceive their communication as successful, meaning it elicits a relevant response, it may encourage them to use more frequent and over time more explicit communicative signals. The results also echo findings from the word-learning literature (for an overview, see Luchkina & Xu, 2022), which have shown that infants learn labels better when the input is related to the infant's focus of attention, rather than directing attention away (Baldwin, 1995; Tomasello & Farrar, 1986). Spontaneous onset and social shaping accounts are not supported by our findings because infant pointing at 12 months is influenced by the social environment. Furthermore, infant pointing is clearly communicatively motivated as it increased as parents' communicative responses increased, challenging social shaping accounts.

In our study, the influence of parental responsiveness may even be underestimated because we exclusively addressed immediate effects. In addition, parental responsiveness was already relatively high at baseline because the self-selected sample was of a high socioeconomic status, which is often associated with educated, responsive parenting (Vanormelingen & Gillis, 2016). In a more diverse sample, experimentally enhanced parental responsiveness could potentially lead to a stronger effect. Nevertheless, parents in this study significantly increased parental responsiveness, allowing for a meaningful comparison between the uninstructed and instructed groups.

Our findings challenge direct imitation as a relevant mechanism of infant pointing. First, neither the absence of parental pointing, nor an increase above the natural rate significantly altered infants' pointing frequencies. In fact, the descriptive data indicated that the instruction not to point but to be responsive (P-R+ condition) produced the highest

mean of infant pointing. In contrast, an experimental longitudinal training study, in which parents were instructed (or not) to point a lot for their infants, showed that infants' pointing frequency increased in the subsequent assessment session (compared to the control group; Rowe & Leech, 2019). One possibility is that the effects of parental pointing to infant pointing are only evident longitudinally (Rüther & Liszkowski, 2023), and thus were not present in the current study. Another possibility we have raised is that parents who point a lot also tend to be more responsive in their communication. The latter account provides an alternative interpretation to reports of associations between parent and infant pointing, consistent with current experimental findings. Imitation learning may still influence the onset of infants' index-finger pointing (i.e., before pointing has emerged). On the other hand, the apparent universality of index-finger pointing in infancy, including cultures where pointing is tabooed (Liszkowski et al., 2012), suggests that the index-finger may also be a latent solution to the challenge of referential ambiguity.

It is appropriate to acknowledge some limitations of our experimental design. Due to a relatively high dropout rate, experimental groups were smaller than intended, resulting in reduced statistical power. Infants used approximately five pointing gestures during data collection and therefore received only a limited number of parental responses. This may lead to an underestimation of the effects reported here. Importantly, if infants immediately adapt their pointing frequency to parental behavior, as our findings suggest, future training studies should take this circumstance into account. Longitudinal training effects need to be statistically separated from immediate adaptations at the time of post-intervention data collection. In addition, it is important to standardize the defined time window of a contingent response to make findings comparable across studies (Ger et al., 2018; Kishimoto, 2017; Liszkowski et al., 2012; Wu & Gros-Louis, 2014).

The present research contributes evidence for an interactional account of the development of pointing, especially regarding parental responsiveness. Responsive, contingent social interaction is crucial for the development of pointing and referential communication. Findings highlight the role of contingent parental responses as a primary candidate to enhance infants' pointing frequency and as a possible way for early treatment to mitigate risks for communicative delays.

4.5. Supplementary material

Table SM.2

Power analysis

F tests - ANOVA: Fixed effects, special, main effects and interaction		
Analysis:	A priori: Compute required sample size	
Input:	Effect size f	= .25
	α err prob	= .05
	Power (1-β err prob)	= .8
	Numerator df	= 2
	Number of groups	= 6
Output:	Noncentrality parameter λ	= 9.88
	Critical F	= 3.06
	Denominator df	= 152
	Total sample size	= 158
	Actual power	= .80

Note. The power analysis was calculated with G*Power 3.1.9.4

Specific instructions for the different experimental conditions

Baseline: P0R0

In dieser Studie möchten wir beobachten wie Kinder und Eltern mit der digitalen Präsentation von Objekten und Handlungen umgehen. Bitte schauen Sie sich also die folgenden Folien gemeinsam mit ihr/ihm an. Verhalten Sie sich dabei so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie wenn (Name) das Interesse an der aktuellen Seite verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir nochmal Zeit mögliche Fragen zu beantworten. Also denken Sie bitte daran sich gleich gemeinsam mit (Name) die Gegenstände und Szenen anzuschauen.

Increased pointing: P+R0

In dieser Studie möchten wir beobachten, wie Kinder auf viel kommunikatives Zeigen reagieren. Bitte verwenden Sie also während der folgenden Folien häufig „diese“ Geste. Verhalten Sie sich ansonsten so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie wenn (Name) das Interesse an der aktuellen verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir nochmal Zeit mögliche Fragen zu beantworten. Also denken Sie bitte daran gleich vermehrt für (Name) zu zeigen.

No pointing: P-R0

In dieser Studie möchten wir beobachten, wie sich Kinder verhalten, wenn ihre Eltern die Zeigegeste nicht verwenden. Bitte vermeiden Sie es daher während der folgenden Folien auf den Bildschirm zu zeigen. Verhalten Sie sich ansonsten so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie wenn (Name) das Interesse an der aktuellen verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir

nochmal Zeit mögliche Fragen zu beantworten. Also denken sie bitte daran gleich nicht für (Name) zu zeigen.

Increased responsiveness: P0R+

In dieser Studie möchten wir beobachten, wie sich Kinder verhalten, wenn Sie als Eltern das Interesse Ihres Sohnes/Ihrer Tochter teilen. Eine Möglichkeit von Kindern Ihnen etwas mitzuteilen ist das Zeigen. Bitte gehen Sie daher während der folgenden Folien möglichst intensiv auf das Zeigen Ihres Kindes ein. Verhalten Sie sich ansonsten so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie wenn (Name) das Interesse an der aktuellen verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir nochmal Zeit mögliche Fragen zu beantworten. Also denken Sie bitte daran gleich vermehrt auf (Name) Zeigen einzugehen.

Increased responsiveness and increased pointing: P+R+

In dieser Studie möchten wir beobachten, wie Kinder auf kommunikatives Zeigen reagieren. Weiterhin interessiert es uns wie Kinder sich verhalten, wenn Sie als Eltern das Interesse Ihres Sohnes/Ihrer Tochter teilen. Bitte verwenden Sie daher während der folgenden Folien häufig „diese“ Geste und gehen Sie möglichst intensiv auf das Zeigen Ihres Kindes ein. Verhalten Sie sich ansonsten so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie, wenn (Name) das Interesse an der aktuellen verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir nochmal Zeit mögliche Fragen zu beantworten. Also denken Sie bitte daran gleich vermehrt für (Name) zu zeigen und auf (Name) Zeigen einzugehen.

No pointing and increased responsiveness: P-R+

In dieser Studie möchten wir beobachten, wie sich Kinder verhalten, wenn ihre Eltern die Zeigegeste nicht verwenden. Weiterhin interessiert es uns wie Kinder sich verhalten, wenn Sie als Eltern das Interesse Ihres Sohnes/Ihrer Tochter teilen. Bitte vermeiden Sie es daher während der folgenden Folien auf den Bildschirm zu zeigen und gehen Sie möglichst intensiv auf das Zeigen Ihres Kindes ein. Verhalten Sie sich ansonsten so wie es sich für Sie richtig und natürlich anfühlt. Ich klicke auf die nächste Folie, wenn (Name) das Interesse an der aktuellen verliert oder Sie mir signalisieren, dass Sie gerne die nächste Seite sehen möchten. Das Ganze dauert maximal 5 Minuten und danach haben wir nochmal Zeit mögliche Fragen zu beantworten. Also denken sie bitte daran gleich nicht für (Name) zu zeigen und vermehrt auf (Name) Zeigen einzugehen.

5. Study 3: A training targeting parental responsiveness promotes index-finger pointing in 12-month-old infants

5.1. Introduction

Infants as young as 12 months use index-finger pointing to engage in cooperative communication with social partners, marking a milestone in infants' referential communicative development (Rüther & Liszkowski, 2023). Pointing is suggested to be one trajectory that paves the way for subsequent language development (Iverson & Goldin-Meadow, 2005), as both the onset and frequency of pointing predict later language development (Choi & Rowe, 2021; Colonnesi et al., 2010; Lüke, Grimminger, et al., 2017). Given its crucial interface function, researchers have sought to identify factors that explain the large interindividual variability in infants' pointing development (Cameron-Faulkner et al., 2021; Donnellan et al., 2020; Matthews et al., 2012; Rowe, 2000). Social interaction accounts propose that the development of pointing is influenced by infants' social environment (Carpendale & Carpendale, 2010; Liszkowski & Rüther, 2021). Investigating the influences of the social environment is particularly important because it offers the possibility of reducing the 30 million word gap of infants from low-income backgrounds (Hart & Risley, 2003). If certain parental behaviors influence the development of prelinguistic communication, then training these behaviors in at-risk populations may prevent the manifestation of later language delays. Two specific parental behaviors are currently under investigation. First, parental responses to infants' early communicative signals (Cameron-Faulkner, 2015; Luchkina & Xu, 2022; Tamis-LeMonda et al., 2014), and second, parents' own pointing (Kee, 2020; Matthews et al., 2012; Rüther & Liszkowski, 2023).

Tamis-LeMonda and colleagues (2014) defined parental responsiveness as prompt and contingent reactions to infant behavior. From early on, contingent parental behavior is

positively associated with infants' socioemotional (Koehn & Kerns, 2018), cognitive (Landry et al., 2006), and communicative development (Borairi et al., 2021). In the context of infants' pointing development, research showed that parental responses to infants' early HoG gestures predict infants' subsequent pointing frequency (Cameron-Faulkner et al., 2015). Additionally, Ger et al., (2018) reported on positive longitudinal correlations between parents' contingent responses and infants' pointing frequency. Despite these correlational findings, only cross-sectional studies examined the causal nature of the positive relationship between contingent parental responses and infants' pointing frequency (Kaletsch & Liszkowski, 2024, under review (Study 2); Miller & Lossia; 2013). Longitudinal training studies targeted parental responsiveness in the context of infants' language development (Alvarenga et al., 2021; Ramírez et al., 2020; McGillion et al., 2017; Salter et al., 2023) and to improve joint attention and promote communication in children with or at risk for autism spectrum disorder (Kasari et al., 2014; Siller et al., 2012; Watson et al., 2017).

Most training studies on infant pointing investigated a different aspect of the social constructivist account, namely the role of parental pointing, which may serve as a model through which infants learn via imitation (Kee, 2020). Rowe and Leech (2019) found that training parents' pointing frequency at 10 months increased infants' pointing frequency in a free play session two months later. In contrast, a training study by Matthews et al. (2012) found no effect on the onset or frequency of infant pointing in a comparable training study. However, in the same sample, infants' pointing frequency was significantly correlated with parental pointing during a free play session. This heterogeneity in findings is also evident in correlational studies on infant and parent pointing. Parental pointing is reported to predict the onset of infant pointing (Rüther & Liszkowski, 2023), but not infants' pointing frequency (Ger et al., 2018, 2023; Kishimoto, 2017). Cross-sectional observations found

positive (Matthews et al., 2012; Liszkowski et al., 2012) and no (Kaletsch & Liszkowski, 2024 (Study 1); Salo et al., 2019; Rowe, 2000) relationships between parental and infant pointing. In conclusion, more research is needed to specify the role of parental pointing in infants' pointing development.

To date, no training study has addressed parental responsiveness and pointing simultaneously. However, it is important to consider both parental behaviors because the two represent parental communicativeness and thus may be correlated. Without incorporating parental responsiveness and pointing, positive effects of increased parental responsiveness may be driven by increased parental pointing and vice versa. Another limitation of previous training studies is that, they do not distinguish longitudinal training effects from infants' prompt adaptations to increased parental behavior as reported by Miller and Lossia (2013; see also Kaletsch & Liszkowski, 2024, under review (Study 2)). To this end, analyses of training effects need to control for cross-sectional relationships between infant and parent behavior.

In the present study, we trained parental responsiveness and their pointing to directly contrast their effects on infants' index-finger pointing frequency. Data were collected at two time points using a remote adaptation (Kaletsch & Liszkowski, 2024) of the well-established decorated room paradigm (Liszkowski & Tomasello, 2011). Twelve-month-old infants (t1) and their parents were randomly assigned to either a control or a training group. The training aimed to increase parental responsiveness and their pointing during daily 15-minute parent-infant training sessions. The control group received no corresponding instruction. After one month of training (t2), we examined group differences in infants' pointing frequency, parental responsiveness, and parental pointing. In addition, and as control analyses, we investigated longitudinal and cross-sectional relations between infant pointing and parental behaviors. We expected to find positive associations between

infant pointing and parental responsiveness. In further support of social interaction accounts, we expected a, if any, positive influence of parental pointing on infants' pointing frequency. Consequently, we hypothesized that infants in the training group would point more at t2 than infants in the control group.

5.2. Method

5.2.1. Participants

We recruited families from a database of parents who had agreed to participate in developmental studies (see Appendix B). Participants lived in the metropolitan area of Hamburg at the time of data collection (from March until July 2022). The infants were typically developing and born at full term without visual or hearing impairment. We planned to conventionally collect data of $N = 60$ dyads. This sample size exceeds (Choi & Rowe, 2021; LeBarton et al., 2015; Matthews et al., 2012; Rowe & Leech, 2019) or is similar to (Goodwyn et al., 2000) sample sizes in other training studies of infant pointing. It allows us to test for medium effect sizes with a mixed ANOVA at two time points between two groups ($f = .19$, $\alpha = .05$, Power = .8, see Table SM.3 in the supplementary material section).

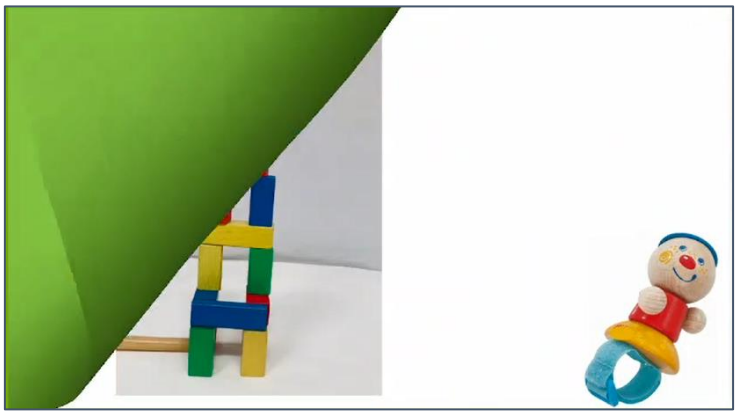
Five dyads were excluded from the analyses due to fussiness (1), technical difficulties (3), and absence at t2 (1). The final sample included 55 dyads (28 females), of which 28 (15 females) were assigned to the intervention group. Infants' mean age at t1 was 12m14d ($SD = 6.91$) and 13m15d ($SD = 7.57$) at t2. Dyads in the intervention group did not differ from those in the control group with respect to parental and infant age, gender, socioeconomic status, and the number of infant pointers at t1.

5.2.2. Procedure

We collected data at both time points in an online video chat session. Prior to the first appointment parents received an email with documents regarding privacy policy, general instructions (see Appendix C for sample parent information, consent forms and socioeconomic questionnaire of the KOKU), and technical requirements (see Appendix D). Before data collection, we focused on optimizing conditions together with the parent in terms of comparability and avoidance of distraction. The dyads then watched a presentation together on their screen for five minutes. Each slide showed two age appropriate stimuli revealed by a page-turning animation (see Figure 5). Four videos and four additional audio signals were evenly distributed throughout the presentation to maintain infants' attention. The duration of each slide was individually adapted to the dyads' behavior and ranged from 5 to 30 seconds. The dyads' behavior was transmitted via webcam at a proper distance to capture all gestures. The same procedure was repeated at t2. A detailed description of the paradigm see can be found in Kaletsch & Liszkowski (2024).

Figure 5

Sample stimuli in Study 3

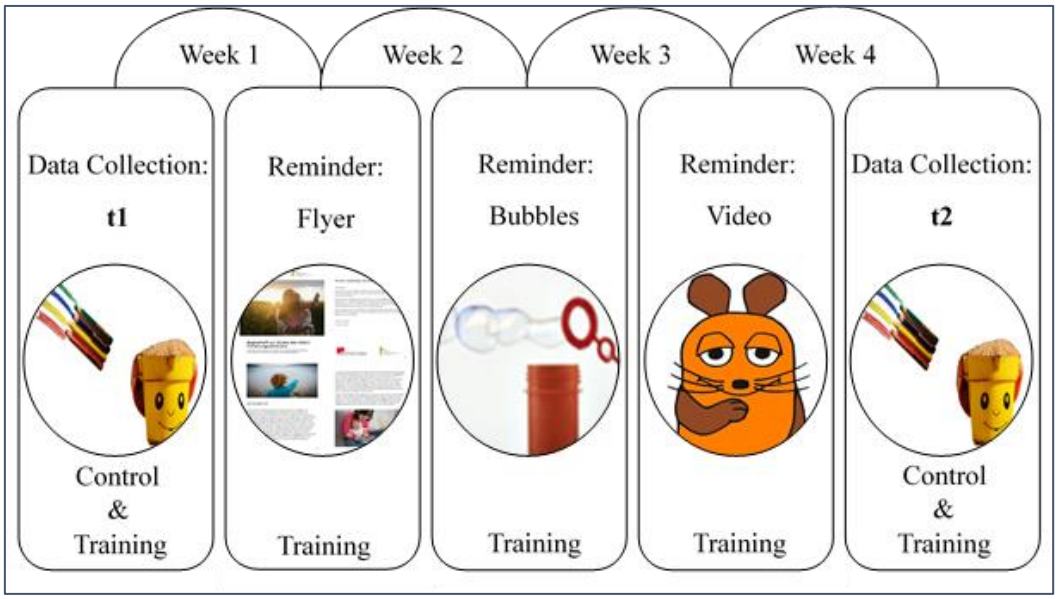


Note. The green slide revealed the two stimuli by a page-turning animation

5.2.2.1. Training. Parents in the intervention group received a training immediately after t1 baseline data collection. Parents watched a video that provided background information on infants' index-finger pointing, details about the training program, and behavioral examples. For the next four weeks, parents were asked to engage in at least 15 minutes of training with their infant each day. The training was divided into three components: (i) creating situations of shared interest (e.g., looking out of the window together), (ii) responding verbally to infants' gestures, and (iii) parental pointing. We provided a link via email so that parents could watch the instructional video at their convenience. Parents received a study protocol (see supplementary material) to document their daily implementation of the training. Parents self-reported an average of more than 25 days of training (M = 26.18, SD = 4.31, N = 22).

Figure 6

Study design of Study 3



The detailed procedure of the study is shown in Figure 6. In the first week, parents received a digital booklet (see supplementary material) that repeated the instructions and provided suggestions for joint activities. One week later, we mailed a set of bubbles and asked parents to use them during the implementation of the training. In week three, parents received a reminder for the next appointment and a link to a video of a popular age appropriate television show. We asked parents to watch the video together with their infant while implementing our training. The study was approved by the local ethics committee of the authors' institution (see Appendix A).

5.2.2.2. Coding and Reliability. Two coders were trained on the coding scheme using Mangold Interact Lab Suite version 18.5.5.1. We coded infants' index-finger points when the infant extended his or her arm and the index-finger was clearly spread relative to the other fingers (Liszkowski & Tomasello, 2011). Parental contingent responses involved a discernible change in parents' behavior (e.g., verbal reactions, nodding) and expressed an uptake of infants' attention or intention within two seconds after the infant pointed (Ger et al., 2018; Wu & Gros-Louis, 2014). Parental pointing was coded independently of hand shape. To capture the duration of unimpaired data collection, we additionally coded off-task activities (e.g., repositioning the screen) and infant fussing.

We calculated Cohen's kappa with the included Mangold Interact tool. 20% of all videos (11) were double coded. We defined a match as two identical codes maximal two seconds apart. Kappas were excellent for infant index-finger pointing (κ = .82), parental responsiveness (κ = .81), and parental pointing (κ = .88).

5.2.3. Analyses

To account for individual differences in the duration of data collection, we calculated infant and parent pointing frequencies per minute. Parental responsiveness was operationalized as a proportion relative to the number of infant points. In our main

analysis, we used a 2 (group, between-subject) x2 (time point, within-subject) mixed ANOVA to assess group differences pre- and post-intervention.

To test whether the training instructions led to observable differences in parental responsiveness and pointing, we conducted 2 (group, between-subject) x2 (time point, within-subject) mixed ANOVAs. We conducted a series of regression analyses to identify factors that explained variance in infants' pointing frequency at t2. Model 1 tested whether infants adapted their pointing cross-sectionally to parental behavior at t2. For this purpose, Model 1 included parental responsiveness and pointing at t2 as predictors, while controlling for infants' pointing frequency at t1. Model 2 tested for longitudinal relations and included parental responsiveness and pointing as well as infant pointing at t1 as predictors of infant pointing at t2. Model 3 examined whether group assignment emerged as a significant predictor when controlling for relevant parental behaviors. We therefore included one-tailed significant predictors of Model 1 and 2, infant pointing at t1 and dummy coded group assignment as predictors.

To account for the overdispersion in count data, we used negative binomial distributions (Ver Hoef & Boveng, 2007). Additionally, we selected robust estimators to obtain robust standard errors for the parameter estimates (Cameron & Trivedi, 2009).

5.3. Results

Descriptive data on infant pointing, parental responsiveness and parental pointing are presented in Table 5. The 2(group) x2(time point) mixed ANOVA on infants' pointing frequency revealed no main effect of group assignment, $F(1,53) = 2.65$, $p = .109$, $\eta_p^2 = .05$, a significant main effect of time, $F(1,53) = 11.32$, $p = .001$, $\eta_p^2 = .18$, and a significant interaction, $F(1,53) = 4.43$, $p = .04$, $\eta_p^2 = .08$. As shown in Figure 7, after the intervention at t2, infants in the training group pointed more frequently than infants in the control group, $F(1,53) = 4.64$, $p = .036$, $\eta_p^2 = .08$. This between-group difference was not evident at t1,

$F(1,53) = .01$, $p = .935$, $\eta_p^2 = .00$. In the control group infants' pointing frequency did not differ between time points, $F(1,53) = .78$, $p = .381$, $\eta_p^2 = .02$, whereas infants in the training group increased their pointing frequency from t1 to t2, $F(1,53) = 15.23$, $p < .001$, $\eta_p^2 = .22$.

Table 5

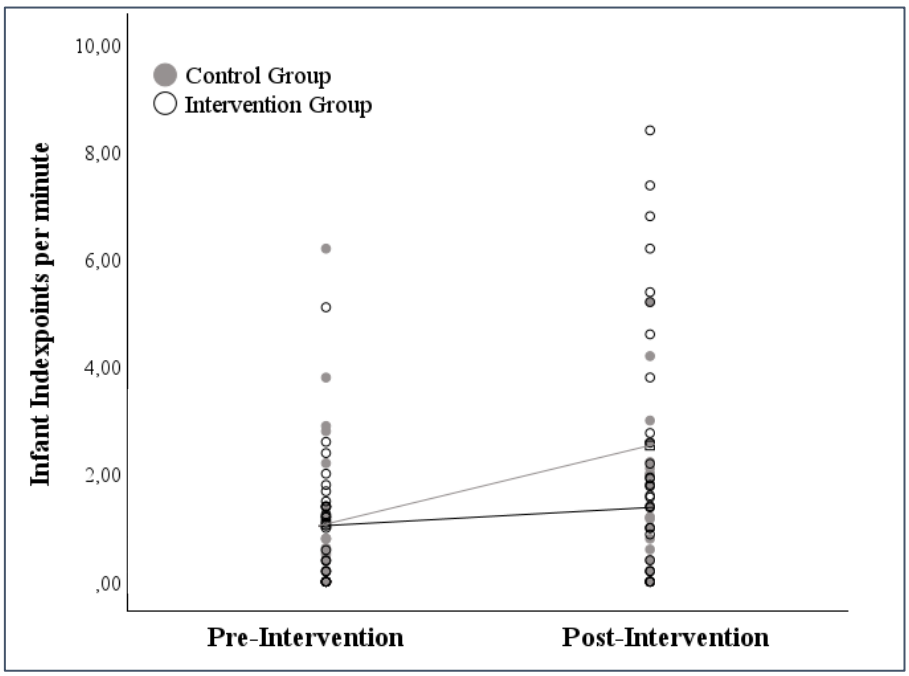
Descriptive statistics of Study 3

	t1		t2	
	Control	Intervention	Control	Intervention
Infant pointing	1.04 (1.44)	1.07 (1.11)	1.38 (1.32)	2.54 (2.47)
Parental responsiveness	.78 (.36)	.85 (.30)	.80 (.29)	.94 (.13)
Parental pointing	1.67 (2.00)	1.61 (1.44)	1.58 (1.62)	4.08 (2.34)

Note. Parameters display means of each group with standard deviations in parentheses.

Figure 7

Infants' pointing frequency in Study 3



Note. The lines connect the mean values of the intervention group (black) and the control group (grey) pre- and post-intervention.

The 2x2 ANOVA on parental responsiveness revealed no effect of group, $F(1,34) = 1.12$, $p = .298$, no main effect of time, $F(1,34) = 2.32$, $p = .137$, and no significant interaction, $F(1,34) = .04$, $p = .846$. However, when the nine infants who did not point at t1 but did point at t2 (N = 4 in the intervention group) were included, parents in the training group were more responsive at t2 than parents in the control group, $t(27.21) = -2.22$, $p = .043$, $d = .22$. The 2x2 ANOVA on parental pointing revealed a main effect of group, $F(1,52) = 7.68$, $p = .008$, $\eta_p^2 = .13$, a main effect of time, $F(1,52) = 20.93$, $p < .001$, $\eta_p^2 = .29$, and a significant interaction, $F(1,52) = 24.16$, $p < .001$, $\eta_p^2 = .32$. Pairwise comparisons showed that parents in both groups pointed equally frequent at t1, $F(1,52) = .02$, $p = .905$, $\eta_p^2 = .00$, while parents in the training group pointed more frequently at t2 compared to parents in the control group, $F(1,52) = 20.66$, $p < .001$, $\eta_p^2 = .28$.

The first regression model assessed cross-section relations at t2 between infant pointing, parental responsiveness, and parental pointing (see Table SM.4). Parental responsiveness and pointing at t2 were correlated, $r = .49$, $p < .001$, but multicollinearity diagnostics indicated no resulting difficulties for the model (*VIF*s < 1.34). The model was not significant, $\chi^2(3) = 4.52$, $p = .210$. Parental pointing emerged as a one-tailed significant predictor, negatively associated with infant pointing, $\chi^2(1) = 3.28$, $p = .035$.

The second regression model examined longitudinal relations between infant pointing at t2 and parental responsiveness and pointing at t1 (see Table SM.5). Parental responsiveness and pointing at t1 were correlated, $r = .33$, $p = .039$, with no confounding effects on the model (*VIF*s < 1.18). The overall model was one-tailed significant, $\chi^2(3) = 7.18$, $p = .034$. Parental responsiveness was positively associated with subsequent infant pointing, $\chi^2(1) = 5.07$, $p = .024$.

The final regression model examined whether group assignment explained variance in infants' pointing frequency at t2 when controlling for relevant infant and parent

behavior (see Table 6). The model included parental responsiveness and infant pointing at t1, parental pointing at t2, and dummy coded group assignment (0 = control group) as predictors. The correlation between parental responsiveness at t1 and parental pointing at t2 did not confound the model, $r = .42$, $p = .002$, *VIF*s < 1.24. The overall model and all included predictors were significant, $\chi^2(4) = 12.48$, $p = .014$. The results indicated that infants in the intervention group pointed more at t2 due to the preceding training. The pattern of results suggested that the effect of training unfolded in line with the positive longitudinal effect of parental responsiveness, and despite the negative cross-sectional effect of increased parental pointing. Analyses support the findings of individual stability in pointing, as infants' pointing frequency at t1 predicted their pointing one month later in all regression models.

Table 6

Regression analysis of Study 3

	B (SE)	Exp (B)	95% CI, Exp (B)		p
			LL	UL	
Intervention Status Control group = 0	-.67 (.23)	.51	.33	.80	**.003**
Parental responsiveness, t1	1.35 (.44)	3.87	1.63	9.17	**.002**
Parental pointing, t2	-.13 (.04)	.87	.81	.95	**.001**
Infant pointing, t1	.18 (.06)	1.20	1.06	1.36	**.004**
Intercept	1.63 (.45)	5.13	2.13	12.35	**<.001**
Goodness of Fit	*deviance* = 50.32		*df* = 35		*value/df* = 1.44

Note. $N = 41$, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

5.4. Discussion

The present study evaluated the effect of a parent-based training on the index-finger pointing frequency in 12-month-old infants. The primary objective of the study was successfully met, as four weeks after training, infants in the training group pointed significantly more than infants in the control group. In addition, parents in the training group increased their communicative behaviors at t2 compared to parents in the control group, demonstrating the effectiveness of the training program. Parental responsiveness was not cross-sectionally related to infant pointing, in contrast to parental pointing, which was negatively correlated with infant pointing. Parental responsiveness and infant pointing at t1 were longitudinal predictors of infant pointing at t2. After controlling for cross-sectional and longitudinal relations between infant pointing and parent behavior, group assignment emerged as a significant predictor for infants' pointing frequency. The findings indicated that infant pointing in the training group increased as a longitudinal function of group assignment, not as a consequence of infants' immediate adaptation to parents' increased behavior during post-intervention data collection. The correlations between parental responsiveness and parental pointing at both time points, confirmed our initial assumption that both behaviors are components of parents' overall communicativeness. Furthermore, these findings highlight the need to consider parental responsiveness and pointing simultaneously, especially in future training studies.

The results were consistent with a social constructivist perspective on the development of infant pointing. In a comparatively lean view, infants' early pointing gestures are neither communicative nor social in nature (Carpendale & Carpendale, 2010; O'Madagain, 2019). Our findings, however, emphasized infants' social and referential pointing intentions, as improved parental responsiveness promoted infants' pointing. A compelling explanation for this relationship appears to be positive reinforcement. Infants in

the training group increasingly experienced their pointing as successful, i.e. their referential goals are met by parental responses, and in turn they use the gesture more frequently (Liszkowski & Rüther, 2021). This construct may not be generalizable to the age of emergence of infant pointing, as the influence of parents on the onset and the frequency of pointing could unfold differently. However, contingent interaction experiences are generally beneficial for infants' communication development (Luchkina & Xu, 2022).

The results indicated that imitation, as a social learning mechanism, does not sufficiently explain the interindividual variability in infants' pointing frequency. On the contrary, parent and infant pointing frequencies were negatively correlated in the current study. One possible interpretation of this cross-sectional finding is that the more parents point, the fewer turn-taking options infants have. Furthermore, infants' cognitive resources may be consumed by following parents' lead, leaving less capacity to share reference and initiate episodes of joint attention themselves. Another explanation for the negative relationship between parent and infant pointing concerns the experimental remote paradigm. Infants are less familiar with digital stimuli and may easily lose their interest in the task, obliging the parents to redirect infants' visual attention to the screen. Besides inflating the natural pointing frequency of parents, this methodological constraint could confound the findings, as parents' tendency to redirect infants' attention is negatively associated with the establishment of joint attention (Garner & Landry, 1994; Legerstee et al., 2002; Tomasello & Farrar, 1986). Regarding the conflicting research findings between infant and parent pointing, it is conceivable that the results are mediated by correlating parental responsiveness. It is likewise possible that the facilitating influence of parental pointing is manifested longitudinally and/or primarily affects the onset of infant pointing, irrespective of the negative cross-sectional relations.

The current study has certain limitations, particularly with regard to two biases on the training effects. First, parental responsiveness in our self-selected sample was already relatively high at baseline which potentially underestimates the training-induced increase. Second, it should be noted that parental behavior during data collection serves only as a proxy for the extent to which parent-child interaction in the home environment differed between the groups. For this reason, we cannot determine with certainty what actually contributed to the training effect. Future studies may collect more representative data during free play sessions or home visits. In addition, long-term effects should be analyzed in follow-up sessions, as well as the transfer of infant training effects to later language abilities. Another interesting research question concerns the impact of parental responsiveness on other infant gestures and the onset of infant pointing.

Although some modifications to the current design are conceivable, the present study provided evidence for the causal role of parental responsiveness on the frequency of infant index-finger pointing. The findings indicated that a brief parental responsiveness training increased infants' pointing frequency. Thus, parental responsiveness emerged as a primary candidate for treating infants' prelinguistic communicative delays in parent-based interventions.

5.5. Supplementary material of Study 3

Table SM.3

Power analysis

F tests - ANOVA: Repeated measures, within-between interaction		
Analysis:	A priori: Compute required sample size	
Input:	Effect size f	= .19
	α err prob	= .05
	Power (1-β err prob)	= .8
	Number of groups	= 2
	Number of measurements	= 2
Output:	Noncentrality parameter λ	= 8.38
	Critical F	= 4.01
	Numerator df	= 1.00
	Denominator df	= 56.00
	Total sample size	= 58
	Actual power	= .81

Note. The power analysis was calculated with G*Power 3.1.9.

Daily training protocol

Tag 1	Haben Sie sich heute 15 Minuten lang im Sinne unseres Trainingsprogrammes mit Ihrem Kind beschäftigt? ☐ Ja ☐ Nein Wurden die 15 Minuten über den Tag verteilt oder fanden sie am Stück statt? ☐ Am Stück ☐ Über den Tag verteilt	Hat Ihr Kind während des Trainings gezeigt? ☐ Ja ☐ Nein ☐ Unsicher Wer hat mit Ihrem Kind geübt? ☐ Mama ☐ Papa ☐ Andere
Tag 2	Haben Sie sich heute 15 Minuten lang im Sinne unseres Trainingsprogrammes mit Ihrem Kind beschäftigt? ☐ Ja ☐ Nein Wurden die 15 Minuten über den Tag verteilt oder fanden sie am Stück statt? ☐ Am Stück ☐ Über den Tag verteilt	Hat Ihr Kind währenddessen gezeigt? ☐ Ja ☐ Nein ☐ Unsicher Wer hat mit Ihrem Kind geübt? ☐ Mama ☐ Papa ☐ Andere
Tag 3	Haben Sie sich heute 15 Minuten lang im Sinne unseres Trainingsprogrammes mit Ihrem Kind beschäftigt? ☐ Ja ☐ Nein Wurden die 15 Minuten über den Tag verteilt oder fanden sie am Stück statt? ☐ Am Stück ☐ Über den Tag verteilt	Hat Ihr Kind währenddessen gezeigt? ☐ Ja ☐ Nein ☐ Unsicher Wer hat mit Ihrem Kind geübt? ☐ Mama ☐ Papa ☐ Andere

Booklet for the training group

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Begleitheft zur Studie des KOKU-Forschungszentrums

KOKU-Forschungszentrum für kognitive und kulturelle Entwicklung
Von-Melle-Park 5, 20146 Hamburg, Tel.: 040/428385410

Mit dem Zeigefinger die Welt entdecken

Liebe Eltern,

wir freuen uns sehr darüber, dass Sie sich für eine Teilnahme an unserer Studie entschieden haben, vielen Dank für Ihre Mithilfe und Ihren Beitrag zu unserer Forschung!

Am KOKU-Forschungszentrum erforschen wir das Zeigeverhalten von Kleinkindern. In diesem Begleitheft zur Studie erfahren Sie etwas über die Hintergründe unserer Forschung und wie Sie aktiv mit Ihrem Kind im nächsten Monat von zuhause aus mitmachen können.

Wir wünschen Ihnen und Ihrem Kind viel Spaß beim Lesen sowie beim gemeinsamen Ausprobieren. Wenn Sie Fragen haben, können Sie sich gern jederzeit an uns wenden.

Herzliche Grüße

Ihr KOKU-Team

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KOKU Forschungszentrum für kognitive und kulturelle Entwicklung

Worum geht es?

Kinder erlernen die Bedeutung von Gesten, Wörtern, Objekten und Ereignissen durch die gemeinsame Interaktion mit ihren Eltern. Die Interaktion wird dabei häufig vom Kind initiiert, welches auf interessante Objekte oder Ereignisse zeigt oder Laute von sich gibt. Eltern reagieren dann auf das kommunikative Signal und geben ihrem Kind Informationen zum betreffenden Objekt oder Ereignis. Das Kind lernt daraufhin, dass sein*ihr Signal eine Reaktion der Eltern hervorruft und erwartet in Zukunft, so auch weiterhin beim Erkunden der Umgebung unterstützt zu werden. Deshalb kommuniziert es immer mehr mit seinen Eltern. Eltern können also die sprachliche Entwicklung ihres Kindes unterstützen, indem sie auf die kommunikativen Signale ihres Kindes eingehen. In vergangenen Studien hat sich bereits herausgestellt, dass bei Kindern der häufige Gebrauch von Zeigegesten mit der späteren Sprach- und Wortschatzentwicklung zusammenhängt.

In unserer Studie möchten wir daher die kommunikative Entwicklung anhand der kindlichen Zeigegeste noch näher untersuchen. Die kindliche Zeigegeste wird vor allem dazu verwendet, die Aufmerksamkeit der Eltern auf interessante Objekte oder Ereignisse in der Umwelt zu lenken und dadurch Interesse zu teilen, aber auch Informationen von den Eltern zu erhalten. Eltern können auf die Geste reagieren, indem sie verbal und durch eigene Zeigegesten auf das betreffende Objekt oder Ereignis Bezug nehmen. So teilen sie den Aufmerksamkeitsfokus ihres Kindes aktiv und fördern sein*ihr kommunikatives Verhalten in der Zukunft.

Aufgrund vorheriger Studien gehen wir davon aus, dass Eltern einen positiven Einfluss auf die kommunikative Entwicklung ihres Kindes nehmen können, indem sie in beschriebener Art und Weise auf die Zeigegesten ihres Kindes eingehen. In unserer aktuellen Studie soll daher der Effekt eines aktiven Zeigetrainings der Eltern mit ihrem Kind näher untersucht werden.

Kleines Zeigetraining

Und wie funktioniert unser Trainingsprogramm?

1) Trainieren heißt im Fall unserer Studie, dass Sie im Alltag Situationen aufsuchen oder auch aktiv herstellen, in denen kindliche Zeigegesten häufig auftreten. Die Situationen sollten dabei Gegenstände oder Ereignisse beinhalten, welche für Ihr Kind sehr interessant sind und zu denen es gerne mehr Informationen erhalten würde.
   Zum Beispiel können Sie gemeinsam mit Ihrem Kind ein Buch mit vielen bunten Bildern anschauen oder spazieren gehen und Ihr Kind einen Hund, eine Blume oder ein Flugzeug entdecken lassen. Auch fliegende Seifenblasen können Ihr Kind zum Zeigen animieren. Indem Sie mit Ihrem Kind solche spannenden Situationen aufsuchen, unterstützen Sie Ihr Kind darin, die Umwelt zu erkunden und das eigene kommunikative Verhalten weiterzuentwickeln.
2) Um das Zeigeverhalten Ihres Kindes darüber hinaus zu unterstützen, geben Sie Ihrem Kind zu erkennen, dass Sie seine*ihre Zeigegeste wahrnehmen: Benennen Sie das betreffende Objekt, erklären Sie Ihrem Kind etwas darüber oder teilen Sie einfach Ihre Begeisterung oder Ihre Gedanken mit Ihrem Kind. Eine typische verbale Reaktion auf das Zeigen Ihres Kindes ist z.B.: „Ja toll, oder? Das ist ein…".
3) Um Ihrem Kind noch deutlicher mitzuteilen, dass Sie seiner*ihrer Zeigegeste und Aufmerksamkeit folgen, sollten Sie Ihre verbale Reaktion mit einer eigenen Zeigegeste begleiten. Wenn Ihr Kind zum Beispiel auf eine Katze im Baum gezeigt hat, könnten Sie folgendermaßen reagieren, um die kommunikative Entwicklung maximal zu unterstützen: "Genau, die Katze ist bestimmt den (*Sie zeigen auf den Stamm bis hoch zur Katze)* ganzen Stamm hinaufgeklettert."

5

Was ist das Ziel des Trainings?

Das Ziel ist es, die kommunikative Entwicklung Ihres Kindes zu unterstützen, indem Sie Situationen erzeugen, in denen Ihr Kind gerne zeigt. Das Zeigen Ihres Kindes können Sie dann durch Ihre verbale Reaktion und eigene Zeigegesten noch weiter fördern.

Dabei ist es unerheblich, ob Ihr Kind schon zeigt! Allein die Herstellung interessanter und kommunikationsanregender Situationen kann sich förderlich auf das zukünftige kommunikative Verhalten Ihres Kindes auswirken.

6

Kleines Zeigetraining

Ihre Umsetzung daheim:

Wir möchten Sie bitten, sich jeden Tag so oft wie möglich, jedoch mindestens 15 Minuten, gemeinsam mit Ihrem Kind in Situationen zu begeben, die Zeigegesten Ihres Kindes auslösen könnten. Sollte Ihr Kind währenddessen zeigen, so gehen Sie bitte verbal auf seine*ihre Geste ein und zeigen ebenfalls auf das spannende Objekt. So können Sie schon vor den ersten Worten aktiv die kommunikative Entwicklung Ihres Kindes positiv beeinflussen.
Die 15 Minuten können Sie am Stück oder über den Tag verteilt mit Ihrem Kind trainieren – meist geschieht das ganz von allein, wenn Sie bemerken, welchen Spaß das gemeinsame Erkunden der Umgebung macht. Je mehr Sie mit Ihrem Kind trainieren, desto mehr wird seine*ihre sprachliche Entwicklung gefördert! Nach vier Wochen (ca. 30 Tagen) laden wir Sie erneut zu einem Zoom-Gespräch ein.

Wir bitten Sie außerdem darum, am Ende jeden Tages an das kurze Studienprotokoll zu denken, um Ihr kleines Training zu dokumentieren. Das Protokoll finden Sie als Anhang in unserer E-Mail, die wir Ihnen nach dem ersten Zoom-Termin geschickt haben. Hängen Sie sich das Studienprotokoll gut sichtbar an einen Ort, den Sie täglich aufsuchen (z.B. an den Kühlschrank, an die Wohnungstür oder neben den Wochenkalender). Nach 30 Tagen können Sie uns die Ergebnisse des Studienprotokolls zukommen lassen, indem Sie es einscannen oder abfotografieren und per E-Mail an
schicken.

Sollten Sie einmal vergessen, das Protokoll auszufüllen, tun Sie dies bitte nur dann nachträglich, wenn Sie sich ganz sicher sind und sich gut an die Übungssituation erinnern können. Lassen Sie ansonsten den betreffenden Tag einfach frei.

7

Zur Inspiration noch ein paar Beispielsituationen:

- Gucken Sie gemeinsam mit Ihrem Kind aus dem Fenster und betrachten Sie die Umgebung: Fährt ein Auto vorbei? Steht der Mond am Himmel? Gibt es ein Tier zu sehen?
- Erkunden Sie gemeinsam Spielsachen: Womit möchten Sie heute spielen? Hat Ihr Kind ein Lieblingsspielzeug oder ein Lieblingsbuch? Gibt es viele spannende Bilder in dem Buch zu sehen? Oder viele bunte Bauklötze?



- Lernen Sie mit Ihrem Kind die Umgebung kennen: Kommen Sie an einer Baustelle vorbei? Fährt dort drüben die S-Bahn? Was kaufen Sie heute im Supermarkt ein?



- Geben Sie Ihrem Kind verstärkt Möglichkeiten, eine Wahl zu treffen und Ihnen diese zu kommunizieren: Möchte es heute Gurke oder lieber Paprika haben? Welche Schuhe möchte es anziehen? Und welchen Weg findet es schöner? Ihr Kind wird Ihnen seine*ihre Wahl auch ohne Worte mitteilen.

8

Weitere Informationen

Bei weiterem Interesse an dem Thema Zeigegesten und Sprachentwicklung finden Sie hier eine interessante wissenschaftliche Studie zum Download:

https://www.researchgate.net/profile/Carina-Lueke/publication/320914066_Development_of_Pointing_Gestures_in_Children_With_Typical_and_Delayed_Language_Acquisition/links/5de656d14585159aa45d965f/Development-of-Pointing-Gestures-in-Children-With-Typical-and-Delayed-Language-Acquisition.pdf

Kontakt

KOKU-Forschungszentrum für kognitive und kulturelle Entwicklung
Von-Melle-Park 5, 4. OG
20146 Hamburg
Tel.: 040/428385410
Mail: koku@uni-hamburg.de
www.koku.uni-hamburg.de

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Table SM.4

Cross-sectional regression model

	B (SE)	Exp (B)	95% CI, Exp (B)		p
			LL	UL	
Parental responsiveness, t2	.87 (.69)	2.39	.62	9.29	.208
Parental pointing, t2	-.09 (.05)	.91	.83	1.01	*.070*
Infant pointing, t1	.14 (.07)	1.15	1.00	1.31	**.044**
Intercept	1.81 (.59)	6.13	1.94	19.39	**.002**
Goodness of Fit	*deviance* = 47.67		*df* = 40		*value/df* = 1.19

Note. $N = 45$, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

Table SM.5

Longitudinal regression model

	B (SE)	Exp (B)	95% CI, Exp (B)		p
			LL	UL	
Parental responsiveness, t1	1.05 (.47)	2.85	1.15	7.09	**.024**
Parental pointing, t1	.03 (.09)	1.03	.87	1.23	.707
Infant pointing, t1	.19 (.08)	1.21	1.03	1.41	**.018**
Intercept	1.17 (.44)	3.23	1.35	7.72	**.008**
Goodness of Fit	*deviance* = 48.08		*df* = 35		*value/df* = 1.37

Note. $N = 40$, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

6. Study 4: Parental responsiveness and pointing influence the development of early deictic gestures in infants: A longitudinal study in the context of training

6.1. Introduction

Shortly before their first birthday, infants demonstrate the ability to direct the attention of others towards external entities. By 10 months of age, infants begin to hold out and give objects to their interaction partner (HoG gestures) in order to share interest and actively initiate episodes of joint attention (Boundy et al., 2019; Cameron-Faulkner et al., 2015 & 2020). At 11 months of age, infants expand their communicative repertoire to refer to distant and even absent entities via index-finger pointing (Bohn et al., 2018; Liszkowski et al., 2007; Rüther & Liszkowski, 2023). Both gesture types are early manifestations of intentional, referential communication and serve as predictors of subsequent language acquisition (Cameron-Faulkner et al., 2021; Choi et al., 2021). The development of referential gestures depends not only on infants' cognitive development, but also on infants' social environment (Liszkowski, 2018b). Within a social constructivist framework, parental responses to infants' interest and communicative signals may shape their communicative development (Luchkina & Xu, 2022). Another conceivable social learning mechanism involves parental gestures, which may serve as a model from which infants learn via imitation (Liszkowski & Rüther, 2021). We conducted a longitudinal training study to assess whether parental responsiveness and the frequency of parental pointing in interaction with their 7-month-old infants predicted the development of infant pointing and HoG gestures at 10 months.

The foundation of human language in the form of reference is already evident in gestures, as they allow infants to express their interest in external entities and initiate triadic exchanges (Boundy et al., 2019; Liszkowski et al., 2004). Index-finger pointing is an extensively studied gesture that typically emerges around 11 months of age (for an

overview, see Liszkowski, 2018a). As in verbal communication, the pointing gesture can serve different communicative purposes, ranging from a rather basic imperative (Carpenter et al., 1998; van der Goot et al., 2014) to the uniquely human declarative motive (Liszkowski et al., 2007). Both the onset and the frequency of index-finger pointing predict subsequent language development (for meta-analyses, see Colonnesi et al., 2010 and Kirk et al., 2022). Specifically, pointing to a particular object predicts the acquisition of the corresponding word and word-point combinations precede the two-word stage (Iverson & Goldin-Meadow, 2005). Infant pointing frequency itself correlates with antecedent HoG gestures (Cameron-Faulkner et al., 2015; Rüther & Liszkowski, 2023; but see Cameron-Faulkner et al., 2021), which in turn predict language development (Cameron-Faulkner et al., 2021; Choi et al., 2021). Infant HoG gestures occur to share interest and attention with social partners (Boundy et al., 2019), but do not overcome the challenge of communicating about spatially or temporally distant objects (displacement feature). HoGs can therefore be considered as a "proximal practice ground" for subsequent index-finger pointing (Cameron-Faulkner et al., 2015). Both gesture types reflect the early presence of intentional, referential, and declarative communication in the first year of life.

Infants' gestural communication does not develop in a vacuum, but in the context of social interactions (for an overview, see Liszkowski & Rüther, 2021). Recent research showed that parental responsiveness to infant signals is positively correlated with several aspects of infants' development (Elmlinger et al., 2023; Goldstein & Schwade, 2008; Luchkina & Xu, 2022; Masek et al., 2021; Tamis-LeMonda & Bornstein, 2002). In terms of infants' gesture development, experimental studies reported that 12-month-old infants directly adapted their pointing frequency to the responses elicited by their previous pointing (Kaletsch & Liszkowski, under review (Study 2); Liszkowski et al., 2004; Miller & Lossia, 2013; Wu & Gros-Louis, 2014). Relevant parental responses, namely those that

addressed the target of the infant's gesture, to 10-month-old infants are predictive of infant pointing at 12 months (Ger et al., 2018). An intervention addressing parental responsiveness to infant pointing at 12 months increased infants' pointing frequency one month later (Study 3). Infants whose HoG gestures elicited longer interaction sequences at 10 and 11 months, used more index-finger pointing gestures one month later (Cameron-Faulkner et al., 2015). To date, research has not investigated whether parental responsiveness prior the infants' tenth month of life influences the onset and frequency of infant index-finger pointing.

In addition to parental responsiveness, imitation learning processes and thus parental pointing gestures may be relevant for infants' pointing development. Parents point for their infants from seven months onward (Rüther & Liszkowski, 2023), which possibly serves as a model for infants' own pointing development. Because parents intuitively adapt their behavior to the developmental stage of their infant (Parsons et al., 2017), infants may be cognitively equipped to adequately process parental pointing gestures by seven months of age. In two training studies, parent and infant (10 to 12 months) pointing was cross-sectionally correlated during free play. Parental pointing training in these two studies produced contrasting results regarding the effect on infant pointing frequency (Matthews et al., 2012; Rowe & Leech, 2019). Cross-sectional correlations during free play were not consistently replicated at 12 (Salo et al., 2019) and 14 months (Rowe, 2000). When measured with the established decorated room paradigm (Liszkowski & Tomasello, 2011), parent and infant pointing (7 to 14 months) was directly correlated cross-sectionally (Liszkowski et al., 2012) and in split median calculations at 12 months (Liszkowski & Tomasello, 2011). In addition to supporting split median correlations of parent and infant pointing at 12 months, Rüther and Liszkowski (2023) found that parental pointing at 8 months correlated with infants' pointing onset. Other longitudinal studies did not confirm

the predictive value of parental pointing in the decorated room for infants' pointing development and found no cross-sectional relations between parental and infant pointing at 8, 9, 10, 11 or 12 months (Ger et al., 2018; 2023). In the remote variant of the decorated room paradigm, parent and infant pointing did not correlate cross-sectionally at 12 months (Kaletsch & Liszkowski, 2024; Kaletsch & Liszkowski, under review (Study 2)). In a longitudinal remote training study, increased parental pointing was negatively correlated with infant pointing at 13 months (Study 3). Given the varying results and the different observational paradigms, the relationship between parental and infant pointing remains unclear, especially with regard to the early development of infant pointing (< 12 months).

Research provides limited data about parental influences on infants' HoG development, although HoG gestures are often considered when studying deictic gestures in general (Choi et al., 2020; Hall et al., 2013). Regarding the influence of responsiveness on infants' HoG development, Boundy and colleagues (2019) found that 10-month-old infants adapted their communicative behaviors based on whether or not their previous HoG gesture elicited joint attention. An intervention targeting parental responsiveness in 6-month-old infants, resulted in more infant prelinguistic communication, including HoG and pointing gestures, at 12 months compared to an active control group (Salter et al., 2023). In summary, infants' gesture development generally benefits from parents' prompt, contingent, and appropriate reactions to the infants' communicative and exploratory behaviors (Alvarenga et al., 2021; Bornstein & Tamis-LeMonda, 1989). Rüther and Liszkowski (2023) found no significant correlation between parental pointing in the decorated room for their 8-month-old infants and the infants' subsequent HoG development. Salomo and Liszkowski (2013) found that infants' HoG frequency differed across cultural groups (Mayan, Dutch and Chinese) as a function of interactional input. At 14 months, infants' general gesture types (including HoGs) during home visits correlated

with parental gesture types (Rowe & Goldin-Meadow, 2009). Further empirical research is needed to examine the specific influence of parental responsiveness and parental pointing on infants' HoG development.

The current study investigated whether a training targeting parental responsiveness promoted early pointing and typical HoG development in infants. We collected longitudinal data (N = 84) at monthly intervals between the infants' seventh and tenth months of age. Parent and infant pointing was observed in the remote decorated room (Kaletsch & Liszkowski, 2024). We collected data on infants' HoG development, parental responsiveness, and pointing during free play sessions. The training aimed to increase parental responsiveness to infants' interest and communication through daily 15-minute parent-infant training sessions. The control group received no corresponding instruction. After three months of training, we examined group differences in infants' pointing and HoG status, as well as pointing and HoG frequency at 10 months. We conducted regression analyses to investigate longitudinal and cross-sectional relationships between infants' gesture development, parental responsiveness, parental pointing and group assignment. Given the consistent findings on parental responsiveness in current literature, we hypothesized that infants of responsive parents are more likely to be pointers and use more pointing gestures at 10 months. As a replication finding, we anticipated longitudinal relations between parental pointing during free play and infant pointing status and frequency. Parental pointing in the remote decorated room was not expected to be related to infants' pointing development (see Studies 1-3). With regard to the similarities between index-finger pointing and HoG gestures, related social learning mechanisms were presumed to influence the development of HoG gestures. We expected a promoting effect of training on infants' pointing and HoG development.

6.2. Method

6.2.1. Participants

Participants were recruited from a database of families who agreed to participate in developmental studies typically from middle to high socioeconomic backgrounds (see Appendix B). The families lived in a German metropolis. All infants were typically developing, without visual or auditory impairment, and born at full term. We planned to collect data of 80 dyads to compare infants' gesture status between groups using a Chi-Squared test (w = .31; α = .05; Power = .8, see Table SM.6 in the supplementary material section). To account for dropouts, we invited 90 infant-parent dyads. Eighty-eight dyads participated at t1, of which three were excluded from analyses because the dyads did not attend subsequent appointments. One additional infant was diagnosed with visual impairment during the study and was therefore not included in the analyses.

The final sample included 84 participants (43 female infants). Forty-one dyads (20 female infants) were randomly assigned to the control group. At the first appointment, infants' mean age was 231.4 days (*SD* = 4.3), and at the last appointment, infants' mean age was 314.1 days old (*SD* = 10.1). The mean time between two subsequent appointments was 28 days. Nine percent of all infants were raised bi- or multilingual. The mean age of the parents was 35 years (*SD* = 3.5), and 85% had at least a bachelor's degree. Participants did not differ between groups in terms of infant gender distribution, age, or socioeconomic background.

6.2.2. Procedure

We collected data at four time points in online video chat sessions. Prior to the first session, parents received an email with documents about the privacy policy, technical requirements (see Appendix D), general instructions, and a link to a questionnaire about their socioeconomic status (see Appendix C for sample parent information, consent form

and socioeconomic questionnaire of the KOKU). During the video chat sessions, we first optimized the data collection conditions whenever necessary, focusing on comparability, visibility and avoidance of distraction. Infant and parent pointing was observed in all four sessions using the remote decorated room paradigm (Kaletsch & Liszkowski, 2024). Dyads watched a slide show (see Appendix E) together via screen sharing for five minutes while being webcam-recorded at an appropriate distance to capture all gestures. Each slide showed two age-appropriate stimuli revealed by a page-turning animation. After seven and eighteen seconds, short animations, such as changes in color or position (see Figure 8), occurred. We implemented these animations to allow the dyads to discover something new during the presentation of each slide, thus increasing the likelihood of triadic communication. For the same reason, a face was shown on each slide. Four videos and five additional sounds were evenly distributed throughout the presentation. The presentation time of each slide was adapted to the dyads engagement and ranged from five to thirty seconds. We asked parents to interact with their infant as naturally as possible during data collection. The infant was either seated in a high chair next to the parent or on the parents' lap.

Figure 8

Sample stimuli in Study 4

Note. In the first animation sequence, the banana is peeled. In the second animation sequence, the rubber duck moves toward the banana.

At the initial and the final appointments, we additionally examined infant-parent-interaction in a five-minute free play session (see Figure 9). Free play was conducted after the remote decorated room, with the order of the paradigms being reversed if the infants' mood required it. Typically, parents placed the laptop on a chair or the sofa to transmit the scene from an elevated angle without distracting the infant. Again, we instructed parents to interact with their infant as naturally as possible. Parents received the relevant toys by mail prior to the first appointment. We selected toys that would encourage different types of play and be of interest to both 7- and 10-month-old infants. The set included four different colored wooden rings, a silver bowl, a wooden treasure chest, a porcupine ball, a rainbow spiral, a rattle, a spoon and a magic wand. While the data collection at t1 and t4 served as baseline and outcome measures, the two appointments in between were included to keep parents involved in our study and to provide an opportunity to clarify questions.

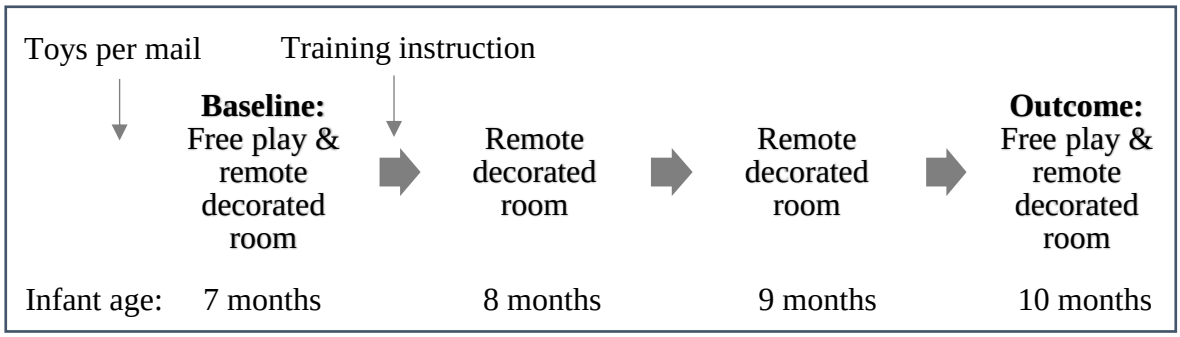
Figure 9

Infant HoG gesture during remote free play

6.2.2.1. Training. As shown in Figure 10, parents in the intervention group received training immediately after baseline data collection. The training instructions were delivered via a pre-recorded eight-minute video for comparability purposes. The video provided information on infants' gestural development and its relevance to language development. Further, we emphasized the influence of parental behavior on infants' communicative development and asked them to implement our training instructions for at least 15-minutes per day. The training involved identifying and/or establishing situations of shared interest in everyday life (e.g., morning routines, walks together). We asked parents to respond to infants' interest by i) sharing infants' focus of attention, ii) communicating about it, iii) temporal immediacy. We refrained from including specific instructions regarding parental pointing so as not to provoke an inflationary increase (see Study 3). By emphasizing the importance of infants' gestural development and the influential role of parents, we sought to increase parental pointing within its natural limits. After explaining the key components of the training, the instructional video showed an exemplary triadic interaction sequence. The instructional video ended with a brief recap. To assess parents' comprehension of the training, we asked them at the end of the instructional video i) whether their infant had specific interests ii) how the parent recognized this interest iii) how the parent should respond according to current training program. Any uncertainties were clarified and parents were emailed a link to return to the video at their convenience. The same email included the digital version of a protocol booklet that contained a weekly survey on parents' training frequency (see supplementary material). On a scale of one to five, parents self-reported that they practiced the training sometimes (3) to often (4) per week (N = 20, M = 3.65, SD = .59).

Figure 10

Study design of Study 4



A flyer and a detailed booklet, both with written training instructions, accompanied the mailed protocol booklet for the training group (see supplementary material section). The training group further received one email between two appointments with information on infants' development, training suggestions, and a reminder of the protocol booklet to keep parents involved in the study. The study materials are included in the supplementary material section. The study was conducted in accordance with the Declaration of Helsinki and was approved by the local ethics committee of the authors' institution (see Appendix A).

6.2.2.2 Coding and Reliability. Data were coded using Mangold Interact Lab Suite version 18.5.5.1. In both coding schemes, we coded the duration of data collection, infant fussing, and off-task activities to maintain the duration of undisturbed data collection. Seven coders were trained on the coding scheme for the remote decorated room. We coded infant index-finger pointing when the arm was extended while the index-finger was clearly extended from the other curled fingers with a communicative motivation (Liszkowski & Tomasello, 2011). Handshape was not further classified for parental pointing gestures. We calculated Cohen's kappa using a tool included in the Interact software. Reliability was determined using a set of previously established reference codings. We defined matching

codes as two identical codes separated by a maximum of two seconds. Kappas were excellent for each coder for infant index-finger pointing (κ > .83) and parental pointing (κ > .85).

Four coders were trained on the coding scheme for the free play sessions. The coding scheme for infant and parent pointing was identical to the coding scheme for the remote decorated room. We coded for infant HoG gestures when the infant held an object in the direction of the parent, regardless of any subsequent transfer of the object (give gesture, see Cameron-Faulkner et al. 2015 & 2021). We coded for parental gestures (pointing, showing, giving and requesting) and toy activations ('Look, you can put something in the box' [putting a ring in the box]). Parental gestures and toy activations were coded as responsive if they addressed an object in the infant's current focus of attention. In addition, we coded for responsive behavior when parents contingently changed their behavior (e.g., gestures, facial expressions, speech) in response to infant communication (gestures and vocalizations) within two seconds (Ger et al., 2018; Nicoladis & Barbosa, 2024; Wu & Gros-Louis, 2014). To this end, we coded infants' reaching gestures (Ramenzoni & Liszkowski, 2016) and intentional vocalizations. Parental gestures and toy activations were classified as initiating if they addressed an object outside the infant's current attentional focus, or removed an object from the infant's attentional focus. Reliability was established as in the remote decorated room. Kappas were excellent for infant communication (κ > .78), parental responsiveness (κ > .78), and parents' initiating behavior (κ > .85).

6.2.3. Analyses

Infant and parent gesture frequencies were calculated per minute of undisturbed data collection to account for the individual durations. Parental responsiveness was operationalized as an index ranging from -1 (fully initiative) to 1 (fully responsive). The

index was calculated by subtracting parents' initiative behaviors from their responsive behaviors and dividing the difference by the total number of coded behaviors. We classified infants as pointers and HoGers when we recorded one clearly communicative index-finger point or HoG gesture on video. When an infant used only one pointing or HoG gesture, we double checked its communicative intend.

After a brief descriptive overview of our data, we present Chi-Squared tests examining differences between the control and the training group in infants' pointing and HoG statuses at t4. Group differences in infants' pointing and HoG frequencies at 10 months were assessed with independent t-tests. As control analyses, we conducted ANOVAs on parental behaviors to evaluate the implementation of training. For parental pointing in the remote decorated room, we calculated a 2 (group assignment, between subject) x4 (time point, within subject) ANOVA. We conducted 2 (group assignment, between-subject) x2 (time point, within subject) ANOVAs on parental pointing and responsiveness during free play.

We used a series of regression models to identify parental behaviors that explained variance in infant gesture status and frequency. Separate regressions were used to model longitudinal and cross-sectional relationships. To predict infants' pointing and HoG status at 10 months, we used binary logistic regressions with robust estimators. We used negative binomial regressions with robust estimators for count data to predict infant's gesture frequency. We included parental responsiveness, parental pointing in the remote decorated room and during free play at t1 (longitudinal models) or t4 (cross-sectional models) as predictors. When infants' gestural development correlated with infants' age at t4 or infants' gesture frequency at t1, we controlled for the corresponding variable. In the case of group differences in infants' gestural development, we conducted further regression analyses to evaluate the effect of training when controlling for relevant parental behaviors.

Parental behaviors were considered relevant if they emerged as one-tailed significant longitudinal or cross-sectional predictors in the initial regression analyses.

6.3. Results

Table 7

Descriptive data of Study 4

	Control group			
	t1	t2	t3	t4
Infants				
Pointer	0	3	5	15
Pointing frequency	.01 (.07)	.10 (.33)	.10 (.34)	.39 (.80)
HoGler	1	-	-	13
HoG frequency	.01 (.06)	-	-	.13 (.22)
Parents				
Responsiveness	.36 (.40)	-	-	.37 (.33)
Pointing (FP)	.26 (.34)	-	-	.32 (.37)
Pointing (D)	1.33 (1.5)	1.35 (1.27)	1.44 (1.61)	1.68 (1.66)
	Intervention group			
	t1	t2	t3	t4
Infants				
Pointer	1	5	8	18
Pointing frequency	.04 (.19)	.13 (.52)	.09 (.38)	.40 (1.32)
HoGler	1	-	-	24
HoG frequency	.01 (.09)	-	-	.32 (.55)
Parents				
Responsiveness	.34 (.41)	-	-	.55 (.27)
Pointing (FP)	.18 (.23)	-	-	.33 (.39)
Pointing (D)	1.20 (1.55)	1.99 (1.83)	2.36 (1.90)	2.40 (2.06)

Note. Behavioral means with standard deviations in parentheses, FP = free play, D = remote decorated room.

Descriptive data on infant and parent behavior in the training and the control group are presented in Table 7. Forty percent of all infants were index-finger pointers at 10 months, and infants' pointing frequency in the remote decorated room ranged from 1 to 41. Forty-five percent of all infants used HoG gestures during free play at 10 months and their frequency ranged from one to fourteen. Infants' pointing and HoG status, $\chi^2(1) = .02$, $p = .896$, and pointing and HoG frequencies were not related at t4, Spearmans $\rho = .03$, $p = .822$.

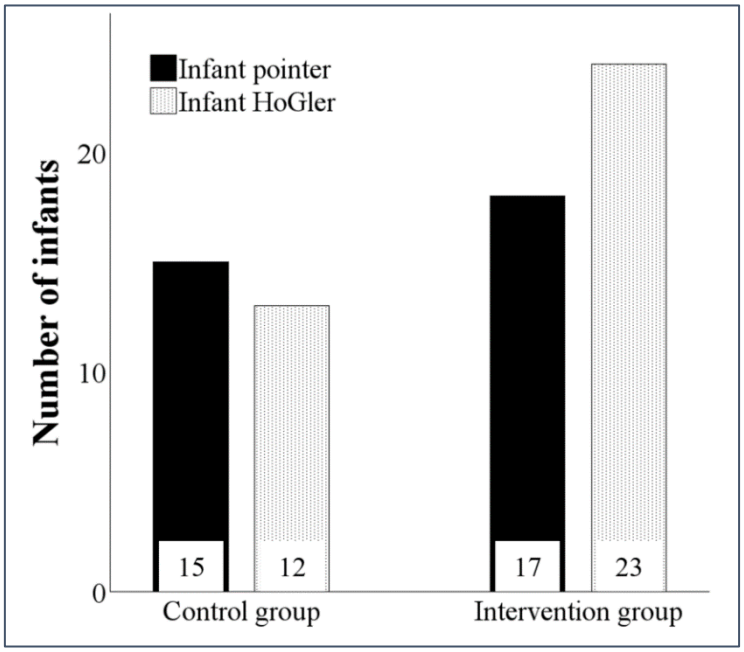
6.3.1. Differences between groups

6.3.1.1. Infant index-finger pointing. One infant pointed already at t1 and was therefore excluded from the following Chi-Squared test. The difference between infants' pointing status in the training and control group at t4 was not significant, $\chi^2(1) = .08$, $p = .782$ (see Figure 11). The difference in infants' pointing frequency between groups at t4 was not significant, $t(79) = -.02$, $p = .988$.

6.3.1.2. Infant HoG gestures. Two infants used HoG gestures during free play at t1 and were excluded from the following Chi-Squared test. The difference in infants' HoG status between groups at t4 was significant, $\chi^2(1) = 4.74$, $p = .029$. The difference in infants' HoG frequency between groups at t4 was significant (see Figure 12), $t(54.69) = -2.08$, $p = .043$.

Figure 11

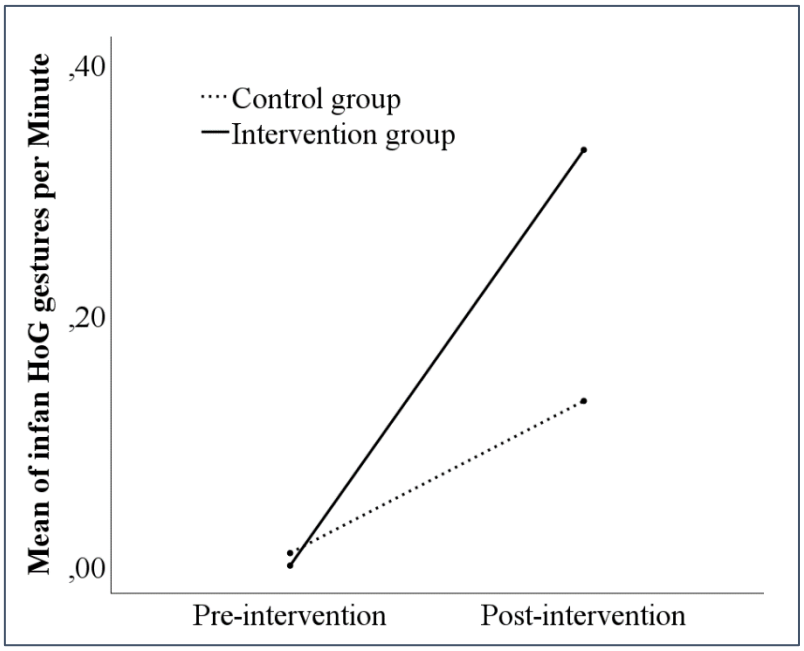
Infants' gesture statuses in Study 4



Note. Infants who used HoG or pointing gestures at t1 are not included in the figure.

Figure 12

Infants' HoG frequency in Study 4



6.3.1.3. Parental behaviors. The following analyses assessed whether training produced differences in parental responsiveness and pointing during free play and parental pointing in the remote decorated room.

The 2x2 ANOVA on parental responsiveness revealed no main effect of group, $F(1,77) = 1.79$, $p = .185$, a main effect of time point, $F(1,77) = 4.48$, $p = .037$, $\eta^2p = .06$, and a significant interaction, $F(1,77) = 5.56$, $p = .021$. $\eta^2p = .07$. Parental responsiveness did not differ between groups at t1, $F(1,77) = .13$, $p = .723$. Parents in the intervention group were more responsive than parents in the control group at t4, $F(1,77) = 9.40$, $p = .003$, $\eta^2p = .11$.

The 2x2 ANOVA on parents' pointing frequency during free play revealed no main effect of group, $F(1,80) = .52$, $p = .516$, a main effect of time point, $F(1,80) = 4.98$, $p = .028$, $\eta^2p = .06$, and no significant interaction, $F(1,80) = .67$, $p = .417$. Parents' pointing frequency during free play was not affected by training.

The 2x4 ANOVA on parents' pointing frequency in the remote decorated room revealed a one-tailed significant effect of group, $F(1,74) = 3.00$, $p = .044$, $\eta^2p = .04$, a main effect of time point, $F(3,222) = 7.26$, $p < .001$, $\eta^2p = .09$, and a significant interaction, $F(1,222) = 3.64$, $p = .014$, $\eta^2p = .05$. Pairwise comparisons indicated that parents in the training group pointed equally frequent compared to parents in the control group at t1, $F(1,74) = .19$, $p = .668$. After training, parents in the intervention group tended to use more pointing gestures than parents in the control group, t2: $F(1,74) = 3.96$, $p = .050$, $\eta^2p = .05$, t3: $F(1,74) = 4.66$, $p = .034$, $\eta^2p = .06$, t4: $F(1,74) = 3.37$, $p = .071$, $\eta^2p = .04$.

6.3.2. Predicting infants' gestural development

Multicollinearity diagnostics revealed no confounding effect of cross-sectional correlations between parental behaviors, infant age, or group assignment at t1 (*VIF*s <

1.11) or t4 (*VIF*s < 1.20). Statistical details of all following regression analyses conducted are presented in the supplementary material section (Table SM.7 – Table SM.10).

6.3.2.1. Infant index-finger pointing. One infant pointed at t1 and was excluded from the regression analyses of infant pointing status. Infants' pointing development did not differ between the training and control group. Infants' age at t4 did not correlate with infant pointing status, $r = .12$, $p = .288$, or frequency, Spearmans $\rho = .14$, $p = .207$. Infant gestures at t1 did not correlate with infants' pointing status, $r = .00$, $p = .990$, or frequency, Spearmans $\rho = .05$, $p = .654$. Thus, the following models included parental responsiveness, parental pointing in the remote decorated room, and parental pointing during free play as predictors.

The longitudinal regression model predicting infants' pointing status at t4 was significant, $\chi^2(3) = 10.30$, $p = .016$ (see Table SM.7). Parental pointing in the remote decorated room at t1 tended to be negatively associated with infant pointing status, $\chi^2(1) = 2.53$, $p = .060$. Parental pointing during free play at t1 was positively associated with infant pointing status, $\chi^2(1) = 4.54$, $p = .033$. The cross-sectional regression model predicting infants' pointing status at t4 was not significant, $\chi^2(3) = .19$, $p = .979$ (see Table SM.7). No predictor reached one tailed-significance.

The model for longitudinal predictions of infants' pointing frequency at 10 months in the remote decorated room was not significant, $\chi^2(3) = 5.34$, $p = .147$ (see Table SM.8). Parental pointing during free play at t1 was positively associated with infants' pointing frequency, $\chi^2(1) = 4.89$, $p = .027$. The model of cross-sectional predictions on infants' pointing frequency at 10 months was not significant, $\chi^2(3) = 3.01$, $p = .390$ (see Table SM.8). Parental pointing during free play at t4 emerged as a one-tailed significant predictor, $\chi^2(1) = 2.99$, $p = .042$.

6.3.2.2. Infant HoG gestures. Two infants used HoG gestures at t1 and were excluded from the regression analysis of infants' HoG status. Infants' HoG status and frequency differed between the training and the control group. Infants' HoG status at t4 correlated one-tailed with infant age at t4, $r = .19$, $p = .043$, but not with infant gestures at t1, $r = .17$, $p = .136$. Infants' HoG frequency did neither correlate with infant age at t4, Spearmans $\rho = .17$, $p = .118$, nor with infants' gesture frequency at t1, Spearmans $\rho = .062$, $p = .580$. The following regression analyses included parental responsiveness, parental pointing in the remote decorated room, and parental pointing during free play as predictors. When predicting infants' HoG status, we additionally controlled for infants' age at t4.

The longitudinal model of infants' HoG status at 10 months was not significant, $\chi^2(4) = 5.05$, $p = .282$ (see Table SM.9). No predictor reached one tailed-significance. The cross-sectional model of infants' HoG status was significant, $\chi^2(4) = 12.18$, $p = .016$ (see Table SM.9). Parental responsiveness at t4 emerged as a significant predictor, $\chi^2(1) = 5.87$, $p = .015$. When assessing the predictive value of group assignment on infants' HoG status, we thus needed to control for parental responsiveness at t4.

The longitudinal model of infants' HoG frequency at 10 months was significant, $\chi^2(3) = 8.88$, $p = .013$ (see Table SM.10). Parental pointing during free play at t1 was positively related to infants' HoG frequency at 10 months, $\chi^2(1) = 7.13$, $p = .008$. The cross-sectional model of infants' HoG frequency was significant, $\chi^2(3) = 24.14$, $p < .001$ (see Table SM.10). Parental responsiveness at t4 was a significant predictor of infants' HoG frequency, $\chi^2(1) = 19.81$, $p < .001$. Parental pointing in the remote decorated room at t4 was negatively related to infants' HoG frequency, $\chi^2(1) = 7.65$, $p = .006$.

To assess the predictive value of group assignment on infants' HoG status, we controlled for parental responsiveness at t4. The model was significant, $\chi^2(2) = 8.87$, $p = .012$. Group assignment and parental responsiveness at t4 emerged as one-tailed significant

predictors of infants' HoG status at 10 months (see Table 8). In assessing the predictive value of group assignment on infants' HoG frequency, we controlled for parental pointing during free play at t1, parental responsiveness at t4, and parental pointing in the remote decorated room at t4. The model was significant, $\chi^2(4) = 15.62$, $p = .004$. All included variables contributed significantly to explaining the variance in infants' HoG frequency at 10 months.

Table 8

Regression analyses in Study 4

		B (SE)	Exp(B)	95% CI, Exp (B)		p
				LL	UL	
HoG status, *N*= 80	Group assignment 0 = control group	-.86 (.49)	.42	.16	1.10	*.077*
	Parent responsiveness (t4)	1.60 (.87)	4.96	.91	27.09	*.064*
	Intercept	-.63 (.57)	.54	.18	1.63	.271
	Goodness of fit	*deviance* = 77.56		*df* = 59		*value/df* = 1.31
HoG frequency, *N* = 79	Group assignment 0 = control group	-.78 (.36)	.46	.29	.93	**.031**
	Parent pointing (FP, t1)	1.01 (.51)	2.76	1.02	7.41	**.045**
	Parent responsiveness (t4)	1.79 (.54)	5.98	2.05	17.41	**.001**
	Parent pointing (D, t4)	-.24 (.10)	.79	.65	.95	**.015**
	Intercept	-.43 (.41)	.65	.29	1.46	.299
	Goodness of fit	*deviance* = 115.94		*df* = 74		*value/df* = 1.54

Note. FP = free play, D = remote decorated room, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

6.4. Discussion

The current study examined the influence of parental pointing and responsiveness on infants' deictic gesture development in the context of training. Three main findings are provided. First, three months of a training program targeting parental responsiveness promoted infants' typical HoG development in terms of gesture status and frequency. The training did not affect the early pointing development in 10-month-old infants. Second, parental pointing during free play with their 7-month-old infants predicted infants' pointing status as well as pointing and HoG frequency at 10 months. Third, parental responsiveness was cross-sectionally related to infants' HoG status and frequency.

Contrary to our hypotheses, parental responsiveness was not a relevant predictor of infants' early index-finger pointing status and frequency. Given that infants were seven months old at t1, we extended the concept of responsiveness to include parental reactions to infants' exploratory behavior. Thus, the constructed variable may include parental behaviors that are less relevant to infants' pointing development. However, research found that parental responses to infants' object exploration promoted infants' communicative development (Suarez-Rivera et al., 2022; Tamis-LeMonda et al., 2013). Given the reported cross-sectional association between parental responsiveness and infants' HoG development, both measured during free play, it could be argued that the effects of parental responsiveness are only evident in direct relation to infants' gestures. Namely, when being measured within the same interaction sequence as infant gestures (Kaletsch & Liszkowski, under review (Study 2); Miller & Lossia, 2013). Nevertheless, research provided evidence for a longitudinal and causal relationship between parental responsiveness and infant pointing (Cameron-Faulkner et al., 2015; Ger et al., 2018; Study 3). In contrast to the current study, previous research measured infants' pointing frequency at 12 months, when infants gained some experience with their own pointing. Therefore, it is conceivable that

the facilitative effect of parental responsiveness on infant pointing unfolds around 11 months of age, when pointing typically emerges. In line with the social constructivist account, this age may represent the developmental stage at which infants are cognitively equipped to efficiently transfer parental input to their own pointing skills.

Learning from direct observations of parental pointing gestures is a relatively straightforward process and appears to be accessible from an early age. Specifically, as soon as parents begin to point for their infants, their pointing frequency is predictive of infants' early pointing status and frequency at 10 months (see also Rüther & Liszkowski, 2023). However, this relationship was only evident when parental pointing was measured during free play and not in the remote decorated room. Parental pointing during free play corresponds more directly to parents' pointing in everyday interactions with their infants and thus more accurately models the relationship of parent and infant pointing. The remote decorated room overestimates the natural frequency of parental pointing, making it a less appropriate paradigm for evaluations of the relation between parent and infant pointing. Furthermore, because infants easily lose interest in digital stimuli, parental pointing in the remote decorated room is disproportionately often aimed at redirecting infants' attention to the screen. Consequently, the frequency of parental pointing in the remote decorated room may reflect parents' tendency to direct infants' attention (see Study 3). Tomasello and Farrar (1986) argue that this directiveness complicates the establishment of joint attention and explains the predominantly negative patterns in relation to infants' gestural development (Garner & Landry, 1994; Legerstee et al., 2002). The difference between parental pointing in the remote decorated room and during free play is supported by the cross-sectional findings of the current study. Parental pointing during free play at ten months tended to be concurrently related to infants' pointing frequency, whereas we found no cross-sectional relationship between infant pointing and parent pointing in the remote

decorated room. It is conceivable that cross-sectional relations with parents' natural pointing become more apparent once infants acquired some experience with pointing a few months later (Liszkowski & Tomasello, 2011; Liszkowski et al., 2012; Matthews et al., 2012; Rowe & Leech, 2019).

In summary, infants' early pointing development at 10 months is predicted by parental pointing during free play, but not by parental responsiveness or parental pointing in the remote decorated room. With regard to increased parental responsiveness in the training group, we would expect promoting effects on infants' pointing development at 11 and 12 months, which were not addressed in the current study. Parental pointing during free play was not affected by training, which is consistent with the findings of Matthews et al. (2012), who reported no training effects on parental pointing when observed during free play sessions. Considering that infants' pointing development at 10 months was predicted solely by parental pointing during free play, no training effects were to be expected. We concluded that the insufficient transfer of increased parental pointing from specific contexts to everyday interactions in the training group and the early stage of infants' pointing development at 10 months accounted for the absence of training effects on infants' early pointing development.

Consistent with our hypotheses, infants' HoG development was influenced by similar social learning mechanisms as infants' pointing, providing evidence for the proximity of the two gestures. 10-month-old infants were more likely to use HoG gestures and used them more frequently when their parents were more responsive at t4. The positive relationship between infants' HoG frequency and parents' concurrent responsiveness highlights the communicative motive of infants' HoG gestures. Moreover, this relationship supports the proposal that the facilitative effect of parental responsiveness on infants' development manifests itself at specific junctures. We found no relationship between

parental responsiveness at seven months and infants' subsequent HoG development, suggesting that the effect of parental responsiveness on infants' HoG development becomes evident between eight and ten months of age. Another interpretation of the concurrent findings between infants' HoG development and parental responsiveness is that there are isolated immediate adaptations of infant behavior to parental responsiveness (see Kaletsch & Liszkowski, under review (Study 2)). However, it is unlikely that the emergence of infants' HoG gesture (HoG status) is significantly influenced by direct adaptation processes. We assume that parental responsiveness facilitated infants' HoG development over the course of the study, not exclusively at t4. This assumption is discussed in relation to training effects in the next section.

In addition to parental responsiveness, parental pointing during free play at t1 predicted infants' HoG frequency, whereas parental pointing in the remote decorated room was a negative predictor. This pattern of results supports the proposal that parental pointing in the remote decorated room reflects the directiveness of parents, which, if anything, is negatively related to infants' communicative development. The positive longitudinal relationship between parental pointing during free play and infants' HoG frequency supports extended imitation accounts. Infants' do not simply mimic their parents' pointing gestures, but rather learn about the communicative and referential function of gestures in general. Infants then transfer this knowledge to the currently available form of their own gestures, regardless of their particular form (HoG vs. pointing gesture).

Ten-month-old infants in the training group were more likely to use HoG gestures and did so with a higher frequency than infants in the control group. The training effect on infants' HoG status was not significant when controlling for parental responsiveness at t4. As mentioned above, we assume that the majority of infants did not suddenly begin to use HoG gestures during the five-minute observation period in reaction to increased parental

responsiveness. The results on infants' HoG frequency provided evidence that the promoting effect of training persisted when controlling for relevant longitudinal and cross-sectional relationships between infant and parent behavior. We conclude, that parental responsiveness training is an effective way to promote infants' HoG status and frequency. This effect could potentially be enhanced if training successfully increases parents' natural pointing routines.

In addition to the lack of a training effect on parental pointing during free play, there are other limitations to this study. Our sample was recruited from a self-selected database and accordingly lacked diversity in terms of socioeconomic background. Parental responsiveness is positively correlated socioeconomic status (Vanormelingen & Gillis, 2016). By diversifying the sample, and thus the baseline responsiveness of parents, training effects would presumably be more pronounced. Approximately half of the parents in the training group returned the protocol booklet, not allowing to draw firm conclusions about the implementation of the daily 15-minute training sessions at home. Due to limited resources, the number of participants and data collection points were restricted. It is conceivable that small effects of parental responsiveness on infants' early pointing would have been revealed in a larger sample. Further, an extension of the study by two months would have been promising to collect additional data on 11- and 12-month old infants' pointing development. Future studies may address this issue along with investigating the long-term effects of parent-based interventions. We are currently collecting data from this sample on infants' language development at 24 months to assess further effects of training and to replicate findings on the predictive relationship between infants' deictic gestures and subsequent language development.

In conclusion, the current study provided evidence that parents' natural pointing frequency predicts infants' early pointing and typical HoG development. Natural

observations are particularly well suited to investigate this relationship, as they are the best proxy for parents' daily pointing routines. The facilitative effect of parental responsiveness on infants' deictic gestures became apparent at the time when a particular gesture type typically emerges, not in its early stages. Training parental responsiveness for their 7-month-old infants promoted infants' HoG development at 10 months, demonstrating the causal relationship between parent and infant behavior. The possibility of using parental responsiveness training to promote infants' gesture and language development was thus extended from index-finger pointing to HoG gestures.

6.5. Supplementary material of Study 4

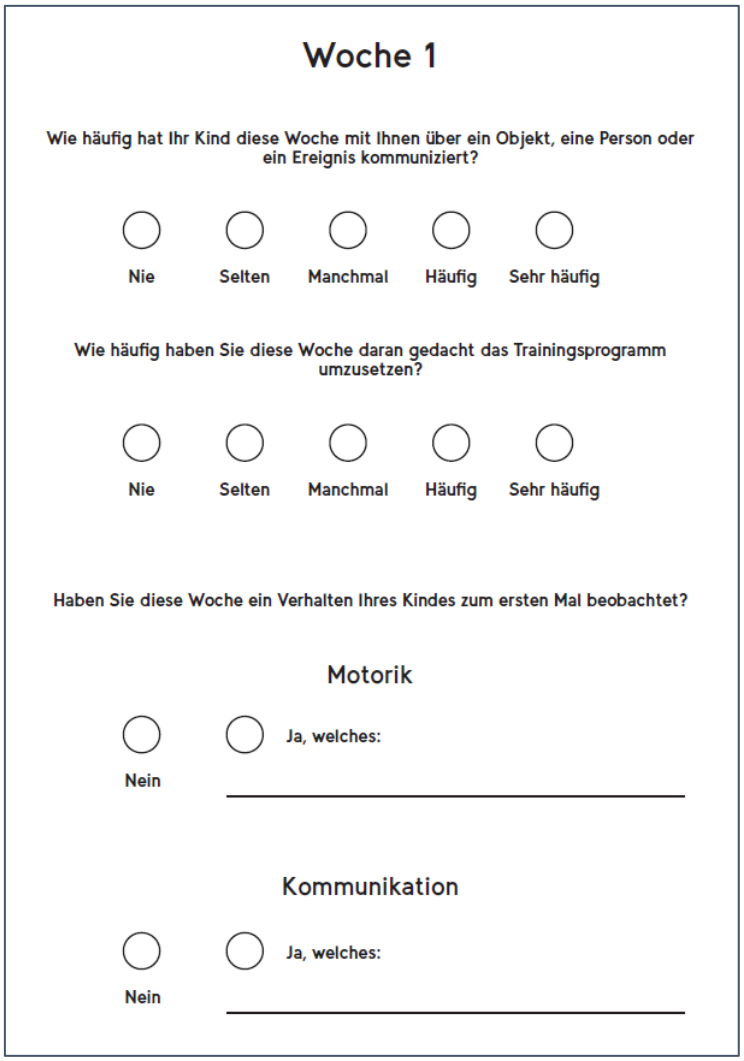
Table SM.6

Power analysis

χ^2 tests - Goodness-of-fit tests: Contingency tables		
Analysis:	A priori: Compute required sample size	
Input:	Effect size w	= .315
	α err prob	= .05
	Power (1-β err prob)	= .8
	Df	= 1
Output:	Noncentrality parameter λ	= 7.94
	Critical χ^2	= 4.84
	Total sample size	= 80
	Actual power	= .80

Note. The power analysis was calculated with G*Power 3.1.9.

Weekly training protocol



Woche 1

Wie häufig hat Ihr Kind diese Woche mit Ihnen über ein Objekt, eine Person oder ein Ereignis kommuniziert?

○ Nie ○ Selten ○ Manchmal ○ Häufig ○ Sehr häufig

Wie häufig haben Sie diese Woche daran gedacht das Trainingsprogramm umzusetzen?

○ Nie ○ Selten ○ Manchmal ○ Häufig ○ Sehr häufig

Haben Sie diese Woche ein Verhalten Ihres Kindes zum ersten Mal beobachtet?

Motorik

○ Nein ○ Ja, welches: _____

Kommunikation

○ Nein ○ Ja, welches: _____

Flyer for the training group

Durch unser Trainingsprogramm gestalten Sie die kommunikative Entwicklung Ihres Kindes aktiv mit. Die gestische Kommunikation ist eng mit der sprachlichen Kommunikation verknüpft, denn Kinder die früh und viel zeigen, fangen häufig früher an zu sprechen und verfügen über einen größeren Wortschatz.

Noch einmal herzlichen Dank für Ihre Unterstützung an diesem Forschungsprojekt des KOKU. Bei Fragen melden Sie sich gerne jederzeit bei uns.

KOKU
Von-Melle-Park 5
20146 Hamburg
Tel: +49 40 42838 5410
Email: koku@uni-hamburg.de

Katharina Kaletsch
K. Kaletsch

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Eltern beeinflussen die kommunikative Entwicklung ihrer Kinder!

Der Entstehung des Zeigens auf der Spur

KOKU
Forschungszentrum für kognitive und kulturelle Entwicklung

Liebe Eltern!

Vielen Dank, dass Sie sich für eine Teilnahme an unserer Studie entschieden haben.

Mit Ihrer Hilfe werden wir in den nächsten Monaten beobachten, ob sich die Entstehung der kindlichen Zeigegeste durch unser Trainingsprogramm beeinflussen lässt.

Bitte versuchen Sie daher bis zum Ende der Studie die folgenden Empfehlungen so häufig wie möglich, mindestens jedoch 15 Minuten am Tag umzusetzen. Um dies zu dokumentieren, füllen Sie bitte am Ende jeder Woche den kurzen Protokollbogen aus.

1 Kommunikative Situationen herstellen

2 Kindliche Kommunikation mit dem AKU-Prinzip beantworten

- A Aufmerksamkeit aufgreifen
- K Kommunizieren
- U Unmittelbar

KOKU
Forschungszentrum für kognitive und kulturelle Entwicklung

Booklet for the training group

KOKU
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Entwicklung

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Liebe Eltern!

Vielen Dank, dass Sie an unserer Studie zur kommunikativen Entwicklung teilnehmen!

Durch Ihre Teilnahme leisten Sie einen bedeutsamen Beitrag, um die Ursprünge der menschlichen Kommunikation besser zu verstehen. Wenn wir diese entschlüsseln, können wir Förderbedarf frühzeitiger erkennen und Kinder gezielter unterstützen. Außerdem hilft es uns einige Entwicklungs–schwierigkeiten wie zum Beispiel Sprachentwicklungs–verzögerungen oder die Autismus–Spektrum–Störung besser zu verstehen.

Für Sie und Ihr eigenes Kind bedeutet die Teilnahme an dieser Studie die aktive Mitgestaltung der kommunikativen Entwicklung und das frühzeitige, achtsame Erkennen der kindlichen Kommunikation. Dieses gemeinsame Miteinander wird Ihnen und Ihrem Kind sicherlich Freude bereiten.

Dieses Begleitheft erklärt Ihnen worum es uns in dieser Studie geht, welche Rolle Sie hierbei spielen und wie die Studie aufgebaut ist. Wenden Sie sich bei Fragen gerne jederzeit an unsere Mitarbeitenden: koku@uni–hamburg.de

HINTERGUND

Innerhalb des ersten Lebensjahres kommunizieren Kinder immer deutlicher mit ihren Bezugspersonen. Dabei beginnen Kinder sich in ihrer Kommunikation auf Objekte, Personen oder Ereignisse zu beziehen. In den bisher zweisamen Aus–tausch kommt der Bezug auf etwas Weiteres hinzu. Die Kinder halten zum Beispiel ein Spielzeug hoch, welches sie besonders spannend finden. Vielleicht geben sie dieses Spielzeug sogar ihren Bezugspersonen. Durch Greifversuche können sie kommunizieren, wenn sie etwas haben möchten.

Wenn Eltern diese vorsprachliche Kommunikation „über etwas" erkennen und sensibel aufgreifen, werden die Kinder in ihrer Kommunikation bestärkt. Diesen Zusammenhang möchten wir nutzen, um zu untersuchen, ob wir durch unser Trainings–programm die kommunikative Entwicklung von Kindern positiv beeinflussen können. Die gestische Kommunikation ist eng mit der sprachlichen Kommunikation verknüpft, denn Kinder die früh und viel zeigen, fangen häufig früher an zu sprechen und verfügen über einen größeren Wortschatz. Deshalb möchten wir in dieser Studie beobachten, ob sich unser Trainingsprogramm positiv auf das Alter in dem Kinder beginnen zu zeigen und auf die Häufigkeit des Zeigens auswirkt.

IHRE ROLLE

Die Bezugspersonen spielen eine wesentliche Rolle in der kommunikativen Entwicklung von Kindern. Ihre Reaktionen ermöglichen es dem Kind seine gestische Kommunikation als erfolgreich wahrzunehmen. Führt eine Geste zum beabsichtigten Austausch über ein Objekt, eine Person oder ein Ereignis, so wird sie in ihrer Verwendung bestärkt. Damit Ihre Reaktion die kommunikative Entwicklung Ihres Kindes fördert, gibt es drei Kriterien zu beachten.

A Aufmerksamkeit des Kindes teilen: Um die Verwendung von Gesten zu fördern, sollte Ihre Reaktion sich auf das Interesse und die Absicht Ihres Kindes beziehen.

K Kommunikation: Ihr Kind möchte mit Ihnen kommunizieren und wünscht sich Ihrerseits eine kommunikative Reaktion. Diese kann verbal und/oder ebenfalls über Gestik stattfinden.

U Unmittelbarkeit: Ihr Kind kann Ihre Reaktion am besten auf seine eigene Geste beziehen, wenn sie in unmittelbarer zeitlicher Abfolge stattfindet.

Beispiel: Ihr Kind streckt sich nach den Himbeeren auf dem Tisch aus und macht sich Ihnen gegenüber bemerkbar. Sie greifen den Aufmerksamkeitsfokus, sowie die Absicht Ihres Kindes Kommunikativ auf und reagieren Unmittelbar. Sie zeigen auf die Himbeeren, sagen: „Ja, ich weiß du möchtest noch mehr Himbeeren haben." Ob Sie Ihrem Kind dann den Wunsch erfüllen oder es erst einmal Abendbrot gibt, ist dabei nicht wichtig. Hauptsache Sie haben den Aufmerksamkeitsfokus Ihres Kindes aufgegriffen und unmittelbar darüber kommuniziert.

KONKRETE UMSETZUNG

Kinder profitieren am ehesten von Reaktionen nach dem AKU–Prinzip, wenn diese möglichst häufig auftreten und nicht nur während eines bestimmten Zeitraums. Trotzdem kann es hilfreich sein, wenn Sie sich im Rahmen dieser Studie vornehmen unsere Empfehlungen jeden Tag für mindestens 15 Minuten umzusetzen. Hier sind einige Beispiele: Setzen Sie sich zu Ihrem Kind auf die Krabbeldecke und beobachten Sie welche Spielzeuge es besonders interessiert. Kommuniziert ihr Kind sein Interesse? Fragen Sie Ihr Kind welche Hose es anziehen möchte. Kommuniziert es seine Vorliebe? Stellen Sie sich gemeinsam mit Ihrem Kind auf den Balkon, ans Fenster oder in den Garten. Kommuniziert es sein Interesse an Vögeln, Autos oder dem Mond? Sicherlich fallen Ihnen viele eigene Beispiele und Situationen ein.

Zusammengefasst beinhaltet unser Trainingsprogramm also zwei Empfehlungen:

1. Kommunikative Situationen erkennen oder herstellen

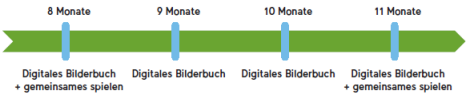
   ↓ sobald Ihr Kind mit Ihnen über etwas kommuniziert

2. Die kindliche Kommunikation nach dem AKU–Prinzip beantworten

Bitte füllen Sie einmal pro Woche den beiliegenden Protokollbogen aus, damit die konkrete Umsetzung unserer Empfehlungen und die kindliche Entwicklung genauer in Erinnerung bleibt. Richten Sie ein besonderes Augenmerk auf das Auftreten der kindlichen Zeigegeste.

STUDIENAUFBAU

Wir begleiten Ihr Kind und Sie für die nächsten drei Monate, um zu beobachten, inwieweit sich unser Trainingsprogramm auf die Entwicklung der kindlichen Zeigegeste auswirkt. Hierzu findet einmal im Monat online ein Treffen statt. Währenddessen werden Sie sich gemeinsam mit Ihrem Kind ein digitales Bilderbuch anschauen. Dies hilft uns die kommunikative Entwicklung Ihres Kindes einzuschätzen. Am ersten und am letzten Termin werden wir Sie und Ihr Kind außerdem bei einer kurzen Spielsequenz beobachten. Hierzu bekommen Sie ein Spielzeug–Set von uns zugeschickt. Die Spielzeuge verwenden Sie zunächst bitte nur im Rahmen unsere Studie. Nach deren Abschluss darf Ihr Kind die Spielzeuge als kleines Geschenk behalten und natürlich jederzeit nutzen.



Wir freuen uns auf Ihre Teilnahme. Bis bald!

K. Kaletsch

Katharina Kaletsch und das gesamte KOKU Forschungsteam

Universität Hamburg
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KOKU
Forschungszentrum
für kognitive und kulturelle
Entwicklung

KOKU
Von–Melle–Park 5
20146 Hamburg
Tel: +49 40 42838 5410
Email: koku@uni–hamburg.de

Table SM.7

Regression models on infants' pointing status

		B (SE)	Exp(B)	95% CI, Exp (B)		p
				LL	UL	
Pointing status, *N* = 79, longitudinal	Parental responsiveness (t1)	.59 (.71)	1.80	.45	7.17	.408
	Parental pointing (D, t1)	-.36 (.19)	.70	.48	1.01	*.060*
	Parental pointing (FP, t1)	1.88 (.88)	6.57	1.16	37.11	**.033**
	Intercept	-.63 (.41)	.53	.24	1.18	.120
	Goodness of fit	*deviance* = 92.76		*df* = 74		*value/df* = 1.25
Pointing status, *N* = 79, cross-sectional	Parental responsiveness (t4)	.14 (.79)	1.15	.25	5.42	.858
	Parental pointing (D, t4)	-.05 (.13)	.95	.74	1.23	.704
	Parental pointing (FP, t4)	.15 (.66)	1.16	.32	4.26	.822
	Intercept	-.50 (.50)	.61	.23	1.60	.311
	Goodness of fit	*deviance* = 101.94		*df* = 74		*value/df* = 1.25

Note. FP = free play, D = remote decorated room, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

Table SM.8

Regression models on infants' pointing frequency

		B (SE)	Exp(B)	95% CI, Exp (B)		p
				LL	UL	
Pointing frequency, *N* = 79, longitudinal	Parental responsiveness (t1)	-.19 (.72)	.83	.20	3.39	.790
	Parental pointing (D, t1)	.04 (.16)	1.04	.76	1.43	.793
	Parental pointing (FP, t1)	2.59 (1.17)	13.29	1.34	131.49	**.027**
	Intercept	-.08 (.46)	.92	.38	2.26	.857
	Goodness of fit	*deviance* = 57.00		*df* = 74		*value/df* = .77
Pointing frequency, *N* = 80, cross-sectional	Parental responsiveness (t4)	.22 (.71)	1.25	.31	5.02	.756
	Parental pointing (D, t4)	-.13 (.12)	.88	.69	1.11	.270
	Parental pointing (FP, t4)	1.20 (.69)	3.32	.85	12.93	*.084*
	Intercept	.33 (.49)	1.39	.53	3.60	.502
	Goodness of fit	*deviance* = 57.28		*df* = 75		*value/df* = .76

Note. FP = free play, D = remote decorated room, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

Table SM.9

Regression models on infants' HoG status

		B (SE)	Exp(B)	95% CI, Exp (B)		p
				LL	UL	
HoG status, *N*= 78, longitudinal	Parental responsiveness (t1)	-.34 (.57)	.71	.23	2.19	.556
	Parental pointing (D, t1)	-.04 (.16)	.96	.70	1.30	.786
	Parental pointing (FP, t1)	1.43 (1.01)	4.16	.57	30.15	.158
	Infant age (t4)	1.04 (.79)	2.82	.60	13.25	.188
	Intercept	-11.43 (8.23)	< .001	.00	119.80	.168
	Goodness of fit	*deviance* = 101.23	*df* = 73		*value/df* = 1.39	
HoG status, *N* = 79, cross-sectional	Parental responsiveness (t4)	2.23 (.92)	9.34	1.53	56.96	**.015**
	Parental pointing (D, t4)	-.22 (.14)	.80	.60	1.06	.119
	Parental pointing (FP, t4)	.48 (.66)	1.61	.44	5.91	.474
	Infant age (t4)	1.27 (.82)	3.56	.71	17.98	.124
	Intercept	-14.32 (.8.68)	<.001	.00	14.75	*.099*
	Goodness of fit	*deviance* = 96.31	*df* = 74		*value/df* = 1.30	

Note. FP = free play, D = remote decorated room, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

Table SM.10

Regression models on HoG frequency

		B (SE)	Exp(B)	95% CI, Exp (B)		p
				LL	UL	
HoG frequency, *N*= 79, longitudinal	Parental responsiveness (t1)	-.55 (.48)	.58	.24	1.48	.254
	Parental pointing (D, t1)	-.14 (.13)	.87	.68	1.11	.252
	Parental pointing (FP, t1)	2.13 (.80)	8.37	1.76	39.81	**.008**
	Intercept	-.12 (.32)	1.03	.55	1.91	.935
	Goodness of fit	*deviance* = 67.91		*df* = 74		*value/df* = .92
HoG frequency, *N* = 80, cross-sectional	Parental responsiveness (t4)	2.06 (.58)	7.82	2.52	24.21	**<.001**
	Parental pointing (D, t4)	-.32 (.12)	.72	.57	.92	**.009**
	Parental pointing (FP, t4)	.54 (.42)	1.71	.75	3.93	.204
	Intercept	-.37 (.45)	.69	.29	1.67	.412
	Goodness of fit	*deviance* = 114.81		*df* = 74		*value/df* = 1.55

Note. FP = free play, D = remote decorated room, B = regression coefficient with standard errors (SE) in parentheses, Exp(B) = exponentiated regression coefficient, CI = confidence interval, LL= lower limit, UL= upper limit, scale = 1, p-values are reported two-tailed.

7. General Discussion

Human infants are born with an innate social motivation and engage in dyadic social interaction from birth onward. Prior to their first birthday, infants utilize communicative gestures, particularly pointing and HoG gestures, to intentionally share their interest and attention in external entities. These early referential abilities serve as a foundation for and predict the subsequent acquisition of the uniquely human language system. Investigating the social learning mechanisms that facilitate the transition from dyadic to triadic and referential interaction provides critical insights into foundational aspects of human communication development.

In this dissertation, I applied novel remote paradigms to examine cross-sectional and longitudinal relations between infants' gestural development and parental behaviors. By considering parental responsiveness and parental pointing concurrently, I compared two social learning processes frequently discussed in the literature. In addition to cross-sectional and longitudinal observations, the effect of training parental responsiveness and pointing was assessed using different study designs.

The results indicated that, from the time a gesture typically emerges, parental responsiveness is cross-sectionally, longitudinally, and causally related to infants' deictic gestures. When measured during free play, parental pointing is additionally predictive for infants' deictic gesture development. These findings prove the causal relation between parental responsiveness and pointing and infants' gesture development. Moreover, the results confirm the importance of this link for early parent-based communication interventions. Taken together, the findings of this dissertation support the hypothesis that the development of infant deictic gestures, as intentional, communicative and referential acts, is influenced by parental behaviors.

In the following section, I present a summary of the results and discuss them in the context of current research. I outline a coherent developmental trajectory of infants' deictic gesture development, along with an examination of the limitations of the studies presented. Finally, directions for future research are proposed.

7.1. Summary of the findings

The primary findings of Study 1 - 4 are summarized in Table 9. In the initial study, we developed a remote paradigm to investigate infant pointing. The results revealed that the number of 12-month-old infant pointers and their pointing frequency achieved the targeted benchmarks from the original decorated room (Liszkowski & Tomasello, 2011). Notably, the social context was preserved as parental responsiveness and pointing were comparable to the original set-up. While infant pointing was found to be cross-sectionally related to parental responsiveness, no relation was observed between infant and parent pointing. In addition to establishing a reliable remote paradigm, Study 1 provided evidence for the relation between infant pointing and parental responsiveness.

In Study 2, we addressed the question of directionality of the relationship between infant pointing, parental responsiveness, and parental pointing. The findings consistently extended the correlational results of Study 1. Infants' promptly adapted their pointing frequency to experimentally increased parental responsiveness, with no discernible effect of changes in parents' pointing frequency. This pattern of results provided evidence for the causal influence of parental responsiveness on infants' pointing frequency.

The first longitudinal study of this dissertation investigated the influence of parental responsiveness and pointing on infants' pointing frequency over the course of one month. The results contributed to those of Studies 1 and 2, indicating that parental responses to infants' pointing at 12 months were predictive of infants' pointing frequency one month later. Moreover, 13-month-old infants pointed more frequently when their parents

participated in a parent-based training targeting parental responsiveness and parental pointing compared to infants in the control group. This effect remained evident when controlling for confounding infant- and parent-level variables. We concluded that parental responsiveness is a primary candidate to promote infants' pointing frequency in longitudinal parent-based communication interventions.

In Study 4, we examined the influence of parental responsiveness and pointing on infants' deictic gesture development from seven months onward. The results revealed that parental responsiveness at 10 months was cross-sectionally related to infant HoG gestures, not to infant pointing. When parents begin to point for their infants at around 7 months of age, their pointing frequency predicted infants' pointing and HoG development at 10 months when being measured during free play. We found no relation between infants' gesture development and parental pointing in the remote decorated room. The training program designed to enhance parental responsiveness and pointing did not affect infants' early pointing development, but it promoted infants' HoG development. We concluded that the facilitating effect of parental responsiveness on infants' gesture development, also in the context of training, becomes evident when infants have acquired some practice with a specific gesture type. The findings indicated that the absence of correlations between infant and parent pointing in Studies 1-3 may be due to methodological constraints of the remote decorated room.

Table 9

Main findings of the empirical studies

	Research questions and main findings
Study 1	*Does the novel online remote paradigm elicit spontaneous infant pointing while preserving natural infant-parent interaction?* Yes. The 'remote decorated room' elicited spontaneous pointing in 12-month-old infants and their parents and preserved a natural interaction context.
Study 2	*Do infants immediately adapt their pointing frequency to experimentally manipulated parental responsiveness and parental pointing*? Yes. Twelve-month-old infants immediately adapted their pointing frequency to experimentally increased parental responsiveness, but not to changes in the frequency of parental pointing.
Study 3	*Does a training targeting parental responsiveness and pointing affect infants' pointing frequency?* Yes. Infants pointed significantly more at 13 months when their parents participated in a training targeting parental responsiveness and pointing.
Study 4	*Do parental responsiveness and pointing influence infants' early pointing status and frequency?* Yes. Infants' early pointing development at 10 months was predicted by parental pointing during free play at seven months. *Do parental responsiveness and pointing influence infants' HoG status and frequency?* Yes. Infants' HoG development at 10 months was predicted by parental responsiveness and pointing. *Does a training targeting parental responsiveness affect infants' early pointing and HoG development?* Yes. Infants' HoG development at 10 months was promoted by training parental responsiveness from seven months onward. Infants' early pointing development was not affected by training.

7.2. Integration of the findings

The findings of this dissertation highlight the importance of parental responsiveness in the development of deictic gestures. Existing correlational findings on the positive relationship between parental responsiveness and infants' communication development are supported by the results of Study 1 and extended in the three subsequent studies. Studies 2-4 provided cross-sectional and longitudinal evidence for the causal facilitative influence of parental responsiveness on infants' gesture frequency. In short, infants use more gestures when their parents are more responsive. Two main conclusions can be drawn from these findings. First, from at least 10 months of age, infants gesture with communicative intentions and in expectation of contingent parental responses. In terms of theoretical accounts, this proposition challenges social shaping accounts, which assume that infant gestures are initially non-communicative behaviors (Carpendale & Carpendale, 2010). Second, interindividual variance in infant gesture frequency is partially explained by differences in parental responsiveness. With regard to theoretical perspectives on infants' gesture development, this proposal questions spontaneous onset accounts, which propose that the development of infant gestures relies exclusively on infant intrinsic factors (Butterworth, 2003). In support of a social constructivist perspective (Liszkowski & Rüther, 2021), I conclude from the current findings that parental responsiveness influences infants' communicative development from early on. Specifically, the facilitating effect of parental responsiveness on certain gesture types becomes apparent around the typical age of their emergence, suggesting that only then are infants cognitively prepared to transfer their social experiences to their own execution of a gesture.

Regarding the predictive value of infants' deictic gesture frequency for subsequent language development, parental responsiveness is identified as a promising target for early parent-based communication interventions. This suggestion is supported by Studies 3 and

4, which report the promoting effect of parental responsiveness training on infants' gesture frequency at 10 and 13 months of age. The results of the training studies further suggest, that the facilitating effect of parental responsiveness on specific gesture types becomes evident around their typical age of emergence.

Furthermore, I hypothesize that infants' cognitive readiness for gestural reference is also influenced by interaction experiences. This idea is supported by the results of Study 4. At seven months of age, infants show little behavior that indicates an ability to refer to external entities. Nevertheless, experiences with parents' referential gestures at this early age, predicted infants' subsequent gesture development. I propose, that infants learn about the referential nature of gestures and consequently reach a level of cognitive readiness to use gestures themselves, by observing their parents' gestural communication. This social learning mechanism, as opposed to mere mimicry of parental gestures, is supported by the finding that parental pointing gestures are not exclusively predictive of infants' pointing gestures, but also of infants' HoG development. Furthermore, infants' advanced point following abilities are predicted by parental pointing, indicating that infants learn referential complexities by experiencing parental gestures (Rüther & Liszkowski, 2020). Whether parental pointing continues to be an influential factor in infant gestures over the course of development remains to be investigated. I interpret the absence of a relationship between infant gestures and parental pointing in the remote decorated room, as a methodological limitation rather than evidence for the absence of a relationship between infant and parental pointing. In general, the discrepancy between the results in the remote decorated room and during free play adds to the mixed findings regarding the relationship between infant and parental pointing in the literature (Ger et al., 2023; Rüther & Liszkowski, 2023) and definitely calls for further research.

The findings of this dissertation suggest that differences in parental responsiveness and parental pointing frequency contribute to the variability in infants' deictic gesture development. Particularly parental responsiveness is highlighted as a promising lever to support infants' prelinguistic communication. In the following section, I discuss general limitations of the current studies and directions for future research.

7.3. Limitations and future directions

The studies presented in this dissertation are subject to certain limitations. While the specific limitations of each study are discussed in the previous chapters, in this section I elaborate on limitations concerning all four studies. In general, larger sample sizes would improve the validity of the results, particularly with regard to Studies 2 and 4. Furthermore, the self-selected samples were predominantly composed of individuals from high socioeconomic backgrounds. Maternal education (McGillion et al., 2017) and socioeconomic background (Rowe & Goldin-Meadow, 2009) predict infants' gesture development. This relationship is possibly mediated by the correlation of socioeconomic status and maternal responsiveness (Vanormelingen & Gillis, 2016). On the one hand, the high socioeconomic status of the samples in this dissertation led to parents' high baseline responsiveness, which possibly resulted in an underestimation of the experimental effects. On the other hand, a low socioeconomic status has been linked to reduced engagement and a higher attrition rate in intervention studies (Chacko et al., 2016), which possibly led to an overestimation of training effects in the current samples.

The majority of the participants were from WEIRD (Western, Educated, Industrialized, Rich, Democratic) cultural contexts, raising concerns about the generalizability of the findings. Mastin and Vogt (2016) for instance reported that in a Mozambican sample, the time spent in triadic joint attention was positively related to language outcomes in urban infants, whereas language skills in rural infants benefited from

dyadic interactions. While infants across cultural backgrounds acquire deictic gestures (Blake et al., 2005; Salomo & Liszkowski, 2013), the role of the social environment in their development may vary depending on the cultural context (Vogt et al., 2020). Consequently, future research should strive to collect data from diversified samples including a wider range of socioeconomic and cultural contexts.

In addition to the potential biases associated with socioeconomic status and cultural contexts, the observational set-up may have increased parents' tendency to show favorable behavior (Gardner, 2000). To mitigate this effect, we kept the settings as naturalistic as possible, instructed parents to behave as naturally as possible and deactivated videos of the experimenter. Remote data collection in the dyads' homes further promoted natural interaction in contrast to laboratory assessments. However, while infants in the current studies may not have been aware of the observational context, parents certainly were. It is particularly relevant to be aware that experimental observations are only an approximation of everyday interaction with regard to parental training implementation. The general issue can be addressed by employing extended home observations. This approach allows for the examination of a wider range of interactional settings and more closely approximates infants' everyday interactional experiences. Moreover, parents may not maintain an artificial form of interaction over a longer period of time. Disadvantages of home visits are that they are time consuming and the amount of video material requires a high coding effort. In addition, the lack of a specific interaction frame and instructions increases the likelihood of observing an insufficient amount of the behavior under investigation.

By choosing the remote decorated room paradigm, we observed a variety of relevant infant and parent behaviors. However, in direct comparison to the free play sessions in Study 4, a specific methodological issue was revealed, that raises questions about the generalizability of some of the findings in the current dissertation. Rather than

approximating parents' natural pointing frequency, the remote decorated room may reflect parents' willingness to redirect infants' focus on the task. In the absence of time and personnel constraints, some adjustments to the current study designs are reasonable. First, the inclusion of free play observations in all studies, may have resulted in the consistent emergence of parental pointing as a significant predictor for infants' pointing frequency. Second and pertinent to future studies employing the remote decorated room, it appears necessary to separately code for parental pointing gestures within sequences of shared attention to the screen and parental pointing to redirect infants' focus of attention.

Conceptually, parental responsiveness and pointing were considered as distinct constructs in this dissertation. However, parental responses to infant communication can include a parental pointing gesture. These responsive points are positively related to infants' pointing frequency (Kaletsch & Liszkowski, 2024; Kishimoto, 2017; Liszkowski et al., 2012). The salience of a parental response is increased when it is conveyed through different modalities, making responsive points a particularly prominent form of responsiveness. In contrast, the precise motive of parental pointing may be less relevant for direct imitation accounts. In investigating the role of parental pointing, future research might distinguish between points that address entities outside the infant's current focus of attention (redirecting), points that refer to entities within infant's focus and parental points in response to infant communication.

With regard to confounding variables, the current studies did not assess infant-level factors that influence infants' gesture development in interaction with the social environment (Rüther & Liszkowski, 2020; Wang et al., 2014). In addition, unaddressed parent-factors may influence the development of gestures (e.g., parent personality). While investigating increased parental responsiveness and pointing, effects of training on non-targeted parental behavior were possibly overlooked. To determine whether training effects

are based on a general increase in parent-infant interaction during the training period, the inclusion of an active control group is reasonable. In a communication training study conducted by Salter and colleagues (2023), the control group participated in a physical health program. Other potential control group instructions include joint musical activities (Matthews et al., 2012).

Besides the effect of having an active control group, three unanswered issues are relevant in the context of training. First, the examination of long-term effects of parent-based trainings on infants' gesture development. Second, the transfer of improved infants' gesture development to subsequent language acquisition. Data are currently being collected on the expressive language skills of 24-month-old infants from the sample of Study 4. Third, further research is needed to assess intervention effects in high-risk populations. In conclusion, the current dissertation provided valuable insights into the role of parental responsiveness and pointing in infants' gesture development. Yet, given the complexity of infants' deictic gesture development, further research is needed to obtain a complete picture of all influencing factors.

7.4. Concluding remarks

Infants communicate their interest in and attention to external entities through gestures before they manage their first words (Guevara et al., 2020). The motivation to acquire complex communication skills before the first birthday is rooted in an innate social orientation (Over, 2016; Rüther & Liszkowski, 2021). It stands to reason that many developmental milestones, above all language acquisition, are notably influenced by infants' social interaction experiences (Tamis-LeMonda et al., 2003). Identifying the social learning mechanisms underlying infants' gesture development helps to understand the roots of human communication and is a necessary basis for communication interventions.

With these objectives in mind, the influence of parental responsiveness and parental pointing on the development of infants' deictic gestures was investigated.

In this dissertation, I introduced and established a new remote tool for observing infant pointing across different age groups. The novel remote paradigm allows for data collection from diverse samples, large-scale multi-laboratory studies, cross-cultural research, and quick and easy diagnostic screening. The data presented suggest that parental responsiveness and pointing influence infants' gesture development. By experiencing parents' referential pointing from seven months onwards, infants learn about the referential nature of deictic gestures. On this social-cognitive basis, parental responsiveness shapes infants' prelinguistic gestural communication. In addition to providing evidence for the social constructivist account, this interpretation of the findings challenges spontaneous onset and social shaping accounts. Infant gestures as communicative acts develop through the influence of social interactional experiences in close interaction with infants' cognitive abilities. Thus, parent-based interventions targeting infants' communicative development are particularly effective when the training is tailored to the infant's current developmental stage. Parental pointing training is a promising candidate for intervention before infants actively initiate episodes of triadic joint attention, while parental responsiveness is a relevant training target afterward.

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Appendix A

Ethical approvals

Ethical approval of Studies 1-3

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Fakultät für Psychologie und Bewegungswissenschaft

Local Ethics Committee
Faculty for Psychology and Movement Science
Universität Hamburg
Von-Melle-Park 5
20146 Hamburg
ethikkommission.pb@uni-hamburg.de

Katharina Kaletsch
Prof. Dr. Ulf Liszkowski

19.12.2022

AZ: 2022_063

Your proposal: **Einfluss elterlichen Verhaltens auf die Entstehung der kindlichen Zeigegeste**

Dear Ms. Kaletsch:

I hereby inform you that the Local Ethics Committee of the Faculty for Psychology and Movement Science of Universität Hamburg has no objections against the planned study. Under ethical considerations, your study has been approved as unobjectionable.

Please note: The Local Ethics Committee of the Faculty of Psychology and Human Movement Science of the University Hamburg (LEC) disclaims any liability with respect to harms that might result from a research project approved by the LEC. This disclaimer is also valid in case the researcher obeys all recommendations of the LEC. Excluded are cases for which it can be documented that the LEC acted deliberately and grossly negligent or gave recommendations contrary to the law. Data protection issues of research projects are checked only cursively by the ethics committee based on the information provided by the authors of an application.
The data protection responsibility according to the DSGVO (i.e., German adaptation of the European General Data Protection Regulation) resides with you as project manager. For specific questions about data protection of sensitive data or deletion of data, please contact the data protection officer at Universität Hamburg.

The LEC wishes you and your collaborators success in running the study.

Sincerely,

Prof. Dr. Nale Lehmann-Willenbrock
Chair of the Local Ethics Committee

Ethical approval of Study 4

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Faculty for Psychology and Movement Science
Local Ethics Committee
Von-Melle-Park 5
20146 Hamburg
ethikkommission.pb@uni-hamburg.de

Ms. Katharina Kaletsch, M.A.
Prof. Dr. Ulf Liszkowski

June 07, 2023

Your proposal:
Parental influence on the development of infants' pointing gesture: a longitudinal training study

(KA_2023_021)

Dear Ms. Kaletsch and Prof. Liszkowski,

Thanks for revising your ethics proposal. I hereby inform you that the Local Ethics Committee of the Faculty for Psychology and Movement Science of Universität Hamburg has no objections against the planned study. Regarding ethical considerations, your study has been approved.

Please note: The Local Ethics Committee (LEC) of the Faculty of Psychology and Human Movement Science at Universität Hamburg disclaims any liability with respect to harm that might result from a research project approved by the LEC. This disclaimer is also valid in case the researcher obeys all recommendations of the LEC. Excluded are cases for which it can be documented that the LEC acted deliberately and grossly negligent or gave recommendations contrary to the law. Data protection issues of research projects are checked only cursively by the ethics committee based on the information provided by the authors of an application.
Data protection responsibility according to the DSGVO (i.e., German adaptation of the European General Data Protection Regulation) resides with you as project managers.
For specific questions about data protection of sensitive data or deletion of data, please contact the data protection officer at Universität Hamburg.

The LEC wishes you success running this study.

Sincerely,

Prof. Dr. Sebastian Gluth,
Vice-Chair of the Local Ethics Committee

Appendix B

Recruitment letter from the KOKU database

Universität Hamburg

KOKU • Forschungszentrum für kognitive und kulturelle Entwicklung
Von-Melle-Park 5, 20146 Hamburg

KOKU • Forschungszentrum für kognitive und kulturelle Entwicklung
Arbeitsbereich Entwicklungspsychologie
Prof. Dr. Ulf Liszkowski

Von-Melle-Park 5
20146 Hamburg
Tel.: +49 (0)40 42838-5410
koku@uni-hamburg.de
www.koku.uni-hamburg.de

02.02.2021

Liebe Eltern,

wir möchten uns kurz vorstellen: Wir sind das **KOKU Forschungszentrum für kognitive und kulturelle Entwicklung**. Am Institut für Psychologie der Universität Hamburg gehen das KOKU und das Babylabor der Abteilung Biologische Psychologie Fragen der kindlichen Entwicklung nach. Am KOKU sind wir den Ursprüngen und der Entwicklung des sozialen Denkens und Miteinanders von Säuglingen und Kindern auf der Spur. Der beiliegende Flyer informiert Sie über unsere Arbeit und Studienabläufe mit Kindern am KOKU.

Wenn Sie neugierig geworden sind und uns helfen möchten, die kindliche Entwicklung besser zu verstehen, freuen wir uns sehr, wenn Sie und ihr Kind bei uns mitmachen. Dazu können Sie das beigefügte Antwortschreiben **kostenlos** an uns zurückschicken. Sie verpflichten sich damit nicht, an einer unserer Studien teilzunehmen. Ihre Antwort dient allein dazu, dass wir Sie dann telefonisch kontaktieren und einladen dürfen, wenn Ihr Kind das passende Alter für eine unserer Studien hat. Sie können natürlich jederzeit die Speicherung Ihrer Kontaktadresse widerrufen, indem Sie uns schreiben oder anrufen. In unseren Studien laden wir Kinder bis zu einem Alter von 10 Jahren ein. Spätestens nach 10 Jahren löschen wir die Kontaktadresse automatisch. Sollten Sie kein Interesse haben mit uns in Kontakt zu treten, werden wir Ihre Daten spätestens zwölf Wochen nach diesem Anschreiben unaufgefordert wieder löschen, auf Ihren Wunsch hin auch umgehend. Wir werden Sie dann in Zukunft nicht mehr kontaktieren.

Die Stadt Hamburg hat uns einmalig Namen, Vornamen, Geburtsdatum und Anschrift Ihres Kindes, sowie aller gleichaltrigen Kinder in Hamburg, zur Verfügung gestellt, um den gesellschaftlichen Forschungsauftrag der Universität Hamburg zu unterstützen (vgl. § 11 Abs. 1 Hamburgisches Datenschutzgesetz und § 46 Bundesmeldegesetz). Datenschutz ist uns wichtig: Wir behandeln Ihre Daten streng vertraulich und geben sie in keinem Fall an Dritte weiter. Weitere Informationen zu Aspekten der Datensicherheit erhalten Sie auf unserer Internetseite **www.koku.uni-hamburg.de** oder indem Sie uns über eine der oben angeführten Möglichkeiten kontaktieren.

Mehr Informationen zu unseren Studien und Publikationen erhalten Sie ebenfalls auf unserer Internetseite. Dort finden Sie auch weiterführende Hinweise zur Darstellung unserer Arbeit in den öffentlichen Medien. Bei Fragen können Sie sich gerne über eine der obenstehenden Kontaktmöglichkeiten an uns wenden.

Wir bedanken uns für Ihr Interesse, und hoffen, Sie und Ihr Kind schon bald bei uns begrüßen zu dürfen!

Herzliche Grüße,
Ihr Team vom KOKU

Prof. Dr. Ulf Liszkowski
(Leiter der Abteilung Entwicklungspsychologie)

Einverständniserklärung

Ich bin/ Wir sind damit einverstanden, dass das KOKU Forschungszentrum für kognitive und kulturelle Entwicklung der Universität Hamburg mit mir/ uns telefonisch Kontakt aufnimmt, um mich/ uns und das Kind zur Teilnahme an einer wissenschaftlichen Studie einzuladen. Ich wurde/ Wir wurden darüber informiert, dass die vorliegende Einverständniserklärung sich lediglich auf die Kontaktaufnahme bezieht und nicht zu einer Teilnahme an einer Studie verpflichtet, dass die Kontaktdaten vertraulich behandelt und nicht an Dritte weitergeleitet werden, und dass die Kontaktdaten maximal 10 Jahre lang gespeichert werden. Ich bin/ Wir sind darauf hingewiesen worden, dass diese Einwilligung verweigert werden darf, dass bei Nichtausfüllen dieser Erklärung meine Kontaktdaten spätestens nach 12 Wochen gelöscht werden, auf Wunsch auch umgehend, und dass aus einer Verweigerung keinerlei Nachteile für mich/ uns oder mein/ unser Kind entstehen. Die erteilte Einwilligung kann jederzeit widerrufen werden. Der Widerruf ist zu richten an: KOKU – Arbeitsbereich Entwicklungs-psychologie, Von-Melle-Park 5, 20146 Hamburg.

Familien- und Vorname des Kindes:

_____

Geburtsdatum des Kindes (Tag/ Monat/ Jahr):

__ __ . __ __ . __ __ __ __

Adresse, PLZ:

_____

Name der Mutter/ des Vaters:

_____

Telefonnummer:

_____

E-Mail-Adresse (optional):

_____

_____

Ort, Datum, Unterschrift (Eltern/ erziehungsberechtigte Person(en))

KOKU Forschungszentrum für kognitive und kulturelle Entwicklung

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

Liebe Eltern,

Sie können sich vorstellen, uns durch eine Teilnahme Ihres Kindes an einem unserer Forschungsprojekte zu unterstützen? Senden Sie uns bitte dieses Antwortschreiben ausgefüllt zu. Wir setzen uns mit Ihnen in Verbindung, um Ihnen weitere Informationen zu geben und Sie mit Ihrem Kind einzuladen.

Vielen Dank für Ihr Interesse!

Herzliche Grüße, Ihr KOKU-Team

Rückantwort

KOKU • Forschungszentrum für kognitive und kulturelle Entwicklung
AB Entwicklungspsychologie
c/o Poststelle
Mittelweg 177
20148 Hamburg

Appendix C

Documents for participating parents at the KOKU

Sample study information

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

KOKU
Forschungszentrum
für kognitive und kulturelle
Entwicklung

KOKU • Forschungszentrum für kognitive und kulturelle Entwicklung
Von-Melle-Park 5, 20146 Hamburg

KOKU • Forschungszentrum für kognitive und kulturelle Entwicklung
Abteilung Entwicklungspsychologie
Prof. Dr. Ulf Liszkowski

Von-Melle-Park 5
20146 Hamburg
Tel.: +49 (0)40 42838-5410
koku@uni-hamburg.de
www.koku.uni-hamburg.de

Infoschreiben

Sehr geehrte Eltern,

vielen Dank für Ihr Interesse an der Arbeit im KOKU und Ihre Bereitschaft, uns durch die Teilnahme Ihres Kindes zu unterstützen!

Die Studie, an der Ihr Kind teilnehmen wird, untersucht kommunikative Entwicklungsprozesse bei Kindern. Sie dürfen sich dafür mit Ihrem Kind gemeinsam auf Ihrem PC/Tablet verschiedene Gegenständen und Szenen ansehen. Zur späteren Auswertung wird das Verhalten Ihres Kindes als Video aufgezeichnet.

Die dabei entstehenden Daten werden vertraulich behandelt und in pseudonymisierter Form weiterverarbeitet. Das heißt, dass weder Ihr Name, noch der Name Ihres Kindes für die Speicherung der personenbezogenen Daten verwendet werden. Die Videodaten, die wir während der Studie aufzeichnen, speichern wir auf einem zugangsbeschränkten Server des Regionalen Rechenzentrums der Universität Hamburg.

Bei der Studie sind wir an allgemeinen Aussagen interessiert. Daraus folgt, dass sich die Auswertungen der Daten stets auf eine ganze Gruppe von Kindern, nie auf einzelne Kinder und ihre Leistungen beziehen.

Die Teilnahme an dieser Studie ist freiwillig und kann jederzeit ohne Nachteile beendet werden.

Im Anschluss an die Studie wird unsere Mitarbeiterin Ihnen gerne weitere Fragen zur Studie beantworten. Wenn Sie damit einverstanden sind, dass Ihr Kind an unserer Studie teilnimmt, lesen Sie bitte die beiliegende Einwilligungserklärung und bestätigen Sie ihr Einverständnis zu Beginn der Teilnahme mündlich. Hierzu wird Sie die Versuchsleiterin zu gegebenem Zeitpunkt explizit auffordern.

Für weitere Fragen stehen wir Ihnen jederzeit unter den oben genannten Kontaktdaten zur Verfügung.

Mit freundlichen Grüßen

Prof. Dr. Ulf Liszkowski

Consent form for audio and video recordings

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

KOKU Forschungszentrum für kognitive und kulturelle Entwicklung

KOKU - Forschungszentrum für kognitive und kulturelle Entwicklung

Prof. Dr. Ulf Liszkowski
Ansprechpartner/in für eventuelle Rückfragen:
Katharina Kaletsch
Telefon: *+49 (0)40 42838 - 5410*

Einwilligungserklärung für Bild- und Tonaufnahmen

KOKU - Forschungszentrum für kognitive und kulturelle Entwicklung

Titel der Studie: DecoRoom

Ich (Name des Teilnehmers /der Teilnehmerin in Blockschrift) _____

bin schriftlich und mündlich von Frau Kaletsch darüber informiert worden, dass im Rahmen der Studie eine Videoaufnahme gemacht wird.

Die Aufnahme dient dazu, die kommunikative Entwicklung von Kindern in ihrem ersten Lebensjahr zu beobachten.

Auf den von mir gemachten Videoaufnahmen bin ich potentiell erkennbar.

Die Aufzeichnung und Auswertung der Videoaufnahmen erfolgt pseudonymisiert, d. h. unter Verwendung einer Nummer und ohne Angabe meines Namens. Es existiert eine Kodierliste auf Papier, die meinen Namen mit der Nummer verbindet. Da ich auf der von mir gemachten Aufnahme potentiell erkannt werden kann, habe ich das Recht, diese Aufnahmen jederzeit löschen zu lassen, ohne dass mit daraus Nachteile entstehen. Dazu wird die Kodierliste bis zur Löschung der Aufnahmen aufbewahrt.

Die Videoaufnahmen werden auf einem zugangsbeschränkten Server des Regionalen Rechenzentrums der Universität Hamburg aufbewahrt und spätestens nach 10 Jahren gemeinsam mit der Kodierliste gelöscht. Die Datenanalyse unterliegt auch nicht dem Widerrufsrecht gemäß Art. 7 der Datenschutz-Grundverordnung DSGVO.

Ich bin einverstanden, dass die Aufnahmen zu Forschungszwecken weiterverwendet werden können. Dazu werden sie mindestens 10 Jahre nach Datenauswertung, bzw. mindestens 10 Jahre nach Erscheinen einer Publikation zu dieser Studie aufbewahrt.

Zusatz: Ich gebe mein Einverständnis, dass meine Videoaufnahme zu Demonstrationszwecken in teilnehmerbegrenzten Veranstaltungen (z. B. Lehrveranstaltungen) abgespielt werden. Zutreffendes bitte ankreuzen:

O JA O NEIN

Die Einverständniserklärung für die Videoaufnahme ist freiwillig. Ich kann diese Erklärung jederzeit widerrufen. Im Falle einer Ablehnung oder eines Rücktritts entstehen für mich keinerlei Kosten oder anderweitige Nachteile; eine Teilnahme an der Studie ist dann allerdings nicht möglich.

Ich hatte genügend Zeit für eine Entscheidung. Ich habe alles gelesen und verstanden und erkläre mich hiermit bereit, dass eine Videoaufnahme von mir gemacht wird.

Eine Ausfertigung der Teilnehmerinformation über die Studie und eine Ausfertigung der Einwilligungserklärung habe ich erhalten.

☐ JA ☐ NEIN

Meine Einwilligung gilt unter der Gewährleistung der folgenden Rechte nach der EU-Datenschutzgrundverordnung (EU-DSGVO):

Gemäß Art. 13 Abs.2 lit. b der Datenschutzgrundverordnung haben Sie das Recht auf

- Auskunft (Art 15 DSGVO und §34 BDSG)
- Berichtigung, Löschung und Einschränkung (Art 16-18 DSGVO und §35 BDSG)
- Datenübertragbarkeit (Art 20 DSGVO)
- Widerspruch (Art 21 DSGVO und §36 BDSG).

Möchten Sie eines dieser Rechte in Anspruch nehmen, wenden Sie sich bitte an den/die

Projektleiter Prof. Dr. Ulf Liszkowski, Von-Melle-Park 5, 20146 Hamburg, Tel: +49 (0)40 42838-5410, Email: ulf.liszkowski@uni-hamburg.de

Weiterhin haben Sie das Recht, Beschwerde bei der Aufsichtsbehörde einzulegen:

Die zuständige Landesbehörde für Datenschutz in Hamburg mit dem Serviceportal finden Sie unter: https://datenschutz-hamburg.de/

Verantwortlicher für die Verarbeitung meiner Daten ist

Der Präsident der Universität Hamburg
Mittelweg 177
20148 Hamburg
praesident@uni-hamburg.de

Der/die behördlich zuständige Datenschutzbeauftragte ist

Datenschutzbeauftragter der Universität Hamburg
Mittelweg 177
20148 Hamburg
datenschutz@uni-hamburg.de

Ort, Datum & Unterschrift des/der Teilnehmers/in: Name des/der Teilnehmers/in in Druckschrift:

Ort, Datum & Unterschrift des/der Versuchsleiters/in: Name des/der Versuchsleiters/in in Druckschrift:

Bei Fragen oder anderen Anliegen kann ich mich an folgende Personen wenden:

Versuchsleiter/in:	Projektleiter/in:
Katharina Kaletsch Von-Melle-Park 5 20146 Hamburg +49 (0)40 32838-5410 katharina.kaletsch@uni-hamburg.de	Prof. Dr. Ulf Liszkowski ulf.liszkowski@uni-hamburg.de

Sample parent questionnaire on socioeconomic background

Universität Hamburg
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KOKU
Forschungszentrum
für kognitive und kulturelle
Entwicklung

Demographie:

1. Sind Sie die primäre Bezugsperson für ihr Kind? (Also die Person welche sich am meisten um das Kind kümmert) falls nein, wer ist die primäre Bezugsperson?
JA NEIN: _____
2. Wie alt sind Sie? _____

3. Was ist Ihr höchster Bildungsabschluss?
Volks-, Hauptschule / Realschule, Mittlere Reife / (Fach-)Abitur / Bachelor / Master / Promotion Sonstiger Schulabschluss / Kein Schulabschluss

4. Leben Sie mit dem anderen Elternteil zusammen? JA NEIN
   a. Wenn ja, was ist der Höchste Schulabschluss des anderen Elternteils?
   Volks-, Hauptschule / Realschule, Mittlere Reife / (Fach-)Abitur / Bachelor / Master / Promotion Sonstiger Schulabschluss / Kein Schulabschluss

5. Wächst Ihr Kind mehrsprachig auf? JA NEIN
   a. Wenn ja, welche Sprachen werden im Alltag mit dem Kind gesprochen?
   _____
   b. Wenn ja, wie häufig werden die Sprachen im Alltag benutzt (in %)?
   _____

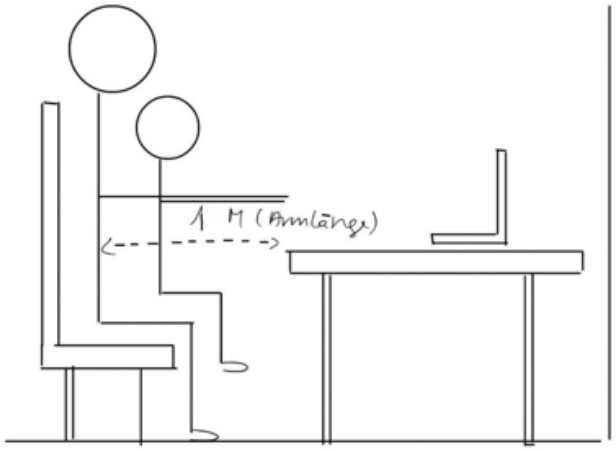
6. Geht Ihr Kind in eine KiTa oder Betreuung? JA NEIN
   a. Wenn ja, seit wann (Alter)? _____
   b. Wenn ja, wie viele Stunden pro Woche? _____

Appendix D

Set-up of the remote decorated room

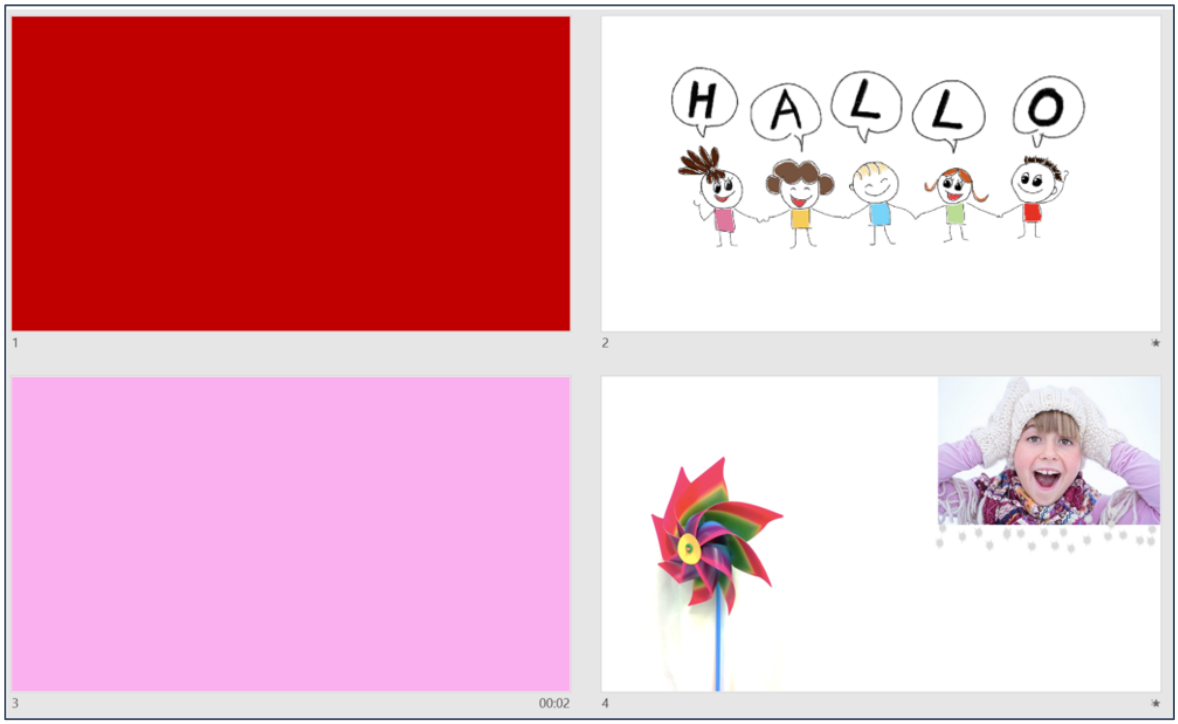
Checkliste – Die perfekten Bedingungen oder „Wir holen den Dekoroom zu Ihnen nach Hause“

- ✓ Der Abstand zum Laptop (unteres Ende der Tastatur) sollte bitte mindestens eine Armlänge betragen
- ✓ Während der Präsentation sollten weder Sie noch Ihr Kind den Bildschirm berühren können
- ✓ Es wäre gut, wenn auf dem Tisch keine weiteren ablenkenden Gegenstände stehen
- ✓ Ihr Kind sollte während der 5minütigen Präsentation nicht essen oder trinken und auch keinen Schnuller benutzen
- ✓ Um Ablenkung zu vermeiden sind bitte möglichst keine weiteren Personen oder Tiere im Raum
- ✓ Für gute Lichtverhältnisse sollten sich keine Fenster in Ihrem Rücken befinden oder die Vorhänge zugezogen sein
- ✓ Die Fenster und Türen des Raumes sind bitte geschlossen
- ✓ Ihr Kind kann während der 5 Minuten gerne auf Ihrem Schoß sitzen, dabei versuchen Sie bitte den Abstand von einer Armlänge zum Laptop stets einzuhalten
- ✓ Wenn Ihr Kind gerne im Hochstuhl sitzt und Sie es hierbei für wahrscheinlicher halten den Abstand zu gewährleisten, so können Sie Ihr Kind auch neben sich in einen Hochstuhl zu setzen

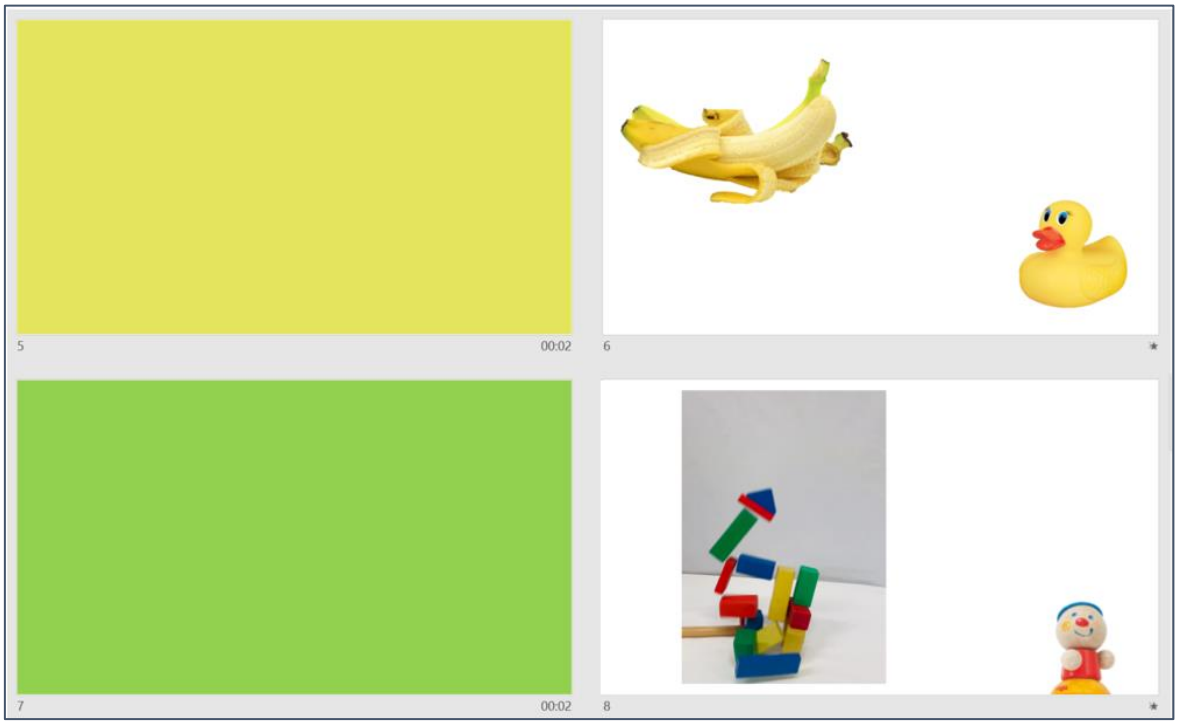


Appendix E

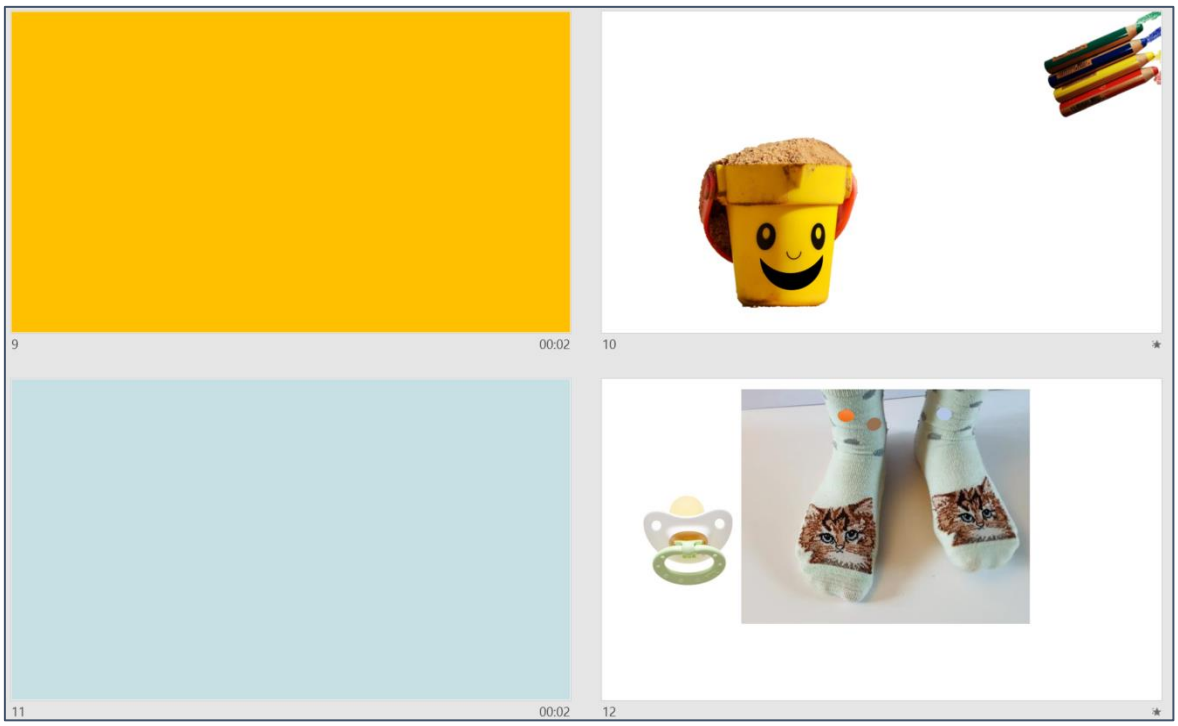
Sample stimulus presentation in Study 4



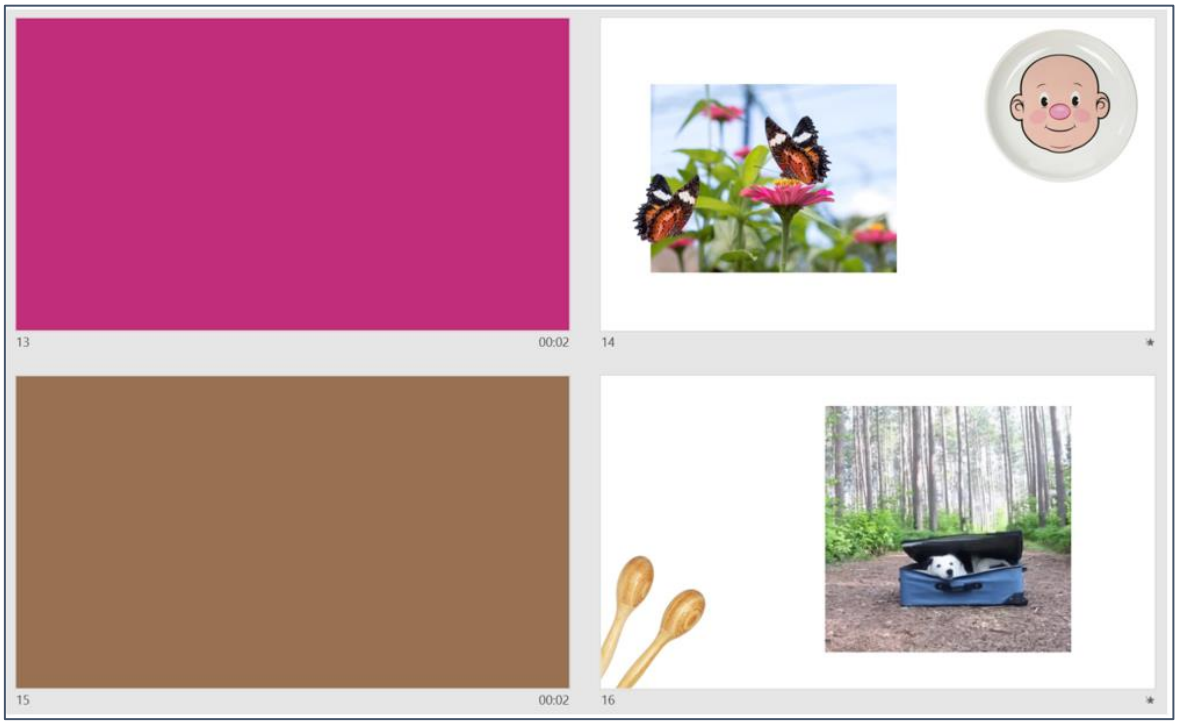
Note. Opening slide, sound: ringing bells, animation A: The windmill moves downward a little, animation B: Snow falls from the top to the bottom of the picture with the child.



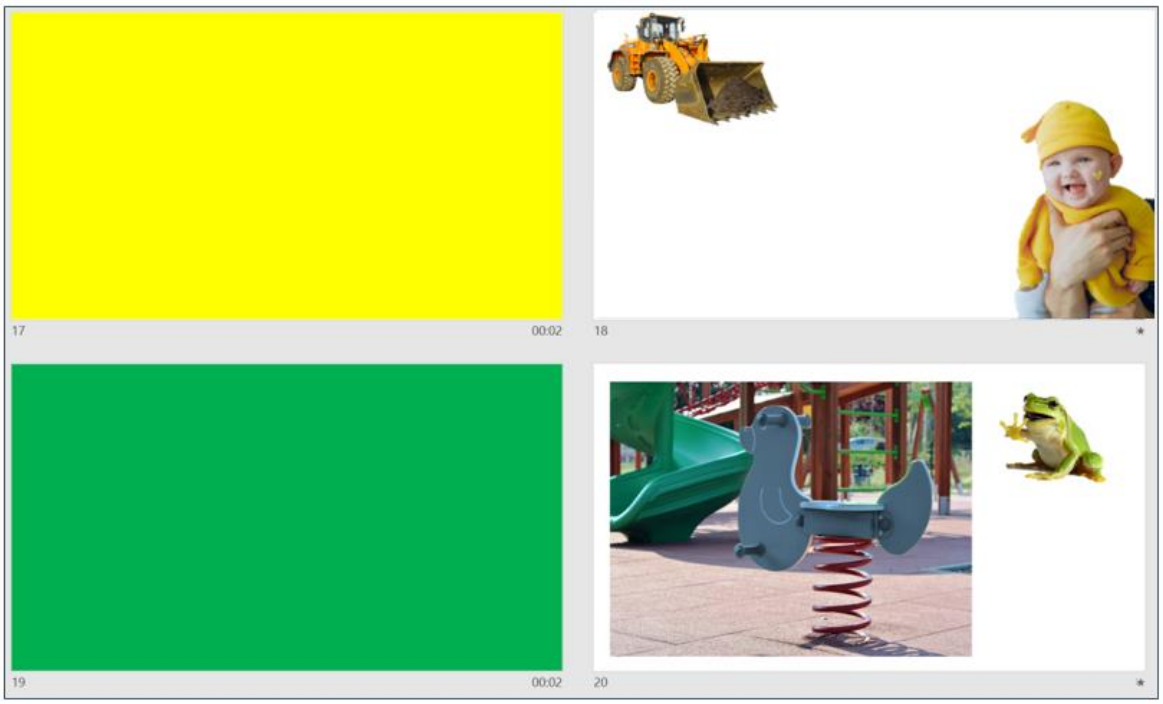
Note. Animation A: The banana gets peeled, animation B: The ducks moves towards the banana, animation C: Video of a falling block tower, animation D: The puppet grows in size.



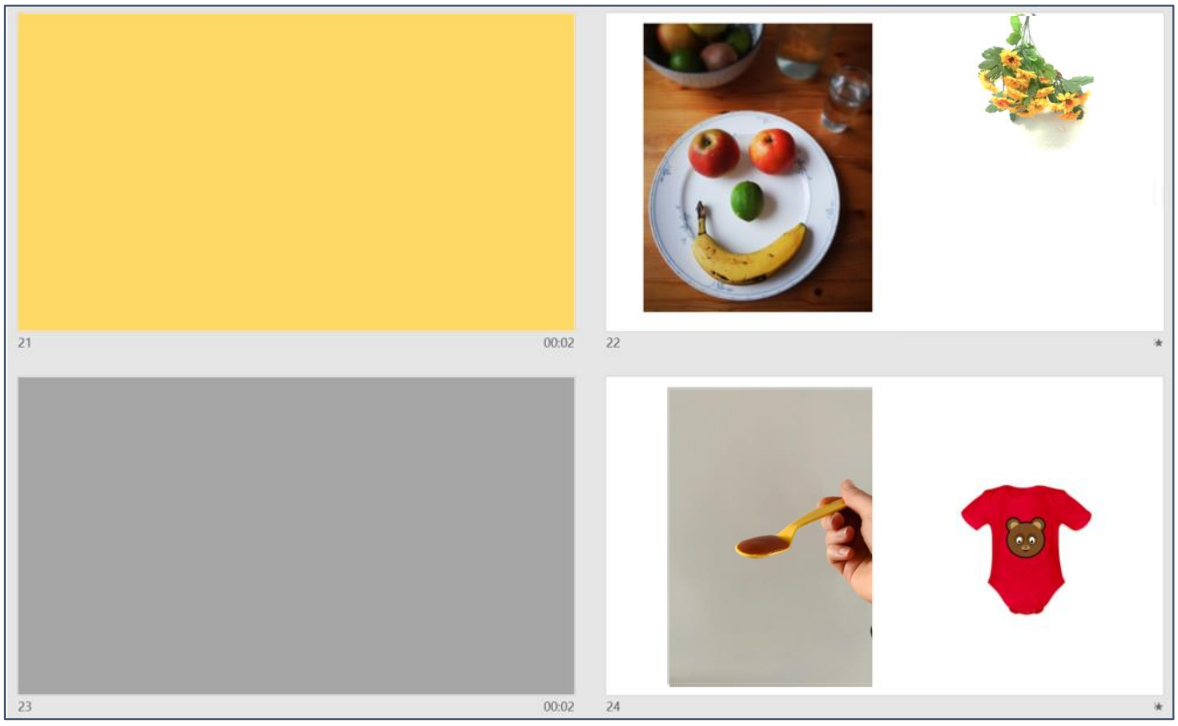
Note. Animation A: The pencils draw a line, animation B: The face on the bucket laughs, sound: whistle, animation C: The dummy moves to the right side of the slide, animation D: The dots on the socks change colors.



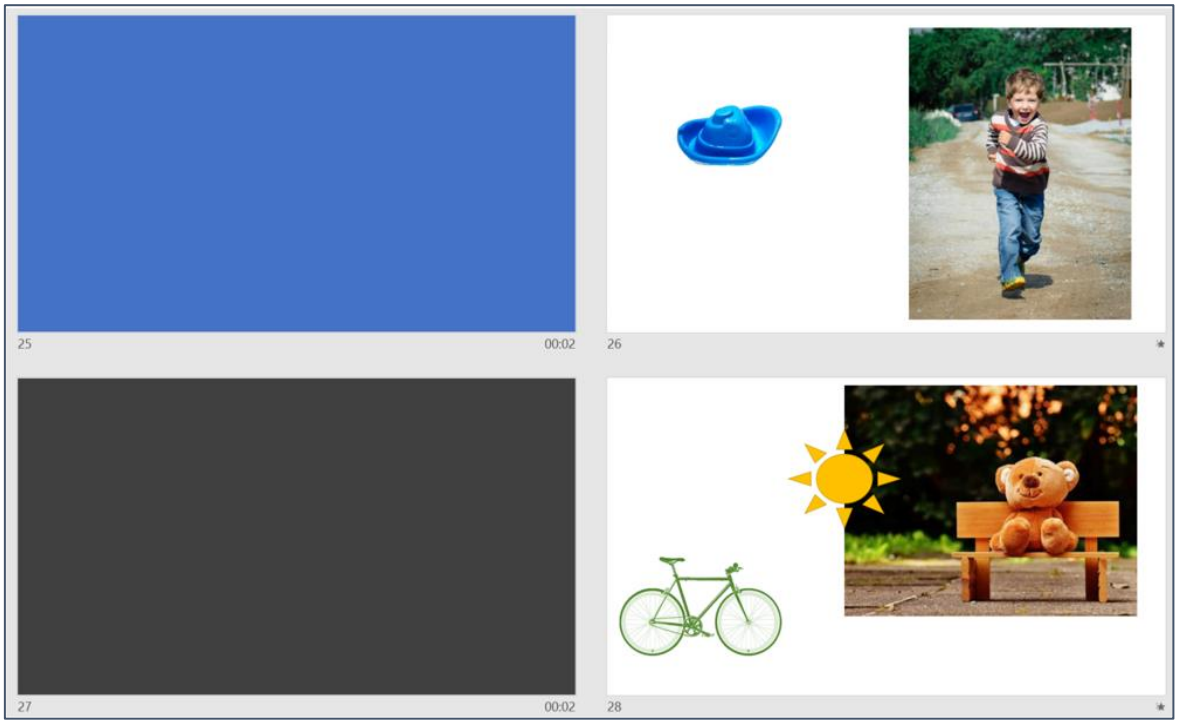
Note. Animation A: One butterfly flies out of the slide, animation B: The face on the plate rotates, animation C: Video of a dog jumping in a suitcase, animation D: The rattles grow in size.



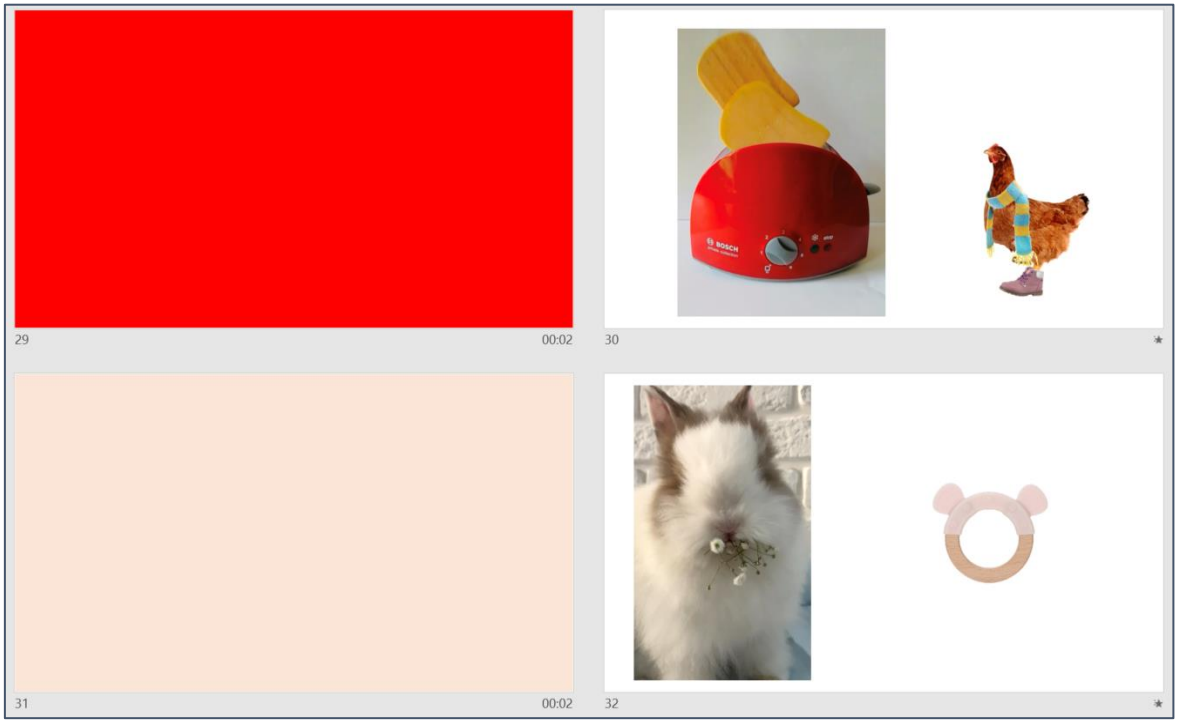
Note. Animation A: The excavator drives to the bottom of the slide, animation B: The excavator dumps the spoil on the ground, sound: ringing bells, animation C: The seasaw changes color, animation D: The frog jumps on the seasaw.



Note. Animation A: The flowers disappear and reappear at the bottom of the slide, animation B: The apples rotate, animation C: Video of an approaching spoon, animation D: The body grows in size.

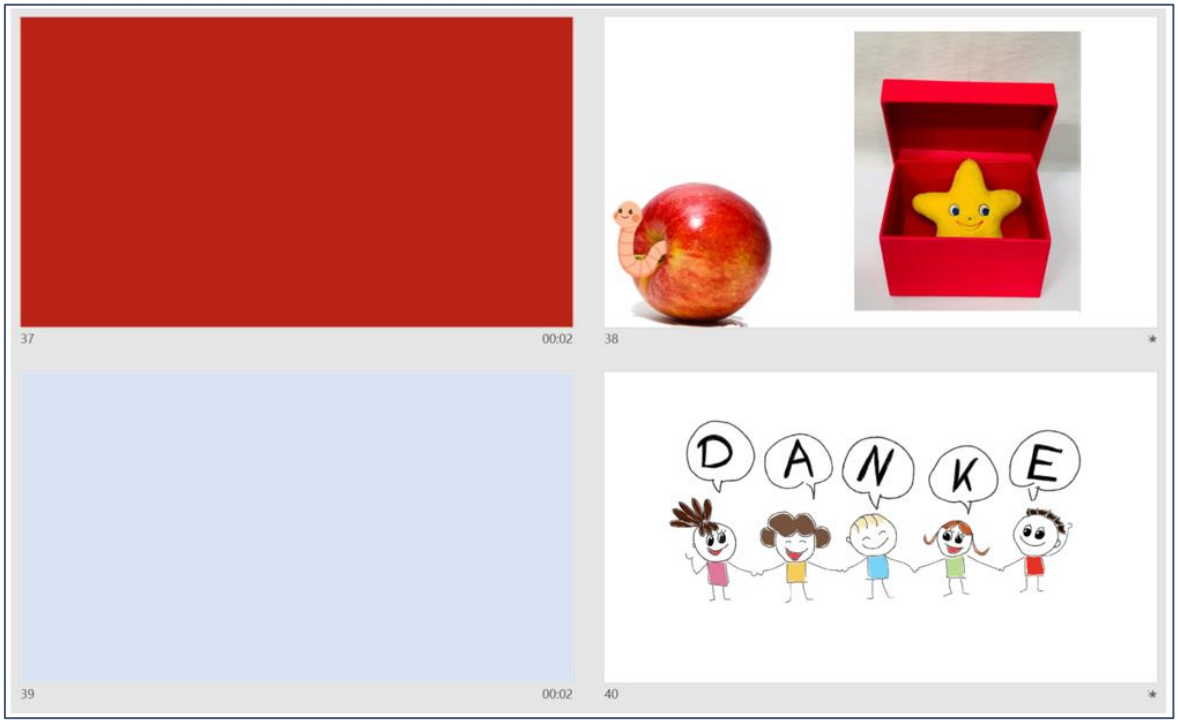


Note. Animation A: The boat drives around, animation B: Waves appear below the boat, sound: whistle, animation C: The sun appears and moves across the picture with the teddy bear, animation D: The bike changes its color.



Note. Animation A: The knob on the toaster rotates, animation B: The chicken gets dressed with boots and a scarf, animation C: Video of a bunny eating flowers, animation D: The body grows in size.

Note. Animation A: The stroller drives closer to the doll, animation B: The doll moves its arms and legs, sound: ringing bells, animation C: The ballons fligh higher, animation D: The dog turns around.



Note. Animation A: The star blinks its eyes, animation B: The worm appears, closing slide.

Appendix F

Formal declarations

Universität Hamburg
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FAKULTÄT
FÜR PSYCHOLOGIE UND
BEWEGUNGSWISSENSCHAFT
Institut für Bewegungswissenschaft
Institut für Psychologie

Erklärung gemäß *(bitte Zutreffendes ankreuzen)*

☐ **§ 4 (1c) der Promotionsordnung des Instituts für Bewegungswissenschaft der Universität Hamburg vom 18.08.2010**

☒ **§ 5 (4d) der Promotionsordnung des Instituts für Psychologie der Universität Hamburg vom 20.08.2003**

Hiermit erkläre ich,

KATHARINA KALETSCH (Vorname, Nachname),

dass ich mich an einer anderen Universität oder Fakultät noch keiner Doktorprüfung unterzogen oder mich um Zulassung zu einer Doktorprüfung bemüht habe.

Hamburg, 15.07.24
Ort, Datum

K Kaletsch
Unterschrift

Studien- und Prüfungsbüro Bewegungswissenschaft • Fakultät PB • Universität Hamburg • Mollerstraße 10 • 20148 Hamburg
Studien- und Prüfungsbüro Psychologie • Fakultät PB • Universität Hamburg • Von-Melle-Park 5 • 20146 Hamburg

www.pb.uni-hamburg.de

Universität Hamburg
DER FORSCHUNG | DER LEHRE | DER BILDUNG

FAKULTÄT
FÜR PSYCHOLOGIE UND
BEWEGUNGSWISSENSCHAFT
Institut für Bewegungswissenschaft
Institut für Psychologie

Eidesstattliche Erklärung nach *(bitte Zutreffendes ankreuzen)*

☐ **§ 7 (4) der Promotionsordnung des Instituts für Bewegungswissenschaft der Universität Hamburg vom 18.08.2010**

☒ **§ 9 (1c und 1d) der Promotionsordnung des Instituts für Psychologie der Universität Hamburg vom 20.08.2003**

Hiermit erkläre ich an Eides statt,

1. dass die von mir vorgelegte Dissertation nicht Gegenstand eines anderen Prüfungsverfahrens gewesen oder in einem solchen Verfahren als ungenügend beurteilt worden ist.
2. dass ich die von mir vorgelegte Dissertation selbst verfasst, keine anderen als die angegebenen Quellen und Hilfsmittel benutzt und keine kommerzielle Promotionsberatung in Anspruch genommen habe. Die wörtlich oder inhaltlich übernommenen Stellen habe ich als solche kenntlich gemacht.

Hamburg, 15.07.24 — Ort, Datum

K. Kaletsch — Unterschrift